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Informing the fuel cell industry

2007 Niche Transport Survey (2)

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Introduction

The second part of the two volume Niche Transport Survey looks at Marine and Auxiliary Power Unit (APU) applications for fuel cells. Marine, which uses fuel cells either for propulsion or in an APU function, has had a really strong year with a range of vessels under testing, construction or planning. APUs which are going into an ever increasing number of vehicles and brands are the market ice-breaker application. Not seen by the adopter and virtually unknown to the press APUs are helping to push fuel cells in development terms, creation of standards, and government awareness.

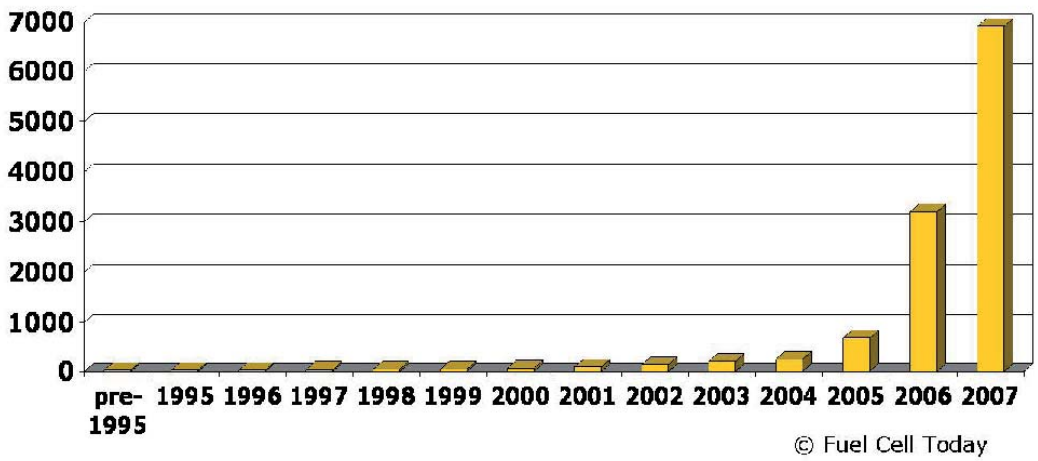
Before however we focus down specifically on these two applications for the usual project and company updates, the first part of this report draws together the full data suite for the last year, and a forecast out to the end of 2007, and discusses the changing market conditions as a whole.

Market Dynamics

The niche applications represent dynamic new markets and are often textbook cases of innovation theory in action. [Although it is very tempting here to go into this in-depth and discuss learning- and experience- curves, lock-in etc the focus of this report has to remain the market dynamics over the past year. Suffice to say that the experience curve being exhibited by the Niche Transport sector is currently close to tracking the (early) solar progression ratio published in the seminal IEA report "Experience Curves for Energy Policy Technology" [1].] Over the past year we have seen cost reductions, increase in adoption, removal of (some) policy barriers and continued certification of products. In summation, all movements we would see in a market moving into the commercial phase.

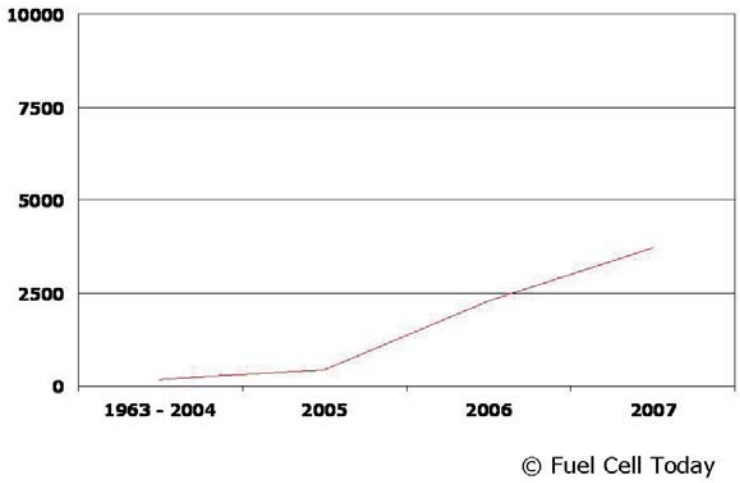
Graph 1 shows this year's market increase in terms of numbers, which we predict will double the cumulative total by the end of the year to just under 7,000 units.

Graph 1: Vol. 1 and 2 Niche Transport, Cumulative Number of Systems (excluding space)



What can be seen from this graph straight away is the jump from 2004 to 2005, 2005 to 2006 and now 2006 to 2007. Each year has been a stride forward for the markets. New units this year have been well over 3,000, with Graph 2 showing what looks like a clear adoption curve based on new annual units.

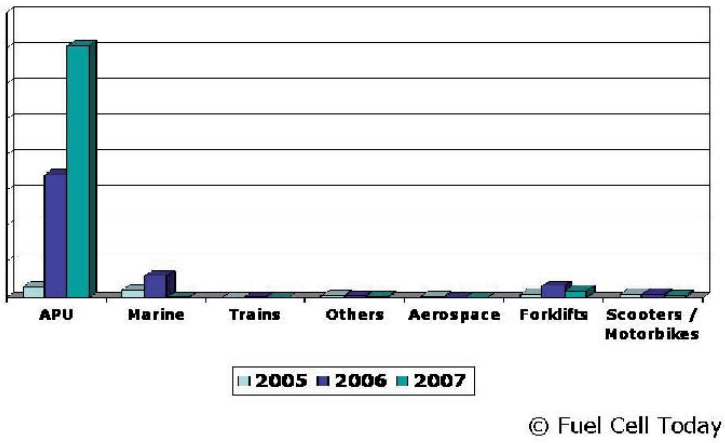
Graph 2: New Units In Niche Transport Shown as a Growth Curve



Remember that all new products go through an S-Curve of adoption which certainly appears to be happening here. Using S-Curve theory it would be tempting to say that we are now in the commercial phase but in reality we are still at the very base of the Curve and therefore we still need to face Death Valley (also known as the Chasm of Commercialisation) before we can safely say that these markets have passed the point of no return.

Graph 3 breaks the data down by application, highlighting that the majority of growth in this sector comes from APU applications.

Graph 3: Breakdown by Application of Niche Transport 2005 – 2007

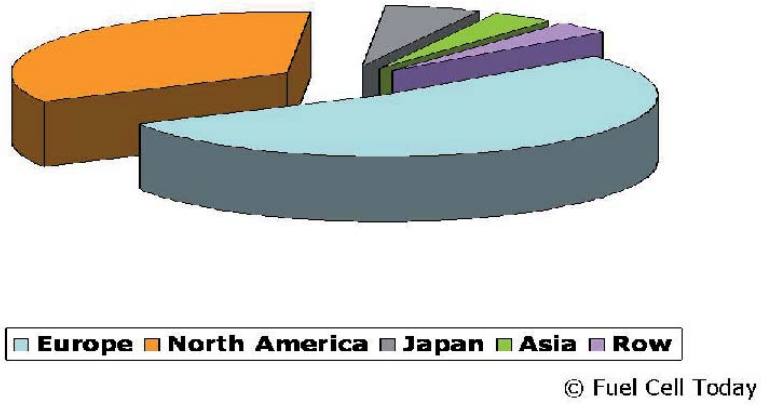


The breakdown shown in this graph should not come as a surprise due to the majority of current commercial products, in this survey at least, being used in an APU function. [Please note that we do not provide a further breakdown as to which APU applications areas are most active]. What we have seen, as already stated in Volume 1 of this survey, is the slowdown in numbers in some of the applications due to the manufacturers either switching from beta prototyping, to building manufacturing facilities, or having built a prototype (as in trains), running this for some time to gain good test data. The application that has to get a medal for being up and down more times than a yo-yo has to be 2-wheeled vehicles. One year media focus is spotlighting on this application, the next nothing. For an application that was originally touted as being one of the original foundation stones of the new fuel cell world it has yet to have a viable product, though money is still being pumped into the ENV bike development, or champion.

Region of Development

Turning to the region of development Graph 4 shows the split by country based on active companies.

Graph 4: Niche Transport 2007 by Region of Company Development



[Note that in this survey we do not break the information down by technology type as this market, to date, is dominated by low temperature fuel cells. In future we do expect to see the percentage of high temperature fuel cells increase but at present showing this graphically would be meaningless.]

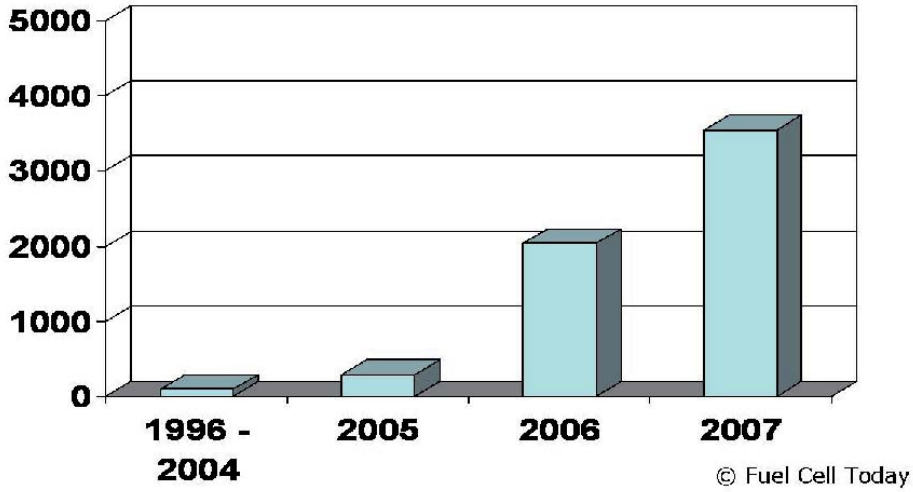
For those eagle eyed readers who have compared this with last year's graph yes, it is virtually identical. This is due to no new fuel cell companies coming into this space but also a limited number of companies either going bankrupt or stopping their (active) involvement in fuel cell development.

It does show that Europe continues to be highly innovative, especially in Small-to-Medium Size Enterprise (SMEs) developments in this sector. Also Europe has a better track record than North America (NA) on early stage tie-ups with integrator companies. Companies such as **SFC Smart Fuel Cell** are working closely with a number of potential product adopters to ensure that its fuel cell products are compatible with current product ranges, thereby removing a substantial barrier to adoption. Finally we still believe that the majority of activity in NA covered in this survey is being driven by the military. The military as end user has very high buying power and uses this to ensure that the products being developed are not only tailored to its requirements, in terms of performance metrics, but also that specific applications are brought along to market quicker. In Asia and Japan many are still surprised by the comparatively poor showing in terms of active companies. China, Japan, South Korea and Taiwan are all heavily involved in fuel cell development but tend to focus on different areas such as consumer electronics, cars and developments for the home. This could change, in Japan and China at least, with new developments in both Marine, and as mentioned in Volume 1, trains.

Marine and APU

Looking specifically at Marine and APU Graph 5 shows the market growth just for these two applications.

Graph 5: New Systems - Marine and APU 1996 - 2007



This graph clearly shows that these areas are the fastest growing of any of the categories that we survey. Outstripping other development due to the complimentary variety of drivers, including increasing awareness of pollution from these forms of vehicles, favourable price points and lower legislative barriers, APU and Marine are the current darlings of the industry. With these factors, and others, aligning themselves to push forward end use adoption we expect to see strong growth rates continue, with some 8,000 new units / systems being feasible by the end of 2009.

Marine

This year Marine has undergone something of a sea change having moved away from personal pleasure boats into industrial shipping. Here this should not be mistaken for just cargo ships but boats that are used by industry. Though we reported last year on a number of potential projects in large vessels these were pretty much at feasibility / planning stage. This year we have already seen a hundred-person fuel cell boat which will potentially be plying its trade on the waters of Amsterdam later this year and (post the publication of last years survey) a sloop that is purported to be able to travel 220 kilometre on one "tank" of fuel. Best of all, at least from my own personal perspective, is the news of a whale watching ship in Iceland being fitted out with fuel cells. More on these projects in the next section of this report.

Project Updates:

Fuel Cell Boat

Location: Amsterdam
Backing: Alewijnse, Integral, Linde Gas, Marine Service Noord and Rederij Lovers
Technical Details:

Capacity:	100 passengers
Dimensions (LxWxD):	20 x 4 x 1 metres
Weight :	?
Maximum Speed:	?
Fuel Cell:	60-70 kW PEM
Battery Hybrid:	Yes – 40kW Battery
Fuel Tank:	350 bar CH2
Distance on 1 tank:	?

Schedule:
2007 / 2008 daily operation

The Amsterdam fuel cell boat is planned to start its working life in 2007/ 2008. The current plan is that during the morning and afternoon rush hour it will be used to ferry around 600 Shell workers from the central station across to the Shell office building, which is also where the new hydrogen refuelling station will be. [Note that the hydrogen will come from electrolysis of wind energy]. During the rest of the day the boat will be in service as a tourist boat. The project budget is €3 million. The project is being subsidised by the local authority.

Smart H2

Location: Iceland
Backing: ?
Technical Details:

Capacity:	150 passengers
Dimensions (LxWxD):	?
Weight :	110 tonnes [2]
Maximum Speed:	?
Fuel Cell:	? (probably 5 -10 kW)
Battery Hybrid:	yes with ICE
Fuel Tank:	hydrogen
Distance on 1 tank:	?

Schedule:

2007 announcement of three year project

The project will see the installation of a hydrogen hybrid engine with an on-board fuel cell APU.

Other projects:

There are a number of other projects that have been announced this year but which are, currently, fairly sketchy in terms of details. Three of these are outlined below with all the information we currently hold on them.

Tianxiang No. 1

Location: Shanghai
Backing: Shanghai Maritime University
Technical Details:

Capacity:	40 passengers (when launched)
Dimensions (LxWxD):	?
Weight :	?
Maximum Speed:	7 km / hr
Fuel Cell:	PEM
Battery Hybrid:	?
Fuel Tank:	hydrogen
Distance on 1 tank:	?

Schedule: ?

Also Norwegian company **Eidesvik** have purchased an LNG supply vessel which will be readied as a fuel cell test bed.

Moving over to Birmingham, England and a project being called **Protium**, which, with only £200,000, is retrofitting a new canal boat with a PEM fuel cell / battery hybrid and a solid state hydrogen storage unit. Once complete the boat will travel between the University of Birmingham and the city centre and will be used as an education tool.

Finally in this section last year we talked about the potential for hydrogen water taxis in Istanbul. This year saw the announcement that the **Hydrogen Engine Centre** has received financial backing for the development of 200 new water taxis running on CNG and hydrogen. No mention was made of fuel cells.

Company Profiles

This section provides a brief overview of the activities of the most active companies over the last year. This is not a definitive list and only covers the most active companies.

A consortium of German shipping and technology companies has signed an agreement to supply the German navy with a further two submarines featuring fuel cell propulsion systems. The deal, made between the ARGE consortium of companies and the **German Federal Office of Defence Technology and Procurement**, will see two new class 212A submarines produced, adding to the four fuel cell-powered craft already being used by the German navy. They will feature air-independent hydrogen fuel cell propulsion systems, consisting of nine polymer electrolyte membrane (PEM) fuel cells equipped with oxygen and hydrogen storage, each providing between 30 and 50 kW for silent slow cruising speeds. It is expected that the submarines will be used in network centric warfare and in special forces operations, in line with the future deployment of the German navy.

Proton Power Systems has said that a fuel cell-powered passenger ship currently in development should be ready for operation by the summer of 2008. The ship, being developed as part of the European Commission-funded Zero Emission Ship project, will operate on the Alster river in Hamburg, carrying up to 100 passengers. Proton is responsible for developing the propulsion system for the ship, based on its existing fuel cell technology previously used in fuel cell-powered buses.

Researchers at the **Tennessee Tech University** are planning to develop fuel cell-based distributed generation systems for military ships and other naval war fighting platforms. Funding for the programme is to be provided by the Office of Naval Research.

Voller Energy Group successfully installed a prototype 1kW fuel cell generator on a Beneteau Oceanis Clipper

411 sailing cruiser. The fuel cell system is fitted to the existing wiring in the boat and operates from the Calor Gas, liquefied petroleum gas (LPG) or propane that is already on board for cooking. In other news, Voller announced the appointment of a new "marine sales specialist" to help exploit the sailing market for fuel cells.

A gorgeous Beneteau Oceanis Clipper 411, one of which is now fitted with a Voller fuel cell

The European Union (EU) is to provide a €1 million (~£675,000) grant to a research consortium for the development of methanol fuel cells to provide electrical power to marine vessels. The grant is being provided to a consortium led by power systems developer **Wärtsilä**, which will run the project entitled "Validation of a Renewable Methanol Based Auxiliary Power System for Commercial Vessels". According to Wärtsilä, the purpose of the project, which will cost a total of €1.9 million, is to develop and assess the suitability of a methanol-based fuel cell system on board a cargo vessel involved in international trade. A 20kW solid oxide fuel cell will be installed on board a **Wallenius** Marine car carrier as part of the programme.

Auxiliary Power Units

Unlike most other areas of current fuel cell research, focus for APU development is less about fundamentals and more about market metrics. Companies are still working on R&D but it is more in line with commercial R&D rather than fundamental work. As was discussed in last year's survey the three main targets for current R&D work are: cost reduction, heat management, reduction in size and fuel flexibility.

Cost Reduction: Costs are coming down with SFC SMART announcing price reductions for the second year running. Also this year saw the announcement that the Phase 1 SECA targets have been met by a number of companies. [See the FCT SOFC Technology Survey for more information on the SECA programme and targets.]

Fuel Use: This year has seen the announcement of a number of products that run on a variety of fossil based fuels as well as hydrogen. This should not be confused with saying that the fuel type can be switched in the units, using hydrogen one time and LPG, for example, the next, but at the point of adoption / sale the consumer selects the unit with the fuel type to best suit their needs. A prime example of this is the **Voller** unit that has been installed in a yacht recently.

Heat Management: A common issue amongst fuel cell development efforts. How much can be produced or should be produced? What to do with excess heat? When a vehicle, such as the cab of an articulated truck, needs to be heated the waste heat is a very useful side product but in other applications it isn't. This problem highlights that the technology will not have a one-size-fits-all approach, but will develop with different APUs for different applications.

Size Reduction: Size matters. For APUs the smaller the better. Getting the stack and balance of plant (BOP) reduced in size whilst increasing the density and ensuring / increasing reliability is a highly challenging area. Many companies have an active programme of de-engineering over engineered parts and other size-squeezing measures. **Delphi** is one of the most active.

As we have mentioned, these challenges are being faced due to APU development becoming more commercial. They will not, in themselves, stop this application but a combination of one or more could slow down market adoption. For this reason alone all companies working in this space still have a high R&D cash burn, and will have for many years to come.

Company Profiles

H2 Logic has announced that it has won the bid to deliver the fuel cell system to the long awaited TH!NK hydrogen city cars. The stacks are to be supplied by **Ballard Power Systems** with H2 Logic integrating them and BOP into the vehicles. H2 Logic collaborates with **Dantherm Air Handling** on the system development.

The TH!NK hydrogen car is expected to have a combined operating range of close to 300 km at an efficiency well above 65% and with no emissions.

The TH!NK hydrogen project was started in 2004 with a €1,35 million grant from the Research Council of Norway. The recently ended phase 1 of the project developed one prototype vehicle. Phase 2 involves the demonstration of up to seven TH!NK hydrogen cars in the Scandinavian Hydrogen Highway Partnership.

Hydrogenics Corporation announced that it received an order for a fuel cell auxiliary power unit from **MAN Nutzfahrzeuge**, a European manufacturer of commercial trucks and buses. The fuel cell auxiliary power unit will be integrated into an urban bus with a hydrogen internal combustion engine that is being deployed in Berlin for the European HyFLEET:CUTE project. Current plans are for the system to be delivered and bench tested later in 2007 and fully installed on the bus by the end of the year. The unit is capable of supplying passenger and driver air conditioning and other peripheral power units on board the bus and is an alternate configuration of Hydrogenics' HyPX Fuel Cell Power Pack product.

Sandia National Laboratories and **Boeing** are jointly researching the possibility of using a polymer electrolyte membrane (PEM) fuel cell as a source of back-up power in aircraft.

SFC SMART Fuel Cell has had a very active year with developments coming thick and fast. Of relevance to this survey is the news that this year saw SFC Smart Fuel Cell receiving the TUEV SUED octagon seal for its EFOY units. The TUEV SUED experts tested safety and quality based on the current draft standard IEC 62282-5. The award is given after strict testing in a number of crucial areas and is supposed to be providing consumers with a quality benchmark. Also this year the EFOY product range became available in **Niesmann & Bischoff** and **Dethleffs** motor homes, as well as the **Hymer** already available.

The increased availability of on-board electrical equipment in motor homes is perfect for the market expansion of fuel cell APU. (picture: kitchen in Dethleff Motor Home)

Staxera is a joint venture between **HC Starck**, **Webasto** and **IKTS Research** developing SOFC APUs.

The targets for the unit include:

Electric Efficiency:	1-2 kW (at market entry)
Thermal Power:	2-5 kW
Mass / Volume:	<35 kg / <70 liter
Start up time (cold):	<60 minutes
Lifetime:	>6000 hours

Topsøe Fuel Cell and **Wärtsilä Corporation** have won a € 4.8 million grant from the EU LIFE Environment programme to develop and demonstrate manufacturing and operation of SOFC fuel cells. DEMO SOFC, as it is known, will include the planning, design, erection and running-in of a new pilot production facility for cells and stacks. The plant is foreseen to have an annual manufacturing capacity of 150,000 – 200,000 cells and 2,000 stacks, an increase of 15 times compared to the capacity of the present laboratory based manufacturing. One of the first units off the production line will be used to test bio-ethanol, which is being looked at as a fuel for an onboard marine fuel cell APU.

Veloform announced the release of the CityCruiser II – a fuel cell-powered three-wheeled bike – onto the commercial market in 2006. The bikes are powered by EFOY fuel cells manufactured by **SFC Smart Fuel Cell**, powering not only the engine, but the lights, radiator and communication equipment as well. The fuel cell runs on methanol fuel, with the Veloform delivering fuel consumption of around 0.3 litres of fuel per 100km. It is expected that the bikes, which resemble three-wheeled golf buggies, will be used in airports or large exhibitions for speedy transportation.

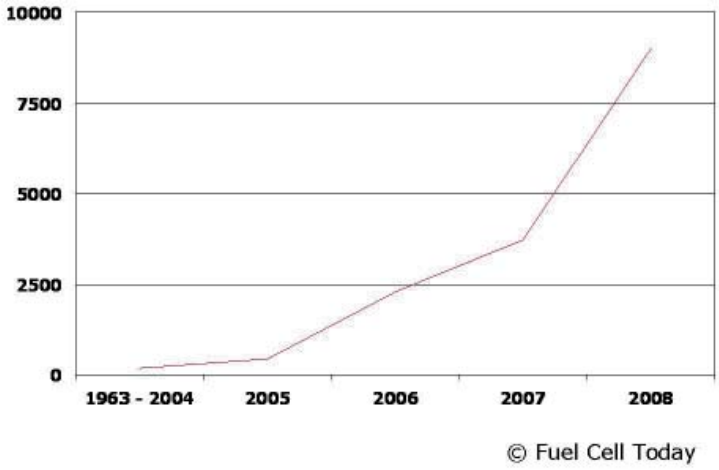
Other companies working in this space that have been quiet this year include: **Bloom Energy** (possibly), **BMW**, **Delphi**, **Powercell** and **Volkswagen**. Companies that have left this space since last year's survey include **Anuvu**, **Astris**, **SiGen** and **ZAP**.

Discussion

When consumer need and technology metrics meet it is a match made in innovation heaven. For APU development what we have seen over the past couple of years is the transition from laboratory testing into an integration phase where a number of fuel cell companies are now talking to, or actively developing with, a number of end product (Tier 1) companies. The knock-on impact of this work is seen in cost reductions (economies of scale), increased consumer awareness and the creation of quality standards. The trickle down impact from this is that other close to market applications, such as Marine and Forklifts, can start to push on a slightly open door coming to adoption just that little bit faster. As more and more units, applications, problems, solutions and work-arounds occur the market in general starts to become normalised so that by the time we get to the "big one" (light duty fuel cell vehicles) a large number of the adoption hurdles will already have been cleared by the innovative forerunners such as those discussed in Volume 1 and 2 of this survey.

So the last year has been positive but what about 2008? Graph 6 shows the growth trend with what see as feasible out to the end of 2008. As usual with our forecasts we have based this on a number of assumptions, and not just a straight line extrapolation from the historical dataset.

Graph 6: New Unit Prediction Out to End of Calendar Year 2008



What this graph shows is that we expect to see a steeper increase in adoption over the next year with new units coming in at around the 10,000 mark. Other market movements we think we will see by the end of 2008 include:

- Further consolidation of companies,
- Market exit by 2 or 3 SMEs,
- Listing on stock exchanges of a further half dozen or so companies,
- Increasing interest in Marine and Aerospace, piggy-backing on the push to include Marine and Aviation in an EU carbon trading scheme,
- Europe remaining dominant with the entry of some new companies,
- The commercialisation of a number of new products and market spaces.

And, hopefully, maybe even the mainstream press will start to pick up on the developments that are happening in fuel cell commercialisation right now and not a decade away!

References and Notes

[1] International Energy Agency, "Experience Curves for Energy Policy Technology", Paris, 2000, available for download from:
http://www.iea.org/textbase/nppdf/free/2000/curve2000.pdf

[2] Please note that this figure was reported as "125 ton". We converted this into long, or metric tonnes, for this report

About the author

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