The Fuel Cell and Hydrogen Annual Review, 2016

4th Energy Wave, 2016

About 4th Energy Wave

4th Energy Wave was founded in 2014 by the ex-head of Fuel Cell Today and FCT Consulting and manager of the Navigant Energy Smart Energy team.

Focused on delivering strategy and analysis on the fuel cell, hydrogen and increasingly energy storage sectors, 4th Energy Wave is trusted as the voice of authority on the rapidly evolving markets.

The Fuel Cell and Hydrogen Annual Review is the continuation of the Fuel Cell Annual Review report from Fuel Cell Today, started by Dr. Kerry-Ann Adamson and her team in 2008. The dataset combines both historical data from FCT and fresh data collected and collated by 4th Energy Wave.

This report is produced as two versions. The free version, of which this is, is complemented by a full length report with a forecast section and analysis of emerging business opportunities and markets. The full report costs £2,000 / $3,000, and includes an hours time with Dr. Kerry-Ann Adamson.

Any questions, orders and requests for the chart book, should be directed to Kerry-Ann at;

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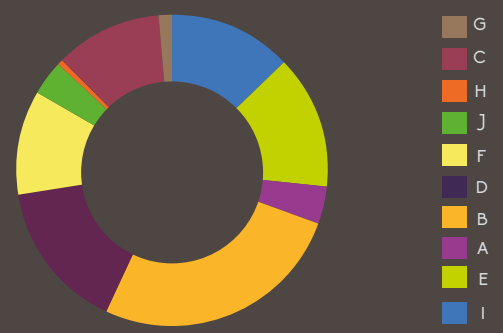
Table of contents

2015 data shows slowing of growth

Global fuel cell system and stack company, by region, 2015

1. Japan and South Korea continues to dominate product availability, and adoption, though the gap between Asia, Europe and North America is closing. The US continues to exhibit strong growth in fuel cell and hydrogen start-ups, but the chasm remains ever wide between start-up and commercial product availability. In North America time to market from lab to commercial market entry remains at over a decade. In the EU the market is still heavily supported by RD&D funding, which has created two tiers of companies. One tier which is focused on research and development, and the other, where the stronger growth is occurring, in companies with commercial product.

Market share, by revenue of top ten stationary fuel cell companies, 2015

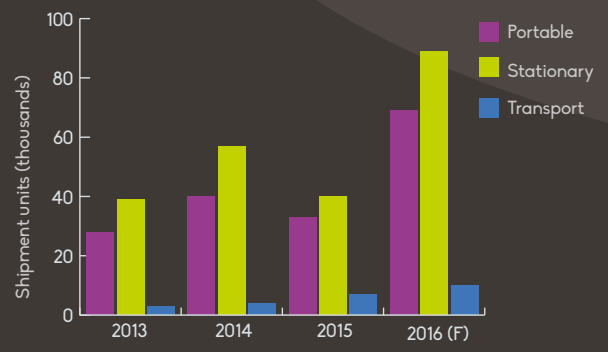


4. During 2014 and 2015 the stationary fuel cell sector became overall substantially more sustainable. With a broader range of fuel cell system suppliers, increasing growth capital flowing to the sector, price drops across the board and an increase in the number of companies with overall annual revenue above $100 million.
The healthiness of the sector is now at a point where if one high profile company was to go out business, whilst it would have an impact on the overall sector, it would no longer signal its death knell. The next great hurdle of profitability still remains elusive.

2. Number of actual systems shipped, surprisingly, dropped in 2015. The reasons why include:
   - Continued low oil price leading to mothballing of investment by oil and gas companies in exploration and system upgrades.
   - Ending of one fuel cell product line and building up for launch of next.
   - Orders in the telecoms sector, especially, continue to be lumpy, with major growth orders not coming on an annual basis.
   - ENE Farm residential fuel cell shipments down.

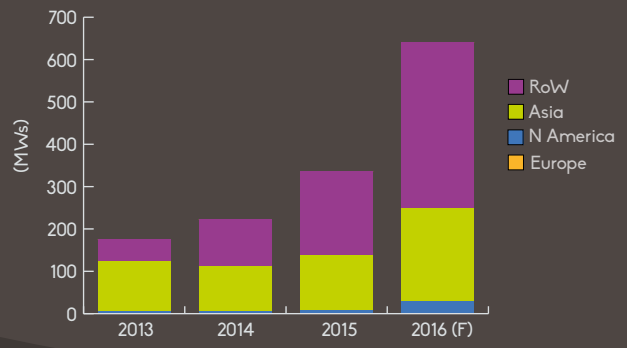
Overall there is no one overriding factor to blame. It is not representative of a drop in interest in the technology, but the focus is now squarely on 2016 as a critical year to bounce back.

Fuel cell systems shipped by sector: 2013 – 2016 (F)



3. Key trends include an increase in the average project size, fleet change over to fuel cell, rather than one by one, and the shift in business models to solution provision, rather than technology selling, unlocking markets at a much faster pace.
Asia Pacific continues to expand its lead in terms of adoption. With the strongest policy drivers for change also being in Asia this lead is forecast to expand.

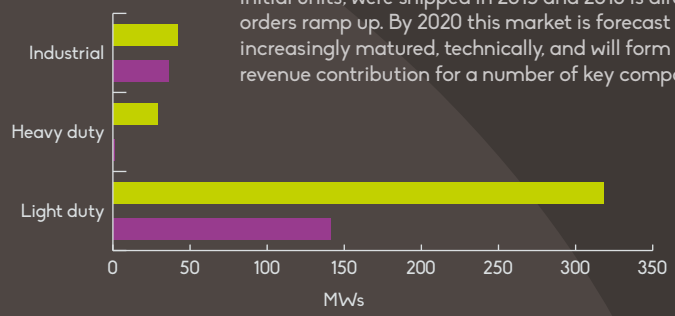
MWs of fuel cells product shipped by region: 2013 – 2016 (F)



6. India has long been focused on for potential deployment, with multiple waves of focus by fuel cell companies, followed a few years later by significant company retrenching. Now though as companies focus on local product for local markets, India could be creating a model of adoption that can be adapted and used in many other emerging economies.

Evolution of the fuel cell transport market continues apace

5. 2015 was the year that the market started to take note of fuel cells for heavy duty transport applications. Trams, trucks, light rail and buses. Initial orders for demo units, or one off initial units, were shipped in 2015 and 2016 is already seeing orders ramp up. By 2020 this market is forecast have increasingly matured, technically, and will form a major revenue contribution for a number of key companies.



Country attractiveness index – Japan leads in 2015

An increasing number of countries are chasing, politically motivated, high value job creation through the aim of a localised fuel cell manufacturing hub. Other governments are focused on deployment and ramping up the benefits of fuel cell adoption to society.
The Country Attractiveness Index was developed by, and is unique to, 4th Energy Wave to rank countries on attractiveness for (1) fuel cell companies to export to and (2) to sell into as a local market. Each country is ranked on 12 parameters. 5 of which are shown below.

5 *4th Energy Wave* influencers

5 Factors in the analysis include:

1. Government level systematic identification and removal of legislative barriers to deployment of fuel cells in stationary, portable or transport systems.
2. Government level, long term support for decarbonisation, reduction in emissions and a shift to faster adoption of renewable energy, and or hydrogen.
3. Fiscal support for fuel cell adoption, either direct, which specifically mentions fuel cells, or otherwise.
4. Barriers to trade. For the export market especially this is important. Countries which have buy local policies, or break WTO rules on trade, are classed as high risk, and therefore much harder to do business with.
5. Economic Growth. A population able to afford fuel cell systems, whether in cars, or homes or companies employing the systems into offices and businesses, is only created or maintained through stable long term economic growth.

With the results of the export and local markets are combined we see that Japan remains at the head of the pack.

Heavy duty fuel cells – a rapidly emerging market opportunity with global potential.

The breakout market of 2015 was heavy duty fuel cells. Not just buses. Light rail, trams and logistics vehicles, such as trucks, all posted gains.

Emerging Business Opportunities:

- Heavy duty powertrain supplier
- Zero carbon logistic fleet operator
- Fuel provider
- Fleet vehicle maintenance

1. Buses

For buses, city fleets around the world are not just looking at demonstrating fuel cell buses but are now moving to creating long term order schedules. South Korea is currently way ahead of the pack, with a plan to replace 27,000 CNG buses with fuel cell buses by 2030. China is to add over 300 fuel cell buses, with orders at Ballard alone of 333 buses, and, through the 3Emotion EU project, 21 new fuel cell buses will also be added in Europe.

4th Energy Wave forecasts that by 2030 a global market of over 40,000 fuel cell buses should be in service, globally. 4th Energy Wave also forecasts that by the mid 2020s, with the level of demand now being created, the price of a fuel cell diesel bus could, all other things being equal, be on a par with a diesel-hybrid bus.

Source: Van Hool, 2016

2. Logistics vehicles

A number of cities in Europe and China are reaching the point where due to increased policy push the use of petrol and diesel vehicles is becoming increasingly challenging. Pollution, and the understanding of the impacts of pollution, is on the rise, consequently the pressure is on to shift to alternative fuels or powertrains.

The potential use of fuel cells in trucks / lorries is not a new idea, with active research for over a decade into using a fuel cell during vehicle idling. The rapidly emerging business opportunity here though is the use of fuel cells as the drivetrain. Here companies such as Loop Energy (formerly Powerdisc), Hydrogenics and Palcan are already working on developing and delivering quality units, in quantity, for this sector. In Norway four hydrogen fuel cell trucks are already running.

4th Energy Wave forecasts that within two years we will see tie ups with truck OEMs for the development, and standardisation, of this drivetrain, and a ramp-up in deliveries within 5 years.

3. Light rail

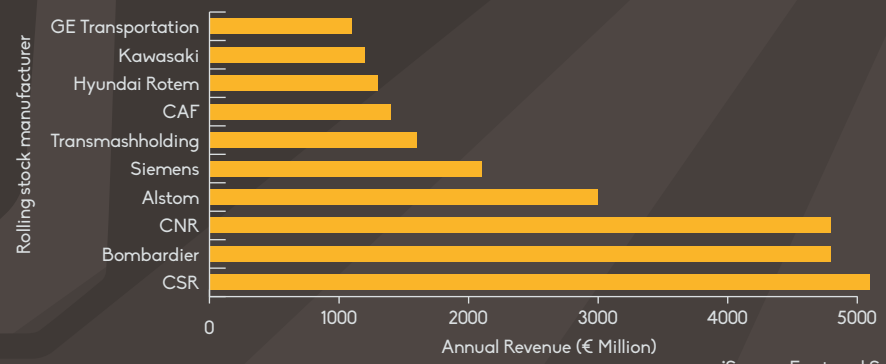
The market for fuel cells in trams and light rail market could post double digit year-on-year growth over the next decade. Trams and light rail are one of the few markets where fuel cells can exhibit significant performance and (overall) cost improvement against traditional vehicle powertrains and infrastructure.

Looking at the scale of the potential market, according to UITP (www.uitp.org), over 15,600 km of light rail infrastructure are being operated worldwide, with another 850 km under construction and 2,300 at the planning stage. Combined with the replacement of aging rolling stock, and the growth in new demand, the light rail sector can very clearly be labelled significant. When the potential saving of some 19% in overall infrastructure costs, from not needing an overhead catenary, is added to the equation the interest in fuel cells for light rail becomes far more understandable.

With the intermodal shift in countries such as the US, investment in urbanisation in China and Africa and replacement of rolling stock in Europe, current demand in the form of the initial €50 million exclusive deal between Alstom and Hydrogenics, and the framework agreement between Ballard Power and Tangshan Railway Vehicle Company, Limited (TRC) for development of a new fuel cell module for trams is, 4th Energy Wave forecasts, is just the start of many such developments over the next five years.

That said the business opportunity clearly lies in a JV, or some form of tie up with a major rolling stack manufacture. As two of the top 10 are already taken, fuel cell companies looking at developing this market have a shrinking target list.

World's largest rolling stock manufacturers, by revenue*



*Source: Frost and Sullivan

Fuel cell industry pain points - diversification in channels to market

The fuel cell industry is still facing a number of pain points and failures. One of the most fundamental has been the ability to leverage a technology into a market. This though is starting to shift with companies switching from selling technology to selling services. This infographic profiles 4 such companies, highlighting that this transition is not always a smooth, or straightforward process.

From selling large stationary fuel cell systems to 20-year power purchase agreements (PPAs). Working with PNC Energy Capital, LLC. FCE has access to a $30 million project financing facility for PPA projects in the USA.

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Bloom Electrons blooming all over. Constellation, a subsidiary of American utility giant Exelon Corporation, is providing equity financing for the deployment of over 40 MWs of Bloom Boxes in the US for 15 year PPAs.

From licensing fuel cell stack IP to becoming a service provider to over 20,000 telecoms towers in India, with over 10,000 to be fitted with IE's fuel cell systems. It has not been a smooth ride for IE and at time of writing the company is restructuring, with this deal central.

Intelligent Energy

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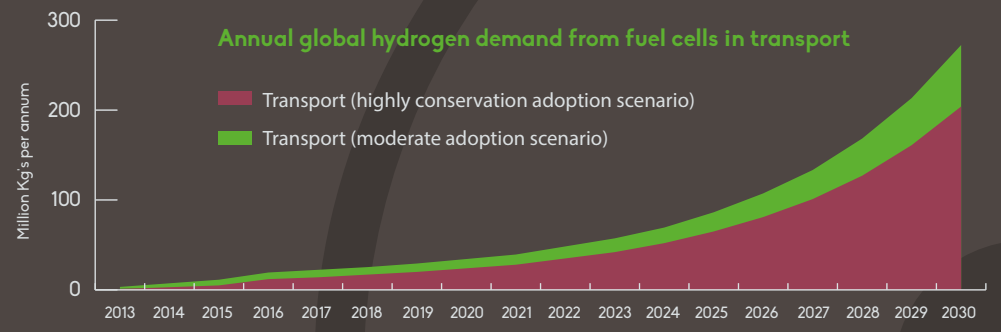
The new RASA new car will not be sold but will be leased on per mile used (price to include the fuel). In one move this removes concern over the technology, maintenance issues etc. This model plays very much into the Asset Lite Generation.

Overall this trend is forecast to accelerate over the next handful of years as companies transition into profit making enterprises. 4th Energy Wave forecast that we will see well capitalised companies move more and more into this model. Companies that want to be tech providers we can expect to see retreat further into the supply chain, becoming a trusted partner, not a delivery agent.

Hydrogen – Matching Supply and Demand. Available in full report only

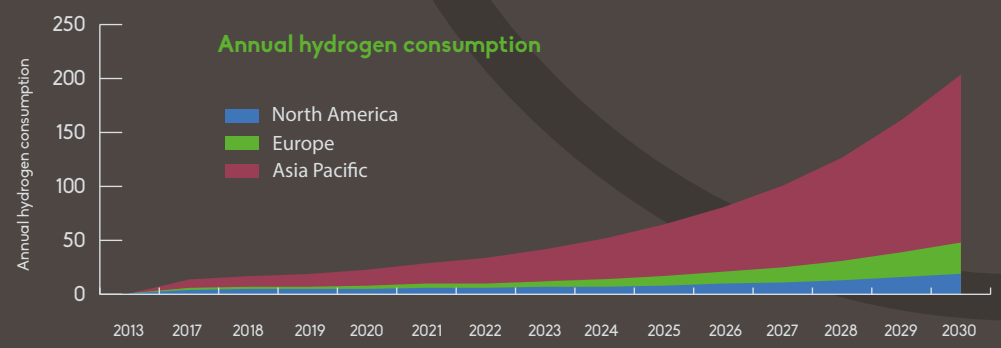
The emerging new business opportunity is that of hydrogen matchmaker. Investment opportunities here centre around the potential for business model disruption.

The demand growth for hydrogen from PEM fuel cells, and to a certain extent internal combustion engines, is forecast to strongly increase year-on-year. With new applications, such as heavy duty fuel cells, along with expected deployment of fuel cells into cars, telecoms towers, homes, buses, and power plants, the use of hydrogen in new applications is now forecast to outstrip even the most aggressive forecast from 5 years ago.



With policy shifts in Japan, to a limited degree China, and now South Korea focusing on adoption of hydrogen, either into urban transport applications, or more broadly across society, new hydrogen demand is forecast to reach over 200 thousand tonnes by 2030. To put this in perspective today's global hydrogen market from refinery production is in the region of 65 million tonnes.

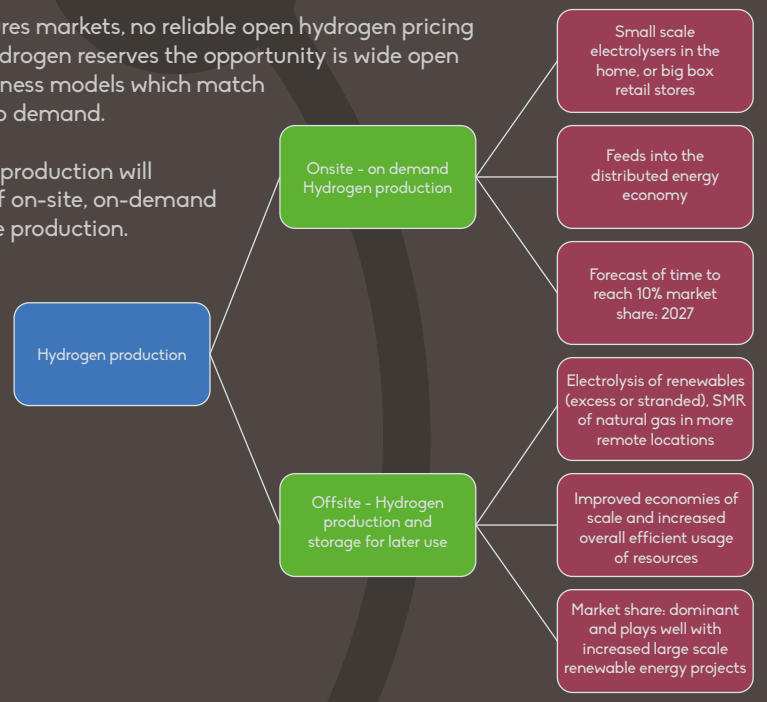
Although it is likely that if the economics was right, refinery production of hydrogen could be increased to meet this new demand, due to political and societal pressure for the increased use of renewables, the potential for hydrogen in the grid balancing market, the emergence of the power-to-gas markets, and the creation of a green hydrogen standard it is likely that in the short term we will see a much more diverse set of hydrogen companies than the current oligopoly.



The impact of policy on the market is graphically highlighted in the chart (bottom left), which takes as its base point that all government targets in China, Japan and South Korea for hydrogen fuelled fuel cell transportation are met. *

With no hydrogen futures markets, no reliable open hydrogen pricing mechanism, and no hydrogen reserves the opportunity is wide open for the creation of business models which match hydrogen production to demand.

In the future hydrogen production will continue to be a mix of on-site, on-demand and larger scale off site production.



As the market normalises, companies which are turnkey solution providers will dominate market share and demand for hydrogen centralises first in the urban conurbations and over time, by 2030, starts to spread out into the rural and emerging economies.

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ITM POWER
Energy Storage | Clean Fuel

NEL HYDROGEN

WOIKOSKI

4th Energy Wave
Companies to watch

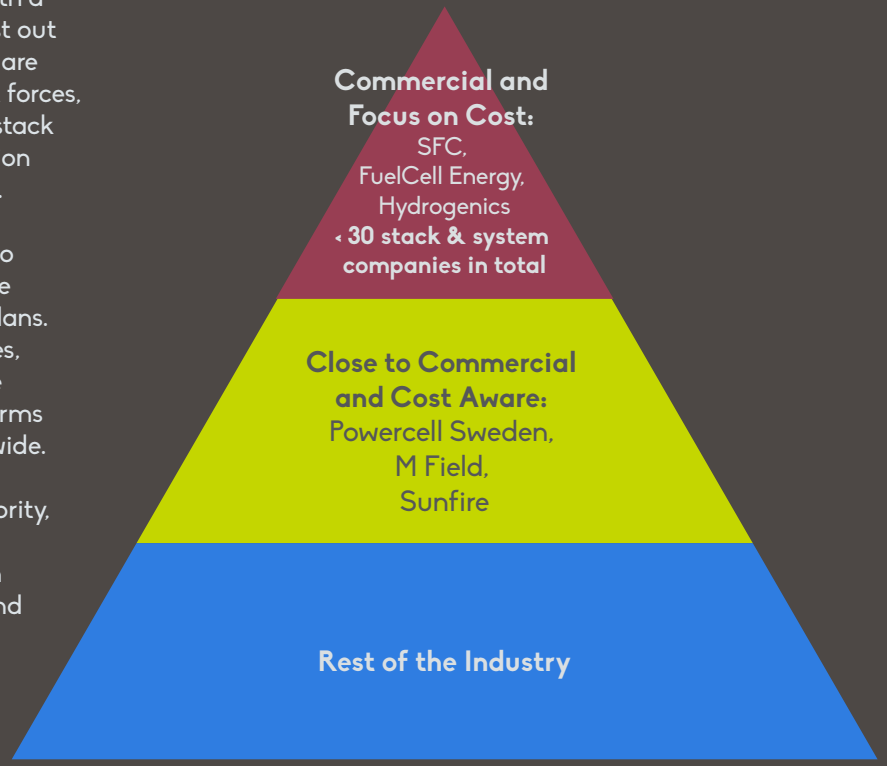
*Note: China is forecast to be a mix of methanol fuel cell vehicles, such as trucks, and hydrogen powered fuel cell buses.

1. Executive Summary

Although overall the fuel cell industry is growing in volume, it remains something of a pyramid. The top, layer are the stack and system companies with a commercial product **and** a clear focus on cost out **and** customer satisfaction. These companies are either driven by policy, as in Japan, or market forces, as in FuelCell Energy. But of the overall 200+ stack and system companies globally, this top section represents less than 30 companies at present.

The second tier is a tranche of companies who are close to, or quasi commercial now, and are building in cost profiling into their business plans. These are companies, like the Tier 1 companies, which are seeing investment from the private sector, and creating customer pipelines. In terms of scale this is less than 60 companies worldwide.

The base of the pyramid, making up the majority, is made up of the rest of the stack or system industry. These companies are still very much focused on RD&D, which doesn't centre around the cost structure of the stack or the system.



What this means for the fuel cell sector in general is that we will see an increase split between, on one side the Tier 1 and 2 companies, and on the other the rest of the industry. Tier 1 and 2 will continue to take the overwhelming majority of the sales and investment, whilst the rest of the industry are ripe for M&A. During 2015 this split became increasingly clear with an increase in consolidation and buy outs.

In terms of overall scale, the fuel cell industry actually grew in terms of overall company numbers in 2015. One of the factors behind the increased number of new entrants into the sector is the reduced barriers to entry to new companies, especially at system level. Historically, a 4th Energy Wave rule of thumb was that there was needed in the region of $1 billion invest in R&D and product commercialisation for a new PEM fuel cell system, and somewhat more for a system with a SOFC.

Now though, as we see the start of stack standardisation, this upfront investment cost is being reduced. There is a long way to go, obviously, but through innovation, and standardisation, as the financial barriers to entry are reduced, and the markets mature, we should see an increase in the number of smaller market entrants.

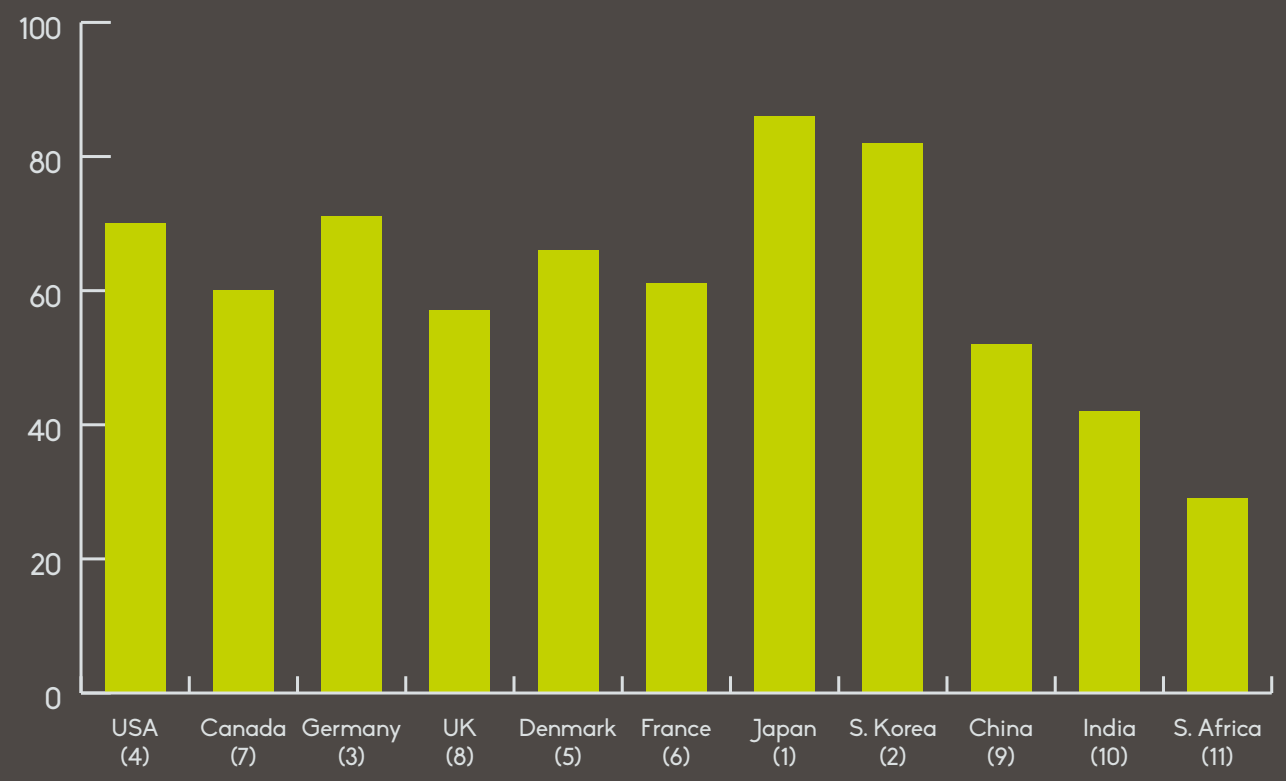
The 4th Energy Wave Country Attractiveness Index, launched in this report, has clearly identified the leading country for fuel cells as Japan, with South Korea second and Germany third.

Whilst most countries' government agencies are still embedded in the high-level discourse of the opportunities that a fuel cell, or hydrogen, sector represents to them, and are not focusing on the long, complex and exceedingly detail-orientated nitty gritty of identifying and removing local barriers to adoption, Japan continues to move forward, in a very focused way, on the implementation of the hydrogen society.

Known globally for government level long term, stable, and well-coordinated approach to the development and creation of a local fuel cell industry. This length of time of sustained investment, clear policy direction on product development and adoption, renewed and agreed upon targets, coordinated activity and focus, has led to the country outstripping any other in terms of developing a strong, indigenous fuel cell sector.

If we dig into the types of fuel cell under development in Japan, we see the current predominance of PEM systems and stacks. With the focus on the residential market, this is somewhat understandable, though as the data is replotted over the coming years, this, 4th forecasts, is likely to change, with an increasing number of companies working on high temperature systems. If we turn to shipments by region, we see that in terms of MWs, Asia Pacific stepped up its lead in 2015, and is forecast to consolidate this in 2016.

Chart 1.1: 4th Energy Wave Overall Country Attractiveness Ranking, 2015

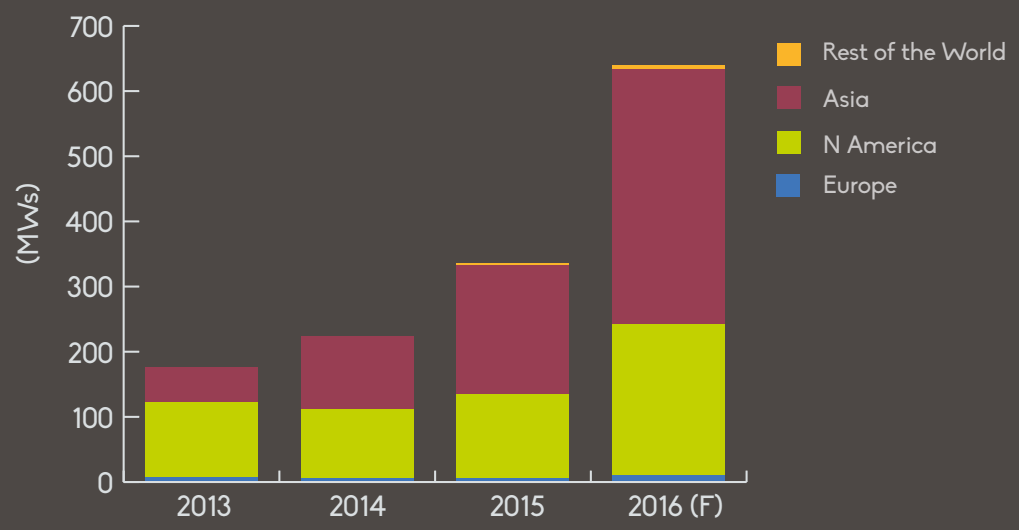


Source: 4th Energy Wave, 2016

Europe still lags far, far behind the rest of the world in terms of system manufacturing. Of the companies with commercial product, most of them are either not manufactured in Europe, or are small 5 kW and under units. The one area that Europe is very strong in is the portable fuel cell market. So when we flip this chart, into systems shipped, the picture is somewhat different.
In terms of revenue, 4th Energy Wave focuses on the revenue generated from the sale of fuel cell systems.

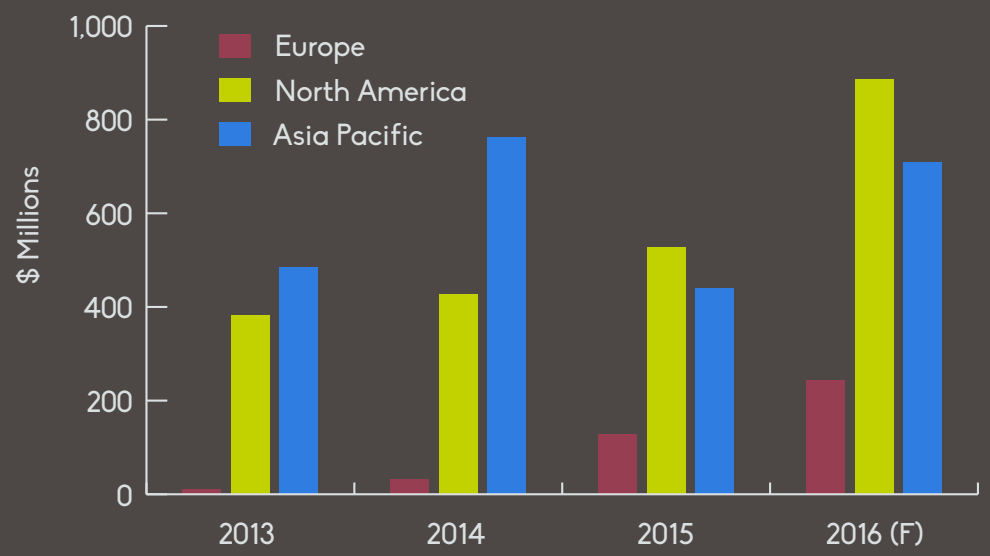
What chart 1.3 shows is that in 2015, North America took the majority revenue from fuel cell system sales. This is a shifting in position from 2014, where Asia dominated. Sales in North America were boosted significantly by a number of high profile deals, including the sale of fuel cell buses to China, with Ballard Power, and the sale of a 1.4 MW CHP unit by FuelCell Energy to Pepperidge Farm. The revenue in the North America for 2016 is forecast to jump again to some $900 million in 2016, primarily on the back of increased deals in 2015 in the large stationary sector, which are due for shipment, and associated revenue recognition, in 2016.

Chart 1.2: Global Fuel Cells Shipped by MW and Region: 2013 – 2016 (F)



Source: 4th Energy Wave, 2016

Chart 1.3: Revenue from Fuel Cell System Sales, Global: 2013 – 2016 (F)



Source: 4th Energy Wave, 2016

2. The Fuel Cell and Hydrogen Annual Review Definitions

The Annual Review covers all markets for stationary, portable and transport fuel cells. It does not cover the fuel cell toy market.

The **stationary** sector is split out into:

- Prime Power
- Backup Power (including indoor and outdoor power for telecoms)
- Residential CHP
- Other CHP
- Remote Monitoring and Sensing

The **transport** sector covers:

- Cars
- Heavy Duty Vehicles (Buses, trucks, trains, marine, etc.)
- Forklifts
- Others (APU, Aerospace, etc.)

The **portable** sector is split into:

- Skid Mounted Systems
- Systems for Personal Electronics

What is not covered in this report is the civilian / military split.

The report divides the world into 4 regions:

- **Europe** – For this report, Europe covers the European Union, Switzerland, Norway, Iceland and Russia. Unless otherwise clearly stated, references in the document to Europe are for the entire continent, and only when tagged as such do they refer to the European Union (EU).

- **North America** – For this document, this refers to Canada and the US only.

- **Asia Pacific** – Refers to the Asian subcontinent and includes India.

- **Rest of the world** – Everywhere else.

As the fuel cell market expands and diversifies, these groupings will evolve and any changes will be clearly highlighted in future report updates.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3. Drivers and Influencers, 2015

Drivers

The main drivers for the switch to, and adoption of, fuel cell technology remain the same at:

- Decarbonisation
- Criteria Emission Reduction
- Electrification
- Resilience
- Reduced Water Consumption

If we look at these as a basket of drivers, what is clear is that none of these drivers are just for fuel cells. They are the societal level drivers for change in the energy and transport system. They are not for pushing the adoption of one technology over another.

This in itself is critical in changing the thinking behind the questions of which technology will 'win', to becoming a question of which system works better for a given location, or problem. Fundamentally, unless the role of government changes to picking winners, the overwhelming majority of governments are supporting the roll out of a suite of new technologies, with some, such as the Danes, Norwegians, Scots and Japanese moving to a system level policy approach.

For issues of infrastructure for fuel cell and battery EVs, for example, there is no government that is only supporting the roll out of just battery EV recharging points. Although behind the curve in terms of volume, the roll out of hydrogen infrastructure is underway, and similar to battery EVs, is being supported by central governments.

Table 3.1, provides a high-level snapshot of the strength of the drivers in 2015, the impact on the fuel cell sector, and the potential for impact on the sector in 2016. This is, by its nature, a very high-level table, and is shown here to provide a framework for the debate on the developments in the industry.

Clearly, country by country and market by market, the drivers shift in importance and impact. For example, the impact of the EU Stage V emissions limits of railroad engines in Europe, which will come into force in 2021, is likely to be one the key drivers behind the current wave of interest and investment in developing and adopting fuel cell drivetrains in urban rail. Using this table though, we can already see that the markets that are developing with business opportunities in the short to medium term are likely to be around the off-road engine sector.

Table 3.1: Drivers for Fuel Cell Adoption

	Strength of Driver for Change in 2015	Strength of Impact on Fuel Cell Sector in 2015	Potential for 2016
Decarbonisation	↑	↗	↗
Reduction in Criteria Emissions			
- On Road	↑	↗	↑
- Off Road	↑	↑	↑
Electrification	↔	↗	↔
Resilience	↔	↗	↑
Water	↔	↔	↔

Source: 4th Energy Wave, 2016

Interestingly, what has become clear over the last year is that resilience as a driver for change, which was extremely strong in 2014, impact has lessened somewhat in 2015.

At present, as a driver for change, at government level at least, it appears to be extremely cyclical, with heightened impact during a 12 – 18 month window post a so called billion-dollar weather event. Then waning somewhat after that. The Rockefeller Foundation, which is supporting the 100 Resilient Cities initiative, recently highlighted the need for more systemic government level planning and funding for resilience to be inbuilt, and not reactionary, post an event.

This though is likely to be still some years away. The impact for the fuel cell industry is likely to be that to effectively capitalise on such a cyclical driver would require a much faster, effective, reactive business development and marketing ability. Something the industry in 2015 remains fairly woeful at.

Stationary Engine Emissions Limits

Emission reduction targets are a very sensitive political issue. Originally, the focus was ozone-depleting chemicals, then greenhouse gas emissions (GHGs). Now, pretty much on a par with GHG emissions are targets for the reduction of the criteria pollutants of carbon monoxide, lead, ground-level ozone, particulate matter, nitrogen dioxide, and sulphur dioxide, as well as some non-criteria pollutants such as arsenic. Unlike GHG reduction targets, which are somewhat universally calculated at country level, criteria pollution targets are set at different spatial levels in different regions and countries. For example, in Europe, cities have very clear emissions targets set by the European Union[1], outlined in table 3.2 below. In China, the targets are at regional level, and in the US, they are at State level.

Table 3.2: EU Air Quality Standard

Pollutant	Concentration	Averaging period	Legal nature	Permitted exceedances each year
Fine particles (PM2.5)	25 µg/m^3	1 year	Target value entered into force 1.1.2010 Limit value enters into force 1.1.2015	n/a
Sulfur dioxide (SO_2)	350 µg/m^3	1 hour	Limit value entered into force 1.1.2005	24
	125 µg/m^3	24 hours	Limit value entered into force 1.1.2005	3
Nitrogen dioxide (NO_2)	200 µg/m^3	1 hour	Limit value entered into force 1.1.2010	18
	40 µg/m^3	1 year	Limit value entered into force 1.1.2010	n/a
PM10	50 µg/m^3	24 hours	Limit value entered into force 1.1.2005	35
	40 µg/m^3	1 year	Limit value entered into force 1.1.2005	n/a
Lead (Pb)	0.5 µg/m^3	1 year	Limit value entered into force 1.1.2005 (or 1.1.2010 in the immediate vicinity of specific, notified industrial sources; and a 1.0 µg/m^3 limit value applied from 1.1.2005 to 31.12.2009)	n/a
Carbon monoxide (CO)	10 mg/m^3	Maximum daily 8 hour mean	Limit value entered into force 1.1.2005	n/a
Benzene	5 µg/m^3	1 year	Limit value entered into force 1.1.2010	n/a
Ozone	120 µg/m^3	Maximum daily 8 hour mean	Target value entered into force 1.1.2010	25 days averaged over 3 years
Arsenic (As)	6 ng/m^3	1 year	Target value entered into force 31.12.2012	n/a
Cadmium (Cd)	5 ng/m^3	1 year	Target value entered into force 31.12.2012	n/a
Nickel (Ni)	20 ng/m^3	1 year	Target value entered into force 31.12.2012	n/a
Polycyclic Aromatic Hydrocarbons	1 ng/m^3 (expressed as concentration of benzo(a)pyrene)	1 year	Target value entered into force 31.12.2012	n/a

Source: europa.eu

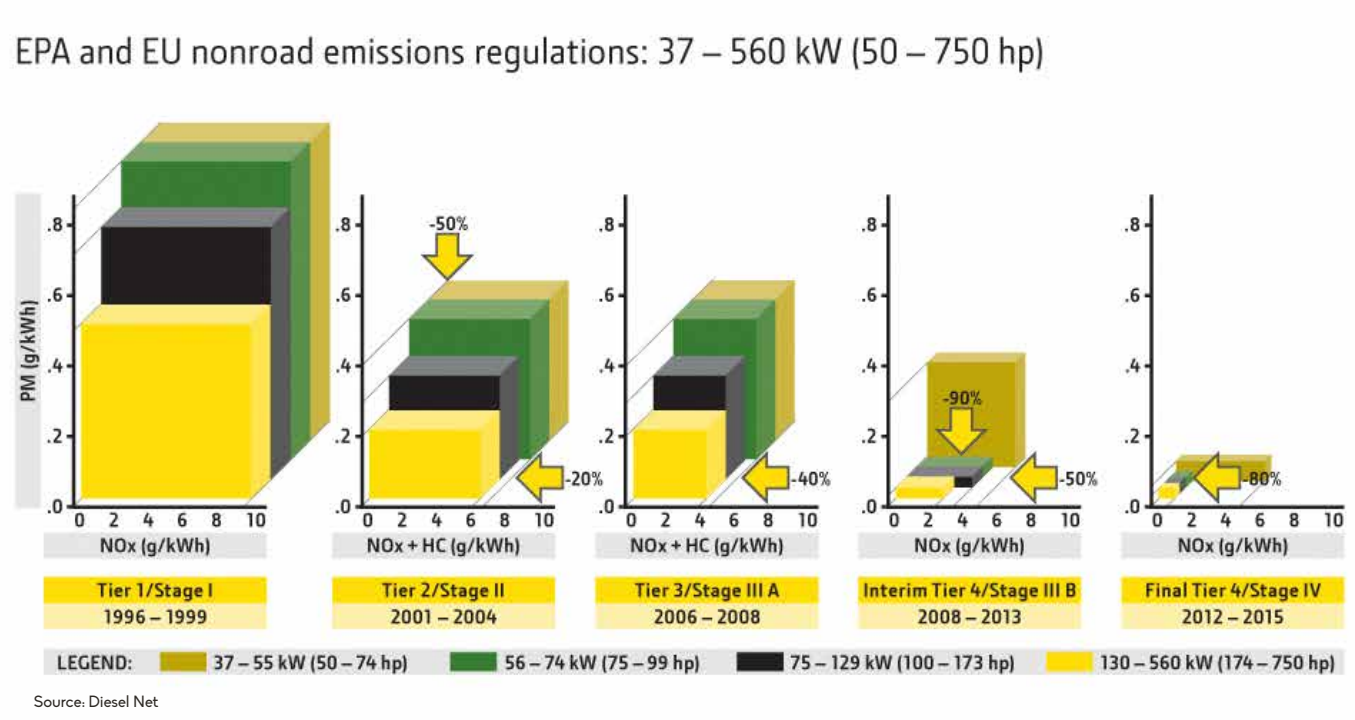
[1] Directive 2008/50/EC

This means that some regions are more relaxed, if you can call it that, over pollution levels. The counterbalance to this is the emergence of a global meta trend, in developed and emerging economies, to rapidly tighten up emission control legislation.

It appears that that the global norm is converging around the equivalent to the Euro Stage IV regulations, and could well be pretty much global within the decade. Interestingly, whilst this will allow the continued sale, and use, of petrol and diesel vehicles, the micro trend, which could become macro, is one of regions moving to outright ban the sale of new petrol and diesel vehicles. So far, this is Norway, the Netherlands and India, above a certain engine size.

Moving away from cars, an increasing lens of focus is moving onto emissions from off-road stationary and portable engines. Currently in Europe, non-road emission standards are Stage IV, with a proposed further cut in Stage V[2]

Image 3.1: (US) EPA and EU Non-Road Emissions Regulations, 37 – 560 kW



Source: Diesel Net

[2] Full information can be found at http://ec.europa.eu/transparency/regdoc/rep/1/2014/EN/1-2014-581-EN-F1-1-ANNEX-1.Pdf

As well as being more stringent, the key differences between Stage IV and V is the broadening of the scope of engines included.

According to Diesel Net, under the Stage V regulation, emissions would be now regulated from the following engine categories:

- **Category NRE** — Engines for mobile non-road machinery, suited to move or to be moved, that are not included in any of the points below;
- **Category NRG** — Engines above 560 kW used in generating sets;
- **Category NRSh** — SI engines below 19 kW exclusively for use in hand-held machinery;
- **Category NRS** — SI engines below 56 kW that are not included in category NRSh;
- **Category IWP** — Engines above 37 kW used for the propulsion of inland waterway vessels;
- **Category IWA** — Auxiliary engines above 560 kW for use in inland waterway vessels;
- **Category RLL** — Engines for the propulsion of railway locomotives;
- **Category RLR** — Engines for the propulsion of railcars;
- **Category SMB** — SI engines used in snowmobiles;
- **Category ATS** — SI engines used in all terrain and side-by-side vehicles;
- Strengthening the emission limits for some engine categories, such as engines of 19-37 kW and engines for inland waterway vessels;
- Diesel (CI) engines from 0 to 56 kW and to all types of engines above 56 kW;
- Compression ignition (CI) engines below 19 kW and above 560 kW, spark ignited (SI) engines above 19 kW, and other previously unregulated engines;
- Adopting particle number (PN) emission limits for several categories of CI engines.

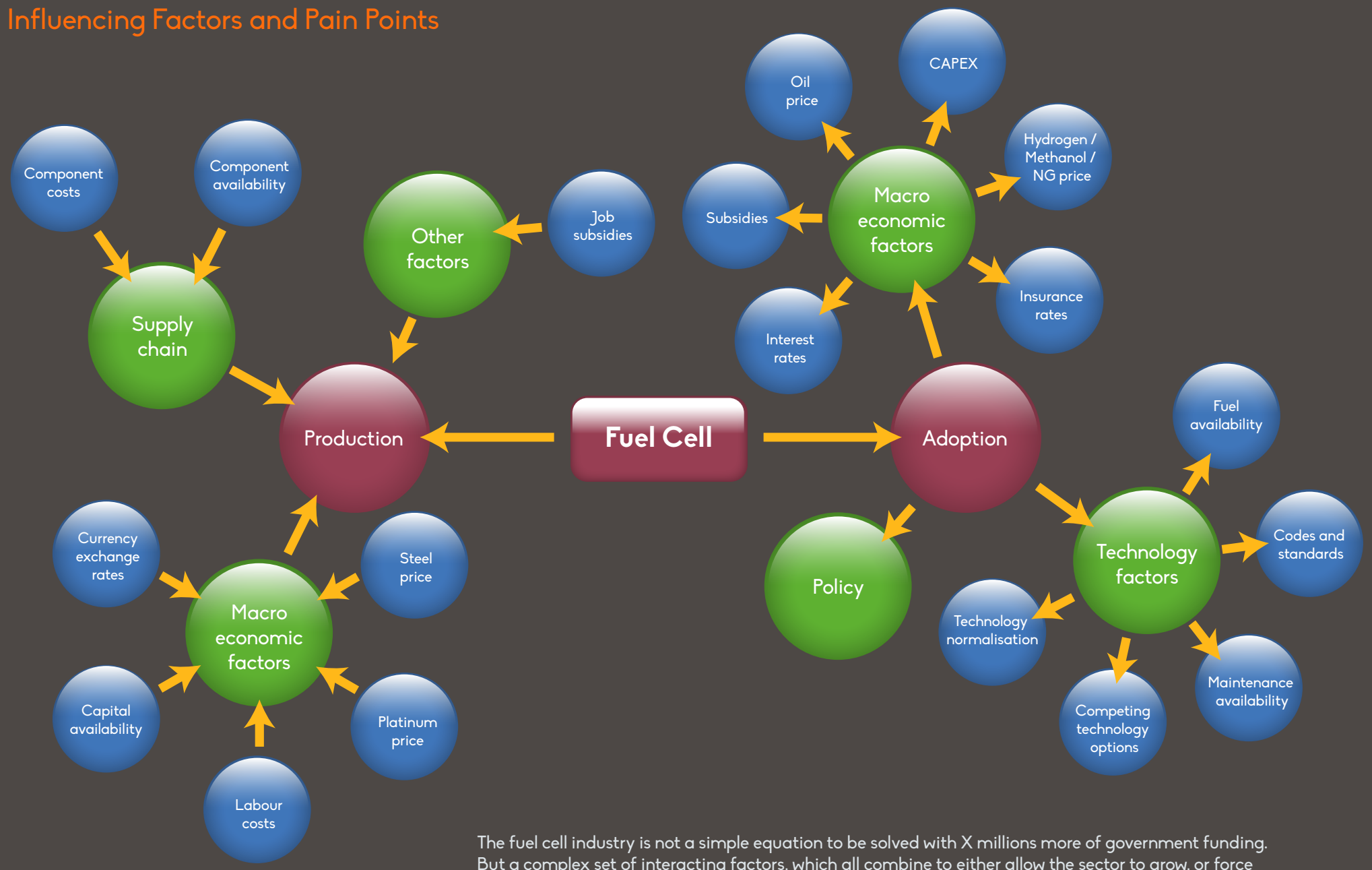
This shift to include smaller engines, as well as sectors such as rail, is forecast to have a significant impact on the market opportunities for fuel cells.

In terms of tipping points, the point at which it is more economical to use an alternative power source then to keep retrofitting more and more complex solutions into, and onto, engine technology, Stage V is unlikely to be it, in overall levels.

But, due to the increased complexity of the off-road engine to meet regulation, the price delta between a small generator, and an equivalent fuel cell generator, is shrinking and in some cases, is now less than £1,500 / $2,100 / ¥243,000. The availability though of the fuel cell generator is extremely limited, and fuel and refuelling networks virtually non-existent.

So although an economic tipping point is potentially on the horizon before 2030, the (fuel cell) market itself is currently lagging behind the opportunity.

Influencing Factors and Pain Points



The fuel cell industry is not a simple equation to be solved with X millions more of government funding. But a complex set of interacting factors, which all combine to either allow the sector to grow, or force it to shrink. The map plots out the basics of these interactions, each of which needs to be more fully unpacked and understood, before we can say with confidence how best to better stimulate the sector. Within these factors, two that are gaining increasing focus is that there is an impact from oil prices, and the (re)emergence of the city state.

Oil prices

One of the most interesting potential linkages that is coming to light is the impact of oil price on the sector. With the decoupling, pretty much at least, of the oil and natural gas price, and, through increased use of renewables, the lessening of the impact of oil price on electricity price, this linkage is somewhat not straightforward to understand, or even to plot.

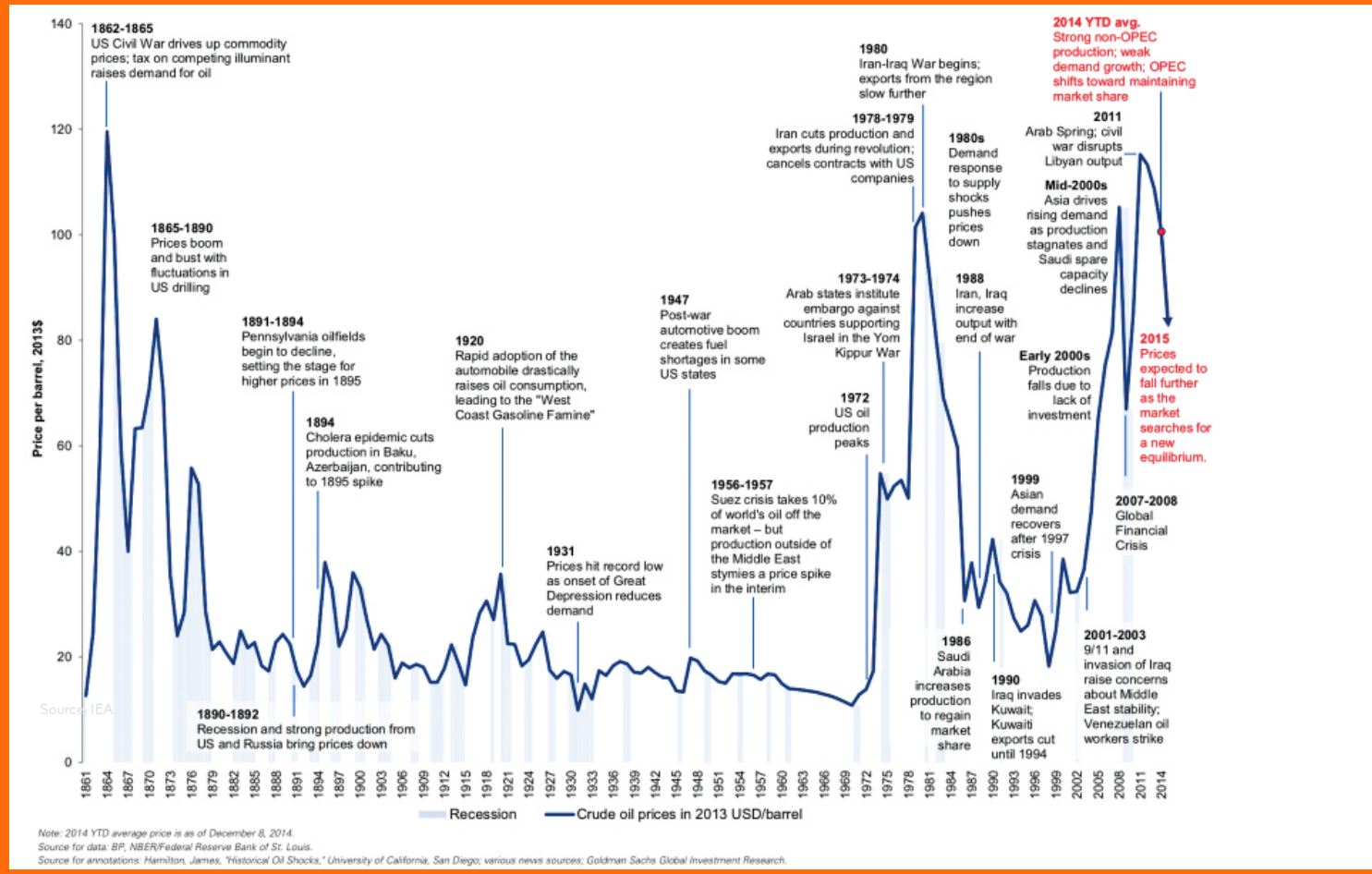
In terms of adoption into the remote area power (RAPs) market, featured in the **Fuel Cell and Hydrogen Annual Review, 2015**, the adoption pipeline into the oil sector has severely dipped as the oil price has crashed. So far, so much that this makes sense. As oil company budgets have been severely squeezed, cuts into investment into exploration, and efficiency upgrades in the distribution networks have suffered.

Efficiency upgrades at least is one area that will likely come back in the short term. Driven by government mandate to reduce emissions, the most economical way to achieve this is to upgrade power installations along the networks. Because of this, this sector at least should see a bounce back within the short term.

The rest of the linkage between oil price and fuel cells is not straightforward, but from the initial data crunching, there is clearly something there. Couple this with the dynamic of increased adoption of EVs, also removing oil demand from the transportation sector, and the increasing cost of oil extraction, the chart below could well continue to populated by up and down swings.

One area to watch.

Image 3.2: History of Crude Oil Prices



Note: 2014 YTD average price is as of December 8, 2014.
Source for data: BP, NBER/Federal Reserve Bank of St. Louis.
Source for annotations: Hamilton, James, "Historical Oil Shocks," University of California, San Diego; various news sources; Goldman Sachs Global Investment Research.

The (Re)Emergence of the City State

Historically, in many countries, the City was a separate trading entity. Over the last few decades, with increased centralisation, in most countries in this was almost totally subsumed to government level. Now many cities are re-emerging as power blocs in their own right. London, Edinburgh, Berlin, Paris, San Francisco to name but a few. And on top of that there is a growing movement of these cities banding together, creating buying power which could enable a change in market behaviour.

Instead, therefore, of focusing on what governments should do for the sector, one other potential route is to work within this re-emergence of the city and bring the market to the front at city level.

Each of the influencers on the map have a different weighting of importance and different response path to the market. What is now very clear though is that they are all in play and need to be monitored and worked with.

4. Geographical Overview

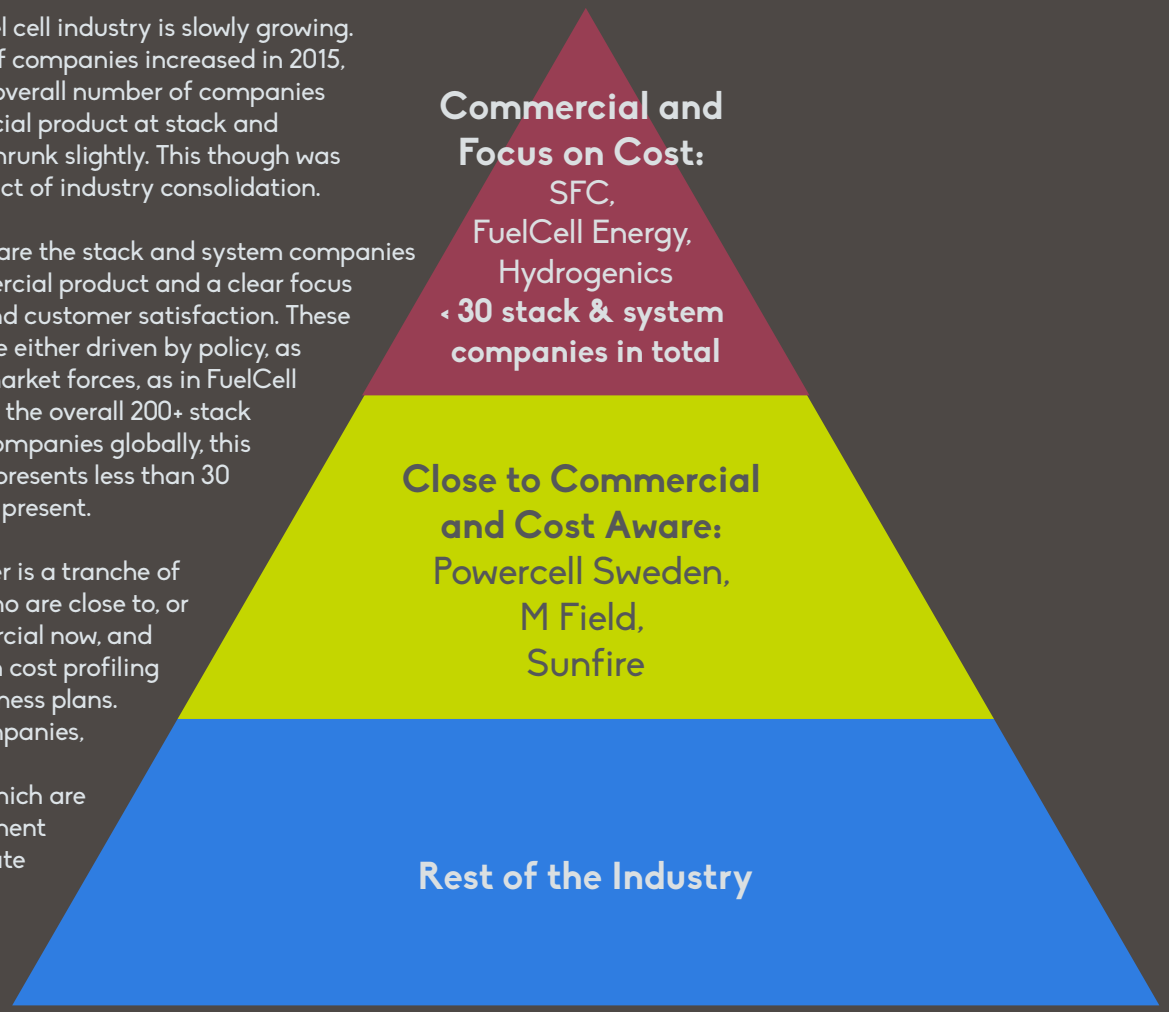
Industry Structure

The global fuel cell industry is slowly growing. The number of companies increased in 2015, although the overall number of companies with commercial product at stack and system level shrunk slightly. This though was more an impact of industry consolidation.

The top, layer are the stack and system companies with a commercial product and a clear focus on cost out and customer satisfaction. These companies are either driven by policy, as in Japan, or market forces, as in FuelCell Energy. But of the overall 200+ stack and system companies globally, this top section represents less than 30 companies at present.

The second tier is a tranche of companies who are close to, or quasi commercial now, and are building in cost profiling into their business plans. These are companies, like the Tier 1 companies, which are seeing investment from the private sector, and creating customer pipelines. In terms of scale this is less than 60 companies worldwide.

The base of the pyramid, making up the majority, is made up of the rest of the stack or system industry. These companies are still very much focused on RD&D, which doesn't centre around the cost structure of the stack or the system.



What this means for the fuel cell sector in general is that we will see an increase split between, on one side the Tier 1 and 2 companies, and on the other the rest of the industry. Tier 1 and 2 will continue to take the overwhelming majority of the sales and investment, whilst the rest of the industry are ripe for M&A. During 2015 this split became increasingly clear with an increase in consolidation and buy outs.

Using data from the 4th Energy Wave Global Fuel Cell Directory, geographically, we can see that the three major regions are now much more closely aligned in terms of the number of companies. This is a clear shift from 2014 when, as can be seen in Chart 4.2, was more weighted towards Asia and Europe.

One of the factors behind the increased number of new entrants into the sector is the reduced barriers to entry to new companies, especially at system level. Historically, a 4th Energy Wave rule of thumb was that there was needed in the region of $1 billion in invest into R&D and product commercialisation of a new PEM fuel cell system, and somewhat more for a system for a SOFC.

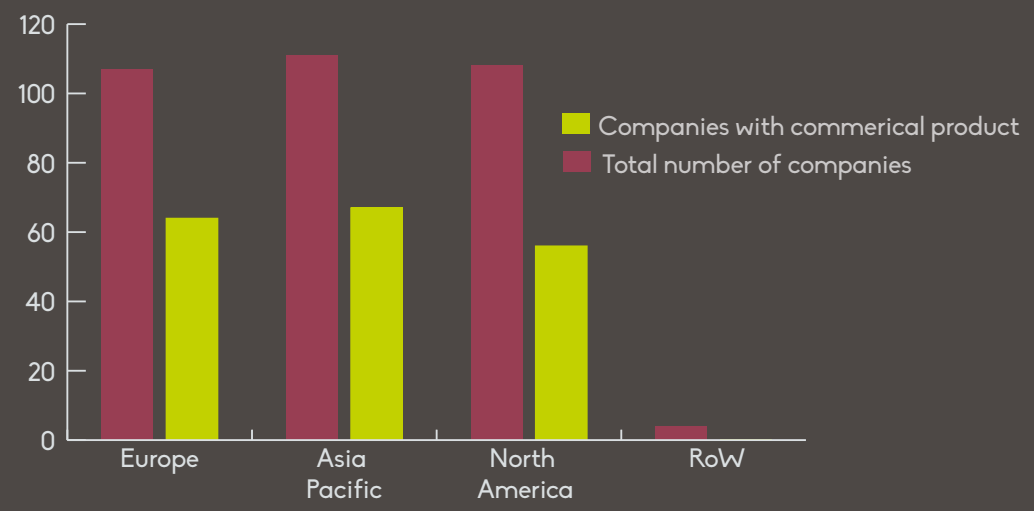
Now though, as we see the start of the stack standardisation, this upfront investment cost is being reduced. There is a long way to go, obviously, but through innovation, and standardisation, as the financial barriers to entry are reduced, and the markets mature, we should see an increase in the number of smaller market entrants.

The downside to this is that in terms of level of commercial availability, it appears that at stack and system level, still half of all companies are non-commercial.

North America still lags behind in terms of commercial system availability. Here, we class a company as having a commercial product if it is available to buy, with warranty, and is somewhat off-the-shelf, i.e. does not require significant re-engineering before delivery. Of the companies that are non-commercial, some 40% of them have the potential to have a product in the marketplace before 2020. The rest are either ripe for asset stripping or consolidation, or stuck in an R&D loop from which they are unlikely to emerge.

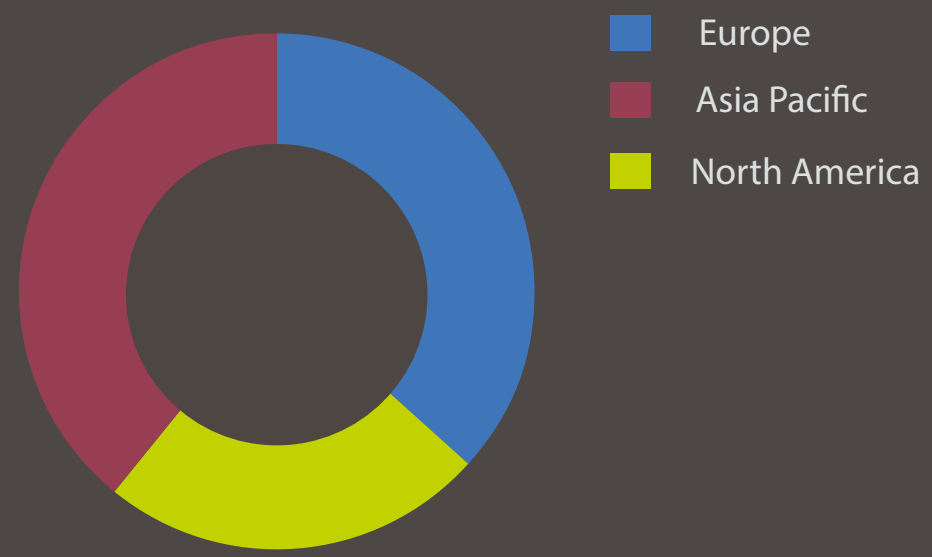
Whilst this may sound brutal, it is unlikely that a

Chart 4.1: Geographical Split of Fuel Cell Stack and System Companies, All Electrolytes, 2015



Source: 4th Energy Wave, 2016

Chart 4.2: Geographical Split of Fuel Cell Stack and System Companies, All Electrolytes, 2014



Source: 4th Energy Wave, 2016

good 25% of all companies that are currently non-commercial are set up, in terms of staffing or capital structure, in such a way that they could successfully transition to a commercial footing. Investment in these companies would need to predicated on the ability to totally turn them around, and often, this level of needed intervention drives investors elsewhere.

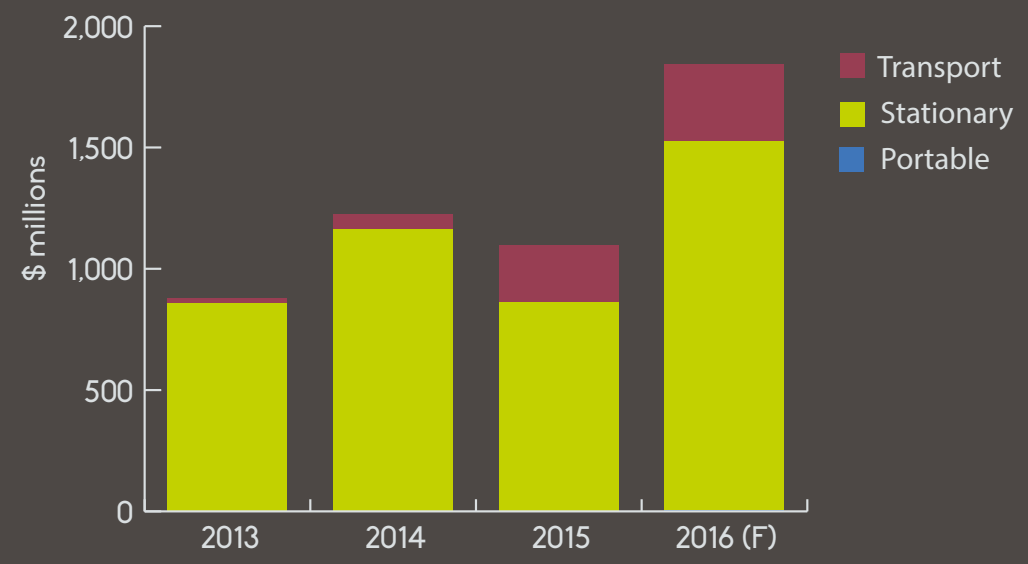
If we turn to shipments by region, we see that in terms of MWs, Asia Pacific stepped up its lead in 2015, and is forecast to consolidate this in 2016.

Note that this chart looks at region of manufacture, not adoption. So although, for example, Kolon Hydrogenics adopted a 1 MW PEM system in South Korea, it was manufactured in Canada, so is within the North American data. The data is also for system level only in this chart.

Europe still lags far, far behind the rest of the world in terms of system manufacturing. Of the companies with commercial product, most of them are either not manufactured in Europe, or are small 5 kW and under units. The one area that Europe is very strong in is the portable fuel cell market. So when we flip this chart, as is shown on the next page, into systems shipped the picture is somewhat different.

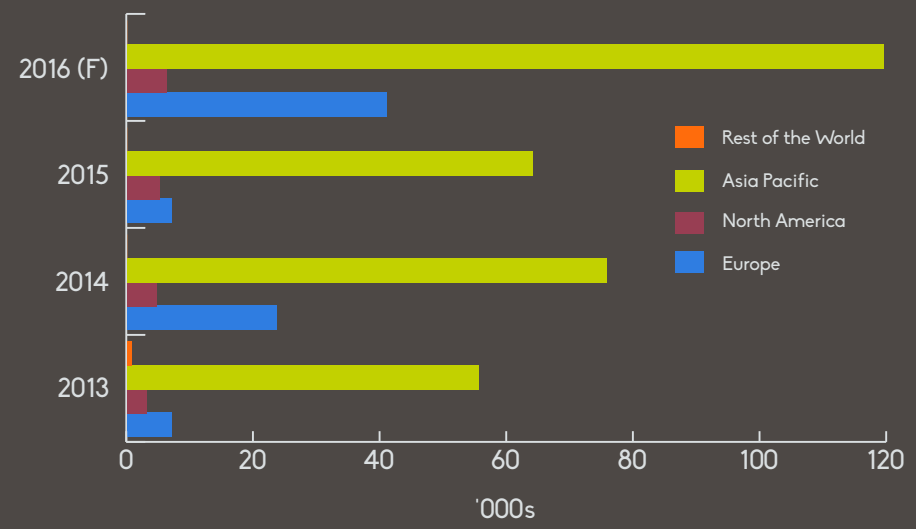
Focusing on Asia, for Japan specifically, and

Chart 4.3: Global Fuel Cells Shipped by MW and Region: 2013 – 2016 (F)



Source: 4th Energy Wave, 2016

Chart 4.4: Global Fuel Cells Shipped by Systems and Region: 2013 – 2016 (F)



Source: 4th Energy Wave, 2016

increasingly, South Korea, to meet their government stated adoption targets, these numbers will have to jump in volume over the next handful of years. The link with adoption here is that as both of these markets are primarily sale to home markets, with export secondary. Therefore, shipments tend to equal adoption.

In terms of revenue, 4th Energy Wave focuses on the revenue generated from the sale of fuel cell systems. To prevent double counting, or artificially inflating the value of the sector, it does not take into account R&D 'revenue', or disaggregate this into revenue per component. Only revenue generated from systems shipped is included in the figures. Due to the number of companies still with closed book revenues, internal estimates on product prices for a number of companies had to be made to generate Chart 4.5.

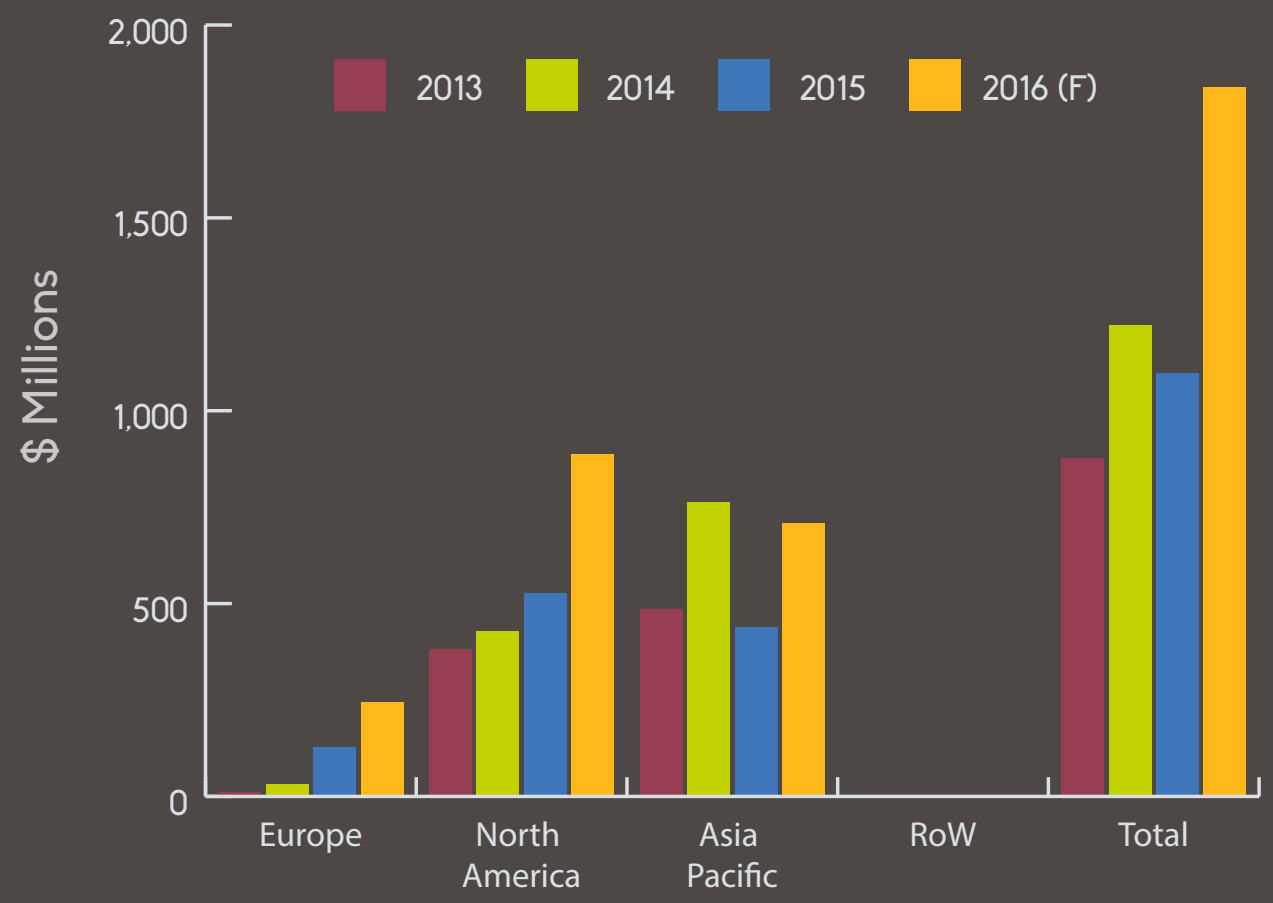
What this chart shows is that in 2015, North America took the majority revenue from fuel cell system shipments. This is a shifting in position from 2014, where Asia dominated. Sales in North America were boosted significantly by a number of high profile deals, including the sale of fuel cell buses to China, with Ballard Power, and the sale of a 1.4 MW CHP unit by FuelCell Energy to Pepperidge Farm.

The revenue in the North America for 2016 is forecast to jump again to some $900 million in 2016, primarily on the back of increased deals in 2015 in the large stationary sector, which are due for shipment, and associated revenue recognition, in 2016.stationary sector, which are due for shipment, and associated revenue recognition, in 2016.

Asia Pacific revenue dropped somewhat in 2015, primarily due to the dip in sales of ENE FARM systems, and the apparent slowdown in sales from industry giant POSCO Power. Within this chart, it should be noted that of the total revenue, the top ten revenue-generating companies still represent over 90% of all commercial revenue. The sustainability of this position is still somewhat precarious.

In total though the headline numbers are, although there was a dip in overall revenue in 2015, down to $1.1 billion, this is expected to rebound in 2016 to over $1.8 billion.

Chart 4.5: Revenue from Fuel Cell System Sales, Global: 2013 – 2016 (F)



Source: 4th Energy Wave, 2016

Country Attractiveness Index

This year's Annual Review launches the 4th Energy Wave Country Attractiveness Index. This has been created by 4th Energy Wave in response to being asked, on multiple occasions, which country was 'leading' the fuel cell industry.

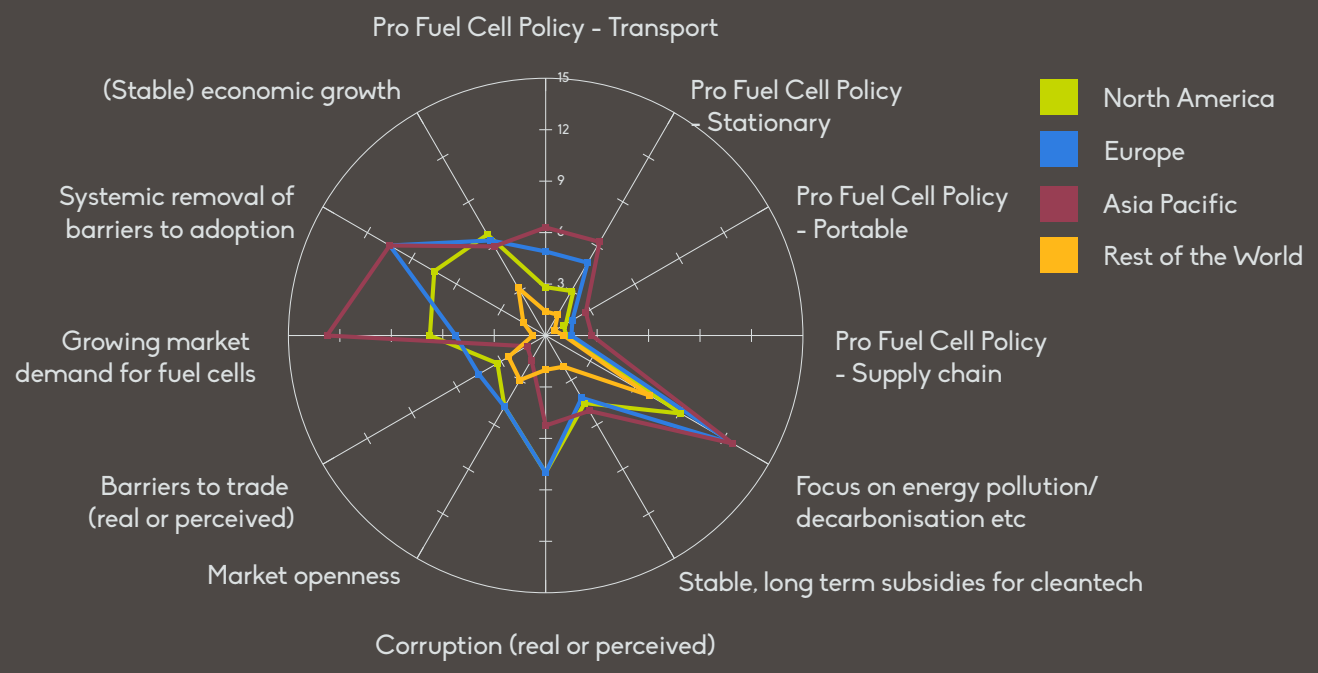
The index has been created to measure and quantify and rank any country. This first set of data presented here takes 12 pre-identified areas of criticality to the fuel cell market, and using an internally assigned weighting and scoring, ranks the countries in two areas:

1. How attractive is a country / region to export fuel cell systems to?
2. How attractive is a country / region to sell into as a home market?

The areas of criticality are:

- Pro Fuel Cell Policy - **Transport**
- Pro Fuel Cell Policy - **Stationary**
- Pro Fuel Cell Policy - **Portable**
- Pro Fuel Cell Policy - **Supply chain**
- Focus on energy pollution / decarbonisation etc.
- Stable, long term subsidies for cleantech
- Corruption (real or perceived)
- Market openness
- Barriers to trade (real or perceived)
- Growing market demand for fuel cells
- Systemic removal of barriers to adoption
- (Stable) economic growth

Chart 4.6: Fuel Cell Attractiveness Index: Countries to Export to.



Source: 4th Energy Wave, 2016

Corruption information was taken from the Corruption Perceptions Index, 2015[3], and economic growth data is taken from the World Bank.

If we look at the data in response to how attractive a region is to export fuel cell systems to, shown in the Chart 4.6, we can see that for the three macro fuel cell regions of North America, Asia Pacific, and Europe, the data is fairly close together, with Asia taking the lead in the policy led areas, including identification and systematic removal of barriers to adoption, and pro fuel cell policy.

There is no great surprise in there, as it is known that Japan and South Korea are very bullish on fuel cells.

One of the key areas that a number of countries scored low on is the systemic removal of barriers to adoption.

This really is critical. It is one thing to support an innovation-based economy, to fund and encourage a start-up culture and growth of a number of high tech companies, but it has been shown that unless there is a local market for fuel cell adoption, these companies have limited options. They either leave the country to manufacture where the market is, sometimes leaving a token head office behind, or, due to the additional capital needed to set up primarily as an export-based company, they struggle to grow.

[3] https://www.transparency.org/cpi2015/

In short, the creation of local market is as critical to long-term success as funding innovation. Most countries' government agencies though are still embedded in the high-level discourse of the opportunities that a fuel cell, or hydrogen, sector represents to them, and are not focusing on the long, complex and exceedingly detail-orientated nitty gritty of identifying and removing local barriers to adoption.

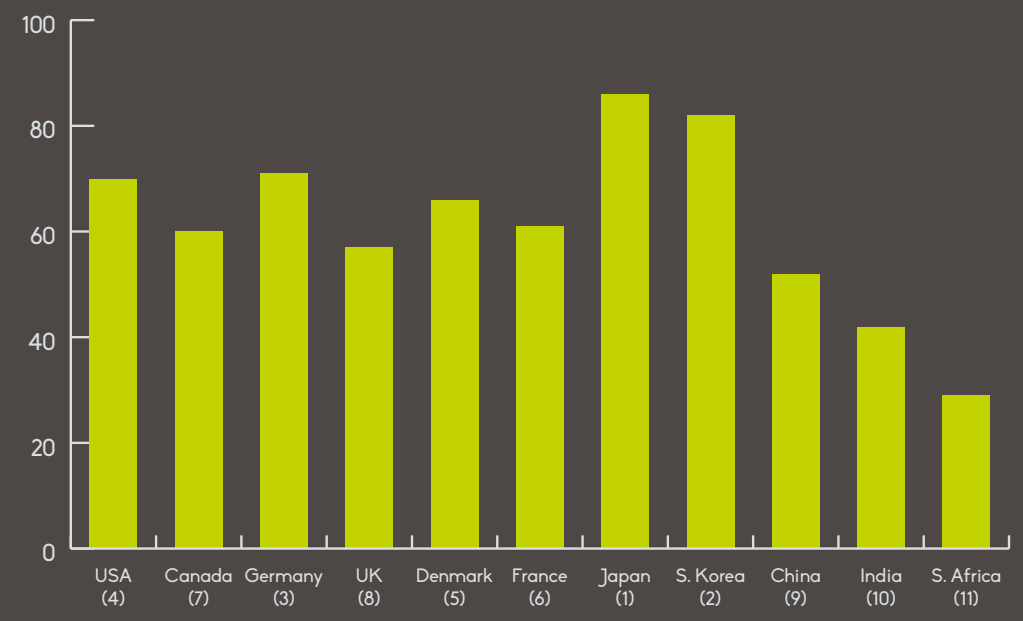
If we unpack the data from regional to country level, the data presented here ranks the USA, Canada, Germany, the UK, Denmark, France, Japan, South Korea, China, India and South Africa. France, India and South Africa have, and continue to, make increasing moves in the fuel cell sector. Whilst at the minute they are somewhat upstarts, with a lot of work to do, it is worth including these countries from year one of the Index to show how fast things can change.

The next chart ranks the countries measured, and shows their overall scores and relative ranking.

In 2015, the most attractive country for the fuel cell sector was Japan.

The US was fourth and China was ninth. Even with the removal of subsidies for large fuel cell CHP systems at the end of this year, Germany was an impressive third.

Chart 4.7: Overall Country Attractiveness Ranking, 2015



Source: 4th Energy Wave, 2016

Japan

Japan is known globally for government level long term, stable, and well-coordinated approach to the development and creation of a local fuel cell industry. One highly pertinent example from the WE NET (International Clean Energy Network Using Hydrogen Conversion) project, from 1994, was the creation of a set of basic specifications and a conceptual designed of an ocean-going liquid hydrogen carrier. The translated text states that in the 2014, the following was achieved:

'Development of liquid hydrogen transportation tanker - Basic specifications were determined and a conceptual design was made on a tanker carrying square-shaped tanks with the same-capacity as that carrying sphere-shaped tanks each with a capacity of 200,000 m3.'

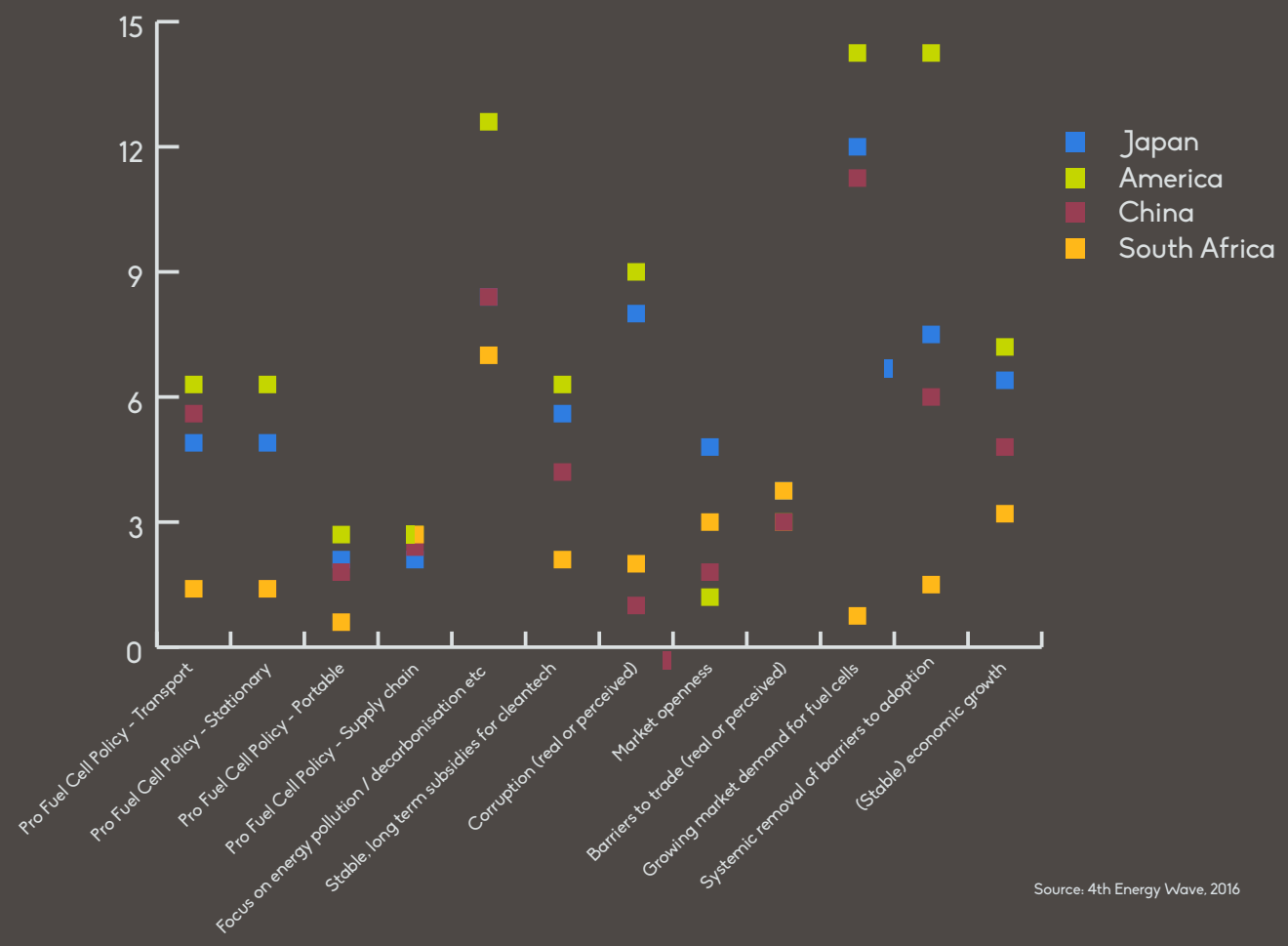
Now, fast forward 20 years, and it was reported in the Japanese newspaper, the Nikkei, that 'Kawasaki Heavy Industries Ltd. (KHI) will build the first ocean-going ships to carry liquefied hydrogen (LH2), with plans for a demonstration test by 2017'.

This length of time of sustained investment, clear policy direction on product development and adoption, renewed and agreed upon targets, coordinated activity and focus, has led to the country outstripping any other in terms of developing a strong, indigenous fuel cell sector.

Image 4.1: Artist's Impression of the KHI Liquid Hydrogen Carrier

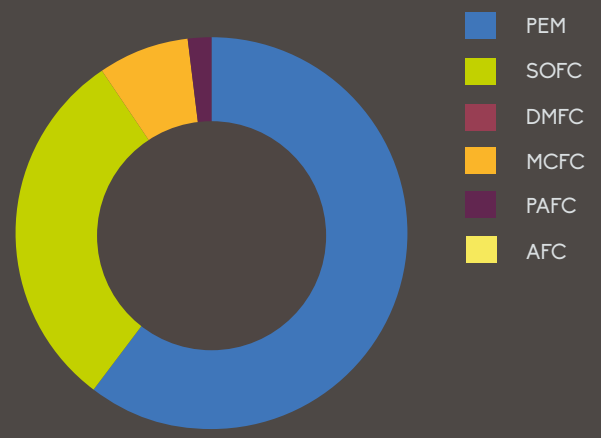
Source: Kawasaki Heavy Industries Ltd

Chart 4.8: Country Attractiveness Index Scores for Japan, America, China and South Africa



Source: 4th Energy Wave, 2016

Chart 4.9: Japanese Fuel Cell Stack and System Company Electrolyte Development Mix, 2015



Source: 4th Energy Wave, 2016

If we dig into the types of fuel cell under development in Japan, we see the current predominance of PEM systems and stacks. With the focus on the residential market, this is somewhat understandable, though as the data is replotting over the coming years, this, 4th forecasts, is likely to change, with an increasing number of companies working on high temperature systems.

What is interesting is that, aside from alkaline fuel cells, there are companies in Japan actively developing, at stack and system level, all of the major fuel cell electrolytes. Within this, SOFC companies are increasingly bullish around short-term deployments and commercialisation, with a 2017 – 2018 timeframe being a somewhat common date being discussed.

The downside though is that, in Japan, one thing that is really clear from the data is that, currently, it is not all going to plan.

An example of this is that the target for fuel cell vehicles to be on the road in Japan has recently been downgraded from multiple millions to 800,000 by 2030. And some 40,000 to be on the road as soon as 2020. This is thought by the automotive companies spoken to be doable, but will still require significant government support out to at least 2020. In terms of hydrogen refuelling, the government plan to have some 320 hydrogen refuelling stations open by 2026.

The other transformational project that has been underway for some time is the ENE FARM project. The current government targets are 5.3 million homes in Japan to have a fuel cell resCHP installed by 2030, and some 1.4 million by 2020.

The issue here, which is graphically illustrated in Chart 4.10 below, is that sales actually dropped last year. With a cumulative installation of 150,000 by the end of 2015, this implies that to hit the target of 1.4 million by, say, the end of 2020 will require 250,000 systems to be installed year-on-year for the next five years. With last year's sales reaching just 35,000 this, it should be said, that is an almost impossible step up.

Japanese suppliers of ENE FARM systems have publically noted that sales into the retrofit market especially have been slower than anticipated [4], so in a very direct fashion, which on many levels should be applauded, Japanese developers have obviated the problem by starting to build new towns.

Within each new home will be a fuel cell and solar panels, and or, energy storage included. With each town being tens of thousands of new homes, the fuel cell distributor companies are circumventing the issues with business-to-customer sales and creating their own sales pipelines.

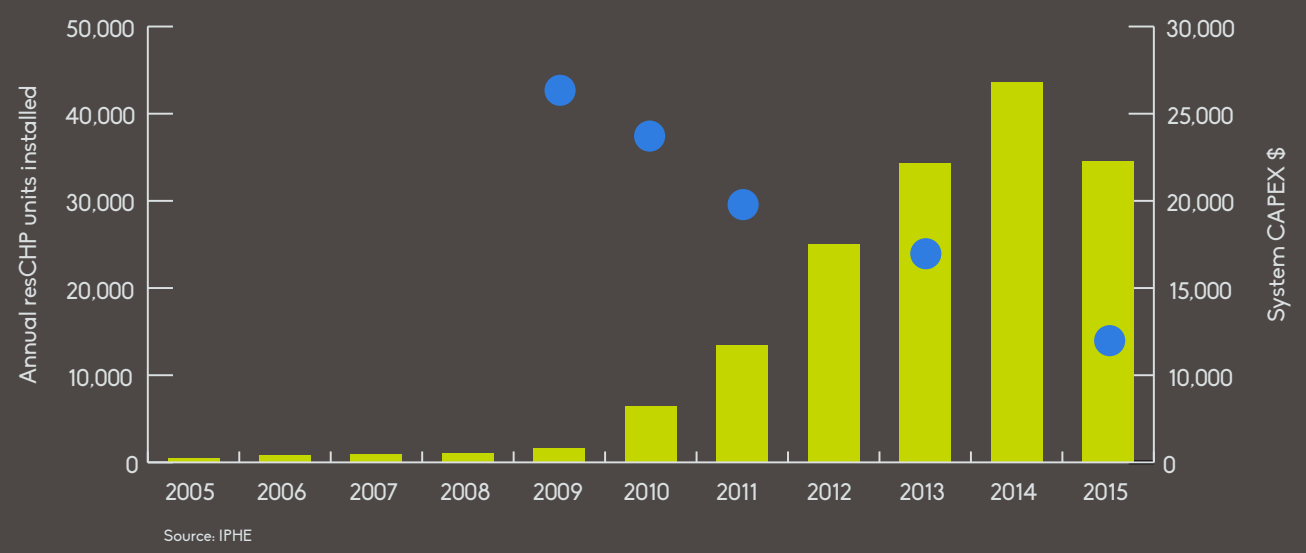
One example, from 2016, was the move by Toyota's housing division to buy the full plans for H2PIA.

For those who either didn't know it had gone away, or had never heard it of it to start with, H2PIA was the zero carbon, fuel cell powered, community plan that was designed by a group of Danish firms and architects in 2006. The housing was planned in three options – Plugged, Unplugged, Hybrid – and each house would come with renewable energy and fuel cells. Unplugged is, as it sounds, not hooked into a grid, plugged is, and hybrid is a bit of both. The mock ups at the time were stunning and truly utopian.

The original plan was to break ground in 2007 in Denmark and have a fully operational community only a couple of years later. But it never got off the ground.

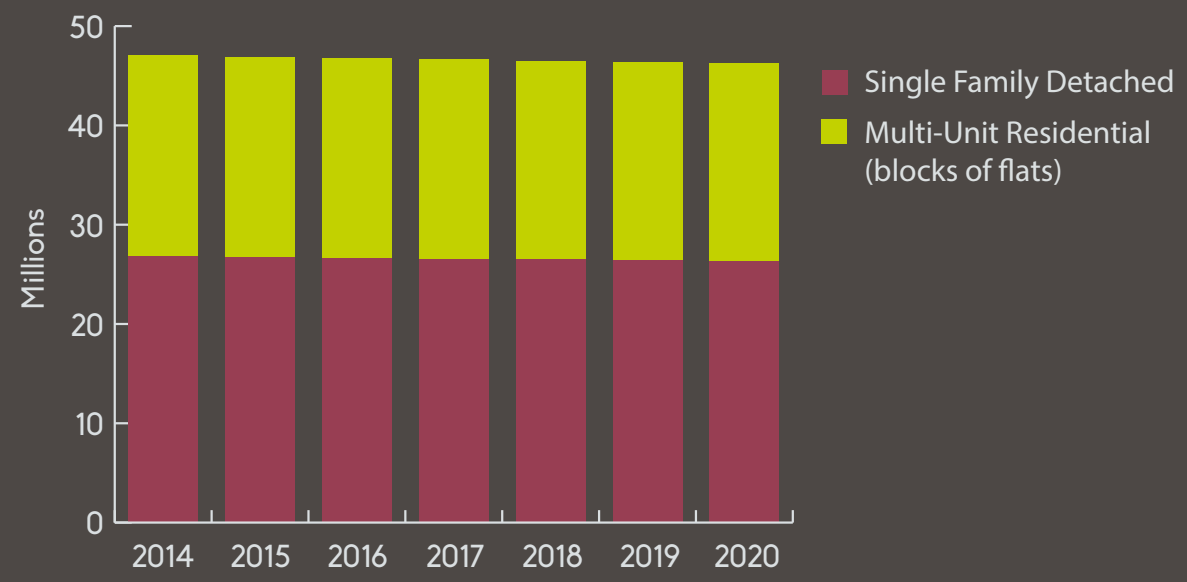
[4] European developers really should take note of this!

Chart 4.10: Japanese ENE FARM Deployments and System Cost: 2005 - 2015



Source: IPHE

Chart 4.11: Forecast of Japanese Residential Building Stock



Source: Japan Statistic Bureau

At the time, there was no reason given why the whole project just upped and died, but it is a fairly safe bet to say that it was funding related. At the time, the whole fuel cell industry was just coming out of a major hype cycle and the very term fuel cells was something of a swear word in the investor community. So the whole concept evaporated into the odder ends of the internet. A dream of what could have been.

Now in 2016 and Toyota's Housing Division have bought the plans and designs lock, stock and barrel. Say hello to '**Toyota H2Pia Division**'. It will be interesting to watch how this plan unfolds.

This, it should be a noted, is a very Japanese way of doing business and if we look at the government forecast of residential building growth, shown in Chart 4.11, we can see that it is very, very flat. Unlike most countries though, building turnover is relatively high in Japan, and although the overall stock could in fact shrink, the relative proportion of new builds, and therefore potential for new towns, within this is higher than say European countries.

The replicability of this model then, of building new towns with fuel cells pre-installed, is certainly not something we are likely to see in Europe, but in the US, Canada, and perhaps Australia, this could provide an interesting medium-term option.

Finally, in this section, to highlight the amount of commercial activity underway in Japan, the table in Appendix A tabulates all the publically announced commercialisation plans from Japanese companies during 2015. As you can see from this table, this should provide a very vibrant few years for Japanese businesses.

Copyright: Sunfire

5. 2015 in Numbers

Each year, 4th Energy Wave reports out the data behind the fuel cell industry growth. The data is gathered from the companies and only reports out actual shipments that have left the factory door. The dataset was first created by Fuel Cell Today in the 2008 Review and represents the only continuous dataset on the industry. The full dataset is commercially sensitive and is not for full public release. The information presented here is designed to complement the bi-annual 4th Energy Wave long range adoption forecast.

Shipments and MWs

If we turn to the actuals, we can see that instead of the forecast growth in shipments during 2015, the headline is that in terms of actual number of units shipped, the overall global industry contracted. Down from 101,000 in 2014, to only 79,000 in 2015.

The main areas of contraction were:

- The portable sector: myFC and Intelligent Energy either stopped, or shifted production of new product, out to 2016. eZelleron missed their projected first 2015 shipment, and it now looks like late 2016, early 2017 is more likely. These took the forecast growth of portable shipments from 2015 and pushed them out to 2016 / 2017.
- ENE FARM. This was projected by 4th to increase to 80,000 in 2015, in line with the ramp up to 1.4 million by 2020. Instead, the number dipped to just under 35,000.
- Other areas that tailed off in 2015 were the telecoms and remote monitoring sectors. The telecoms market remains lumpy with no clear, smooth increase in sales. Although the Intelligent Energy deal to deploy into base stations in India has the potential to change this, and create steady deployment into the market, this is still a year or so away.

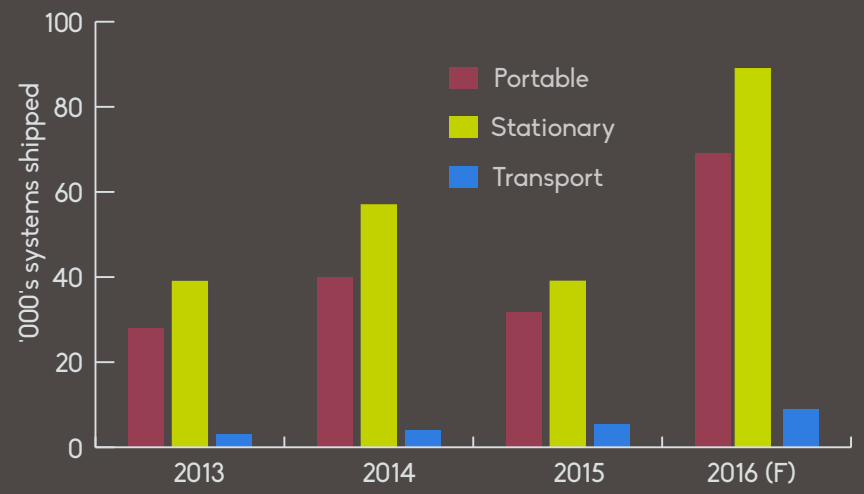
The bounce back in 2016 is forecast on the back of:

- Large deals either signed or under negotiation, at Doosan Fuel Cell America, and FuelCell Energy.
- The residential sector in Japan bouncing back.
- Initial deployment of systems into South Korea as the fuel cell bus order gets underway.
- The portable sector releasing new product and selling at volume.

If we look at MWs shipped, we see that, cumulatively, between 2005 and 2015, the global fuel cell sector has shipped just over 1.2 GWs of systems. Within this, stationary fuel cells have taken the lions share, but 2015 was the first year's transport systems accounted for more MWs than stationary.

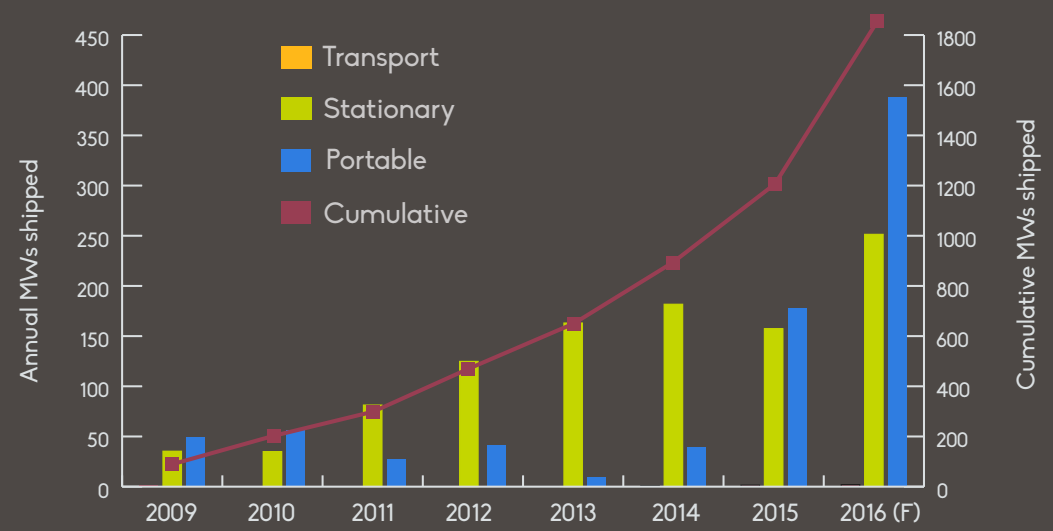
This shifting in ranking was in part due to the slowdown in delivery on large multi MW orders to South Korea, but also the ramp up in interest and orders for heavy duty fuel cells in the transport sector. To put this in context, just 5 fuel cell drivetrains for trains represent 1 MW of fuel cells, or over the equivalent of over 1,000 residential systems.

Chart 5.1: Global Fuel Cell Shipments, by Systems and Sector: 2013 – 2016 (F)



Source: 4th Energy Wave, 2016

Chart 5.2 Global Fuel Cell Shipments, by MWs Shipped and Sector: 2013 – 2016 (F)



Source: 4th Energy Wave, 2016

By 2016, with the shift to interest in heavy-duty fuel cells, the deployment of small fleets of a few thousand fuel cell cars and an increase in niche vehicles such as forklifts, then MWs of power from transport fuel cells are forecast to increase at a much higher rate.

The stationary fuel cell sector continues to grow, but the market now needs a small number of very high profile breakout orders. An example would be a hotel chain announcing that it plans on installing fuel cell CHP systems in 5% of its hotels globally. That sadly really is just an example. Without this then the sector will continue to be project-by-project, implying a much slower growth pattern than transport.

For the large stationary sector, 4th is also forecasting the continued growth of the power purchase agreement (PPA) model. For reference, the 15-year and 20-year PPA model now seems a standard time length that the finance and insurance sectors are accepting in terms of risk.

To put the growth of the fuel cell sector in perspective Chart 5.4 replots the data against that of the growth of the global solar PV market. What we can see is that the solar PV market also sees slight troughs, and that growth now seems to be steady at between 10 – 15 GWs per year. This of course dwarfs the fuel cell sector. At least comparing these two markets directly side-by-side.

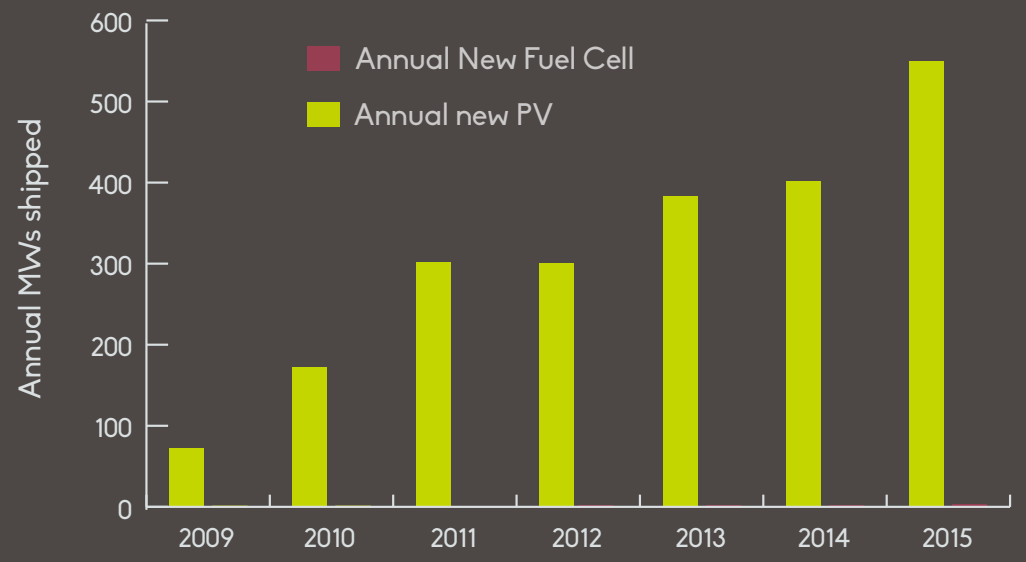
But if we look at the historical growth of the solar sector, using public data, we can say that if the fuel cell sector were to exhibit the same growth curve, then it is lagging about 13 years behind where the solar industry is today, and the kick in the S Curve should be around 2023. This does in fact dovetail somewhat with the 4th Energy Wave long term adoption forecast!

The growth to date of the fuel cell industry is following a similar deployment pattern, but will need to exhibit a similar cost out to take the step change to many GWs per annum that the solar industry now sees. This cost threshold is returned to later in this chapter.

Electrolyte Mix

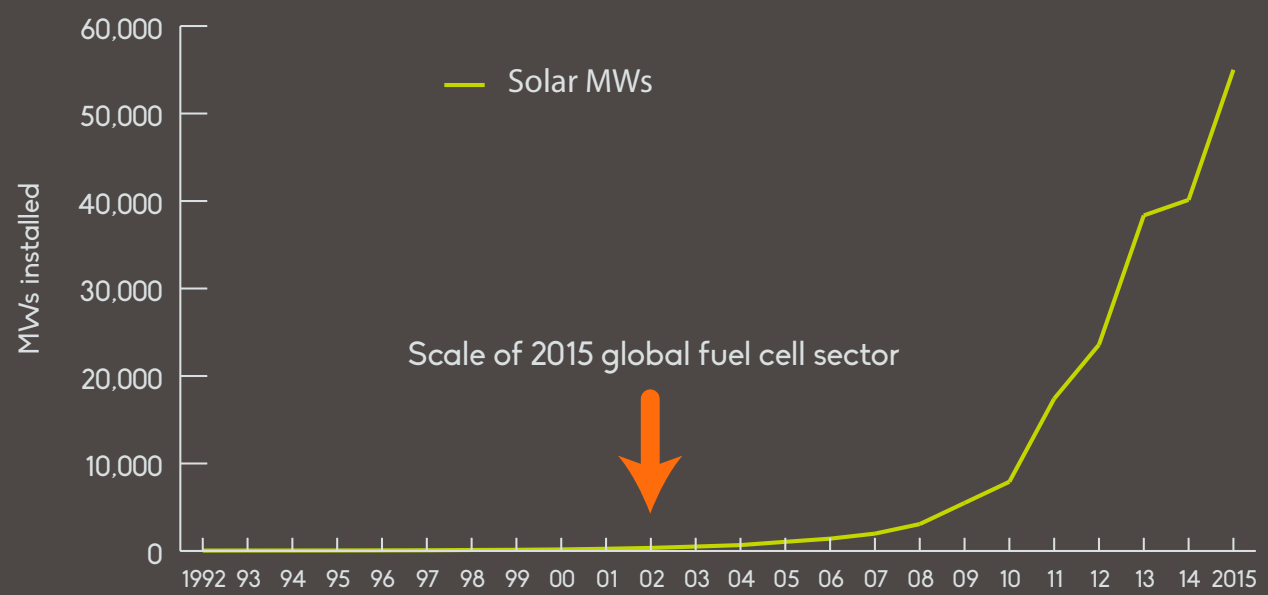
One of the other obsessions with onlookers into the industry is the identification of the 'winning' electrolyte. As always, the answer is that the markets are so big, and so diverse that all electrolytes have a place and a play, if they can be commercialised. That is not to say that there won't be two more dominant electrolytes, and it is already clear that PEM and SOFC will form the majority market share going forward.

Chart 5.3: Global Installations of Fuel Cell Systems as Compared With Solar PV: 2009 - 2015



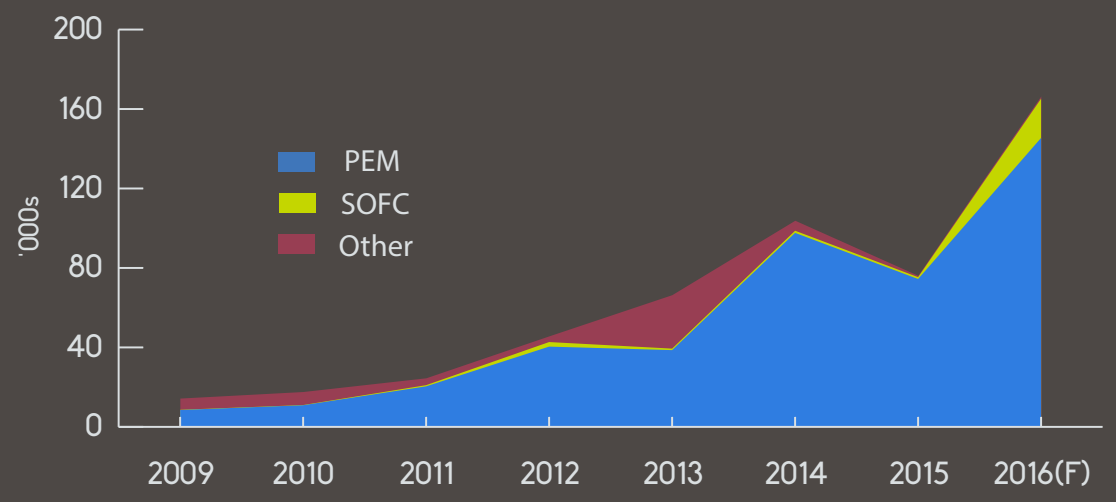
Source: Solar Data Derived from IEA, 4th Energy Wave, 2016

Chart 5.4 Annual Solar PV Shipments, Global: 1992 - 2015



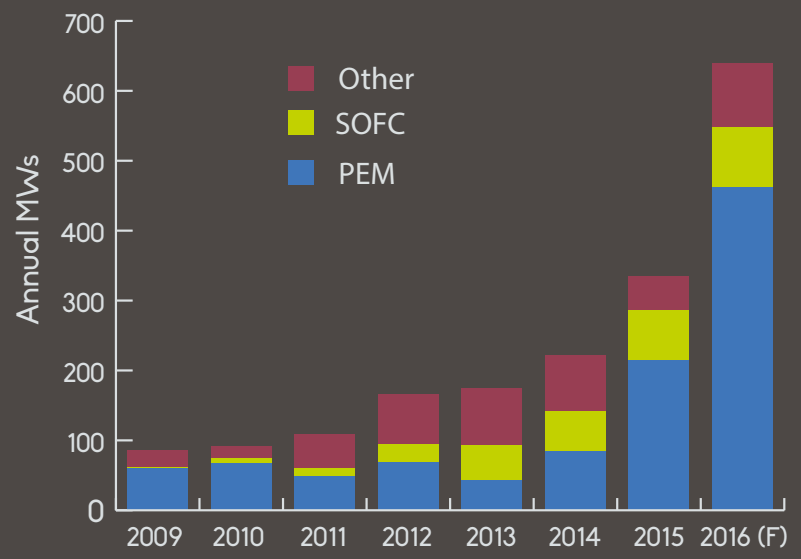
Source: Various

Chart 5.5: Development of Fuel Cell Electrolyte Mix, by Systems Deployed, Global: 2006 – 2016 (F)



Source: 4th Energy Wave, 2016

Chart 5.6: Development of Fuel Cell Electrolyte Mix, by MWs Deployed Global: 2006 – 2016 (F)



Source: 4th Energy Wave, 2016

The reason for the dominance of both PEM and SOFC is the combination of a number of factors, including:

- Broad spread of markets being targeted by both electrolytes;
- Largest numbers of developers globally;
- Largest amount of concentrated government level R&D funding;
- Modular power ranges, from low number of kWs upwards.

Clearly, of these two, PEM has the broadest spread of markets, as it includes transport applications.

What is interesting is that is if we switch to MWs, instead of volume of shipments, we see that PEM fuel cells are still dominant. This is the first year, since 2011, that this has tipped over into this phase. Again, as has been mentioned before, it is the emergence of the heavy-duty transport sector, along with the start of the roll out of fuel cell vehicles, which has caused this.

Even when you see the development of the PEM fuel cell market side-by-side to markets, such as the potential 67 MW Beacon Falls project by FuelCell Energy, the volume of MCFC and PAFC projects is limited, literally due to the lack of wide spread commercial product and product developers.

If SOFC and PEM are dominant, is there a chance that the electrolytes will be pushed out of the market? Unlikely. As has been said, the markets that are being targeted are so diverse, and the current market players so well embedded into the industry, that only in the long term, post 2030, can the internal 4th Energy Wave adoption models be somewhat artificially forced into a scenario where there are only two electrolytes in the mix.

Another interesting trend that is emerging from the market, and the data, is the re-emergence of SOFCs. It was only a couple of years ago that the SOFC sector was somewhat moribund. Outside of Bloom Energy, it was questionable if any other SOFC company was capable of developing a fully commercial product.

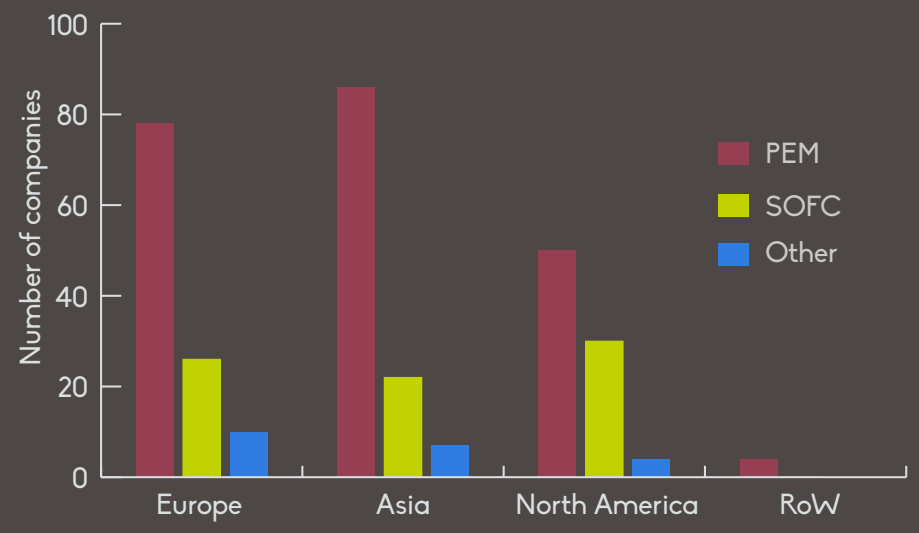
Now though, there at least 5 companies globally with a good SOFC product, either in market, or very close to market, with potential price points in the medium-term, which could well catapult them in mass market by the early 2020s. The number of SOFC developers has also increased in 2015, and if you refer back to table in Appendix A, it is clear that there is a lot of close to commercial activity in Japan alone.

Of the bigger developer nations, China has the least number of SOFC developers. North America, primarily the US, has the largest number of developers of SOFC systems, but the lowest number of commercial companies.

In short, by 2020, the SOFC sector should be significantly more vibrant with products in multiple power ranges.

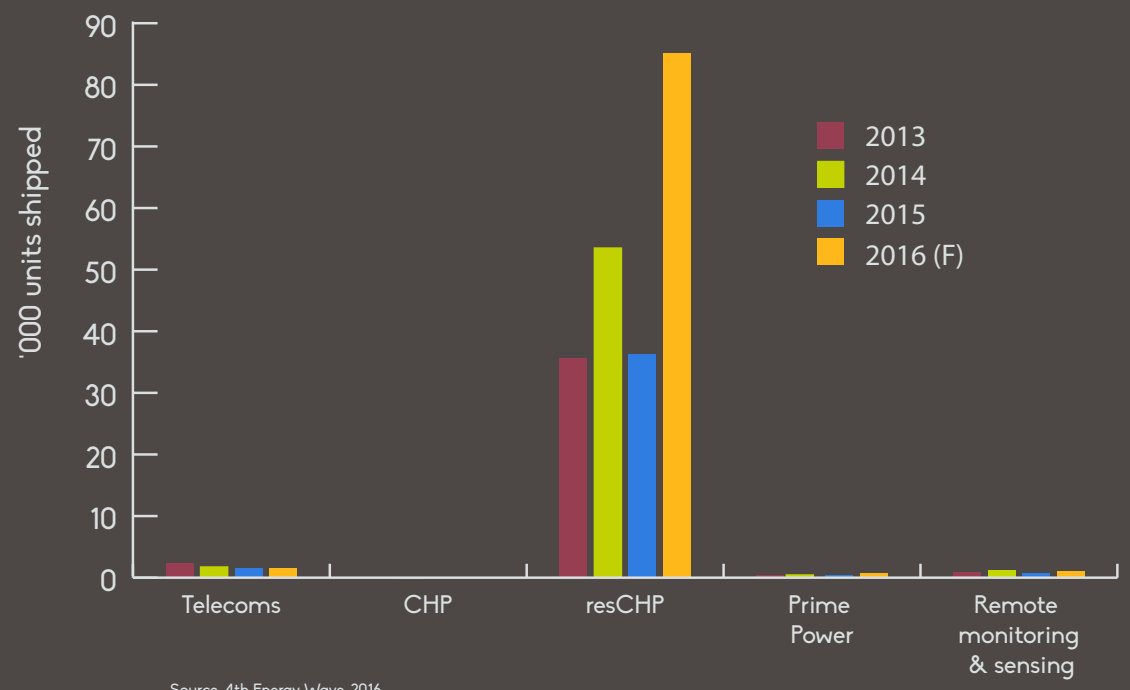
From virtually dead in 2012 / 2013, this is a very fast turnaround.

Chart 5.7: Electrolye Mix by Region, Global: 2015



Source: 4th Energy Wave, 2016

Chart 5.8: Global Stationary Fuel Cell Sector by Systems Shipped: 2013 – 2016 (F)



Source: 4th Energy Wave, 2016

Shifting Sector Mix

The different markets that are being targeted for fuel cells are getting more diverse and volume markets are rapidly starting to emerge.

Stationary

The stationary fuel cell market continues to diversify. Some are linked to new markets for hydrogen, and some are linked to a greater understanding of the potential emerging energy demands from the transition to the 4th energy wave of electricity. What is key though is that now we see the growth

in potential volume markets for stationary fuel cells, we have yet to see a step change in companies' ability to create the demand pipelines and sell at volume. Partly, this is still down to a lack of education on the level of the adopter, partly down to the huge diversification of people who need to be involved in the decision, partly down to a difference in CAPEX and lifetime costs debate, and partly down to the lack of products in the marketplace.

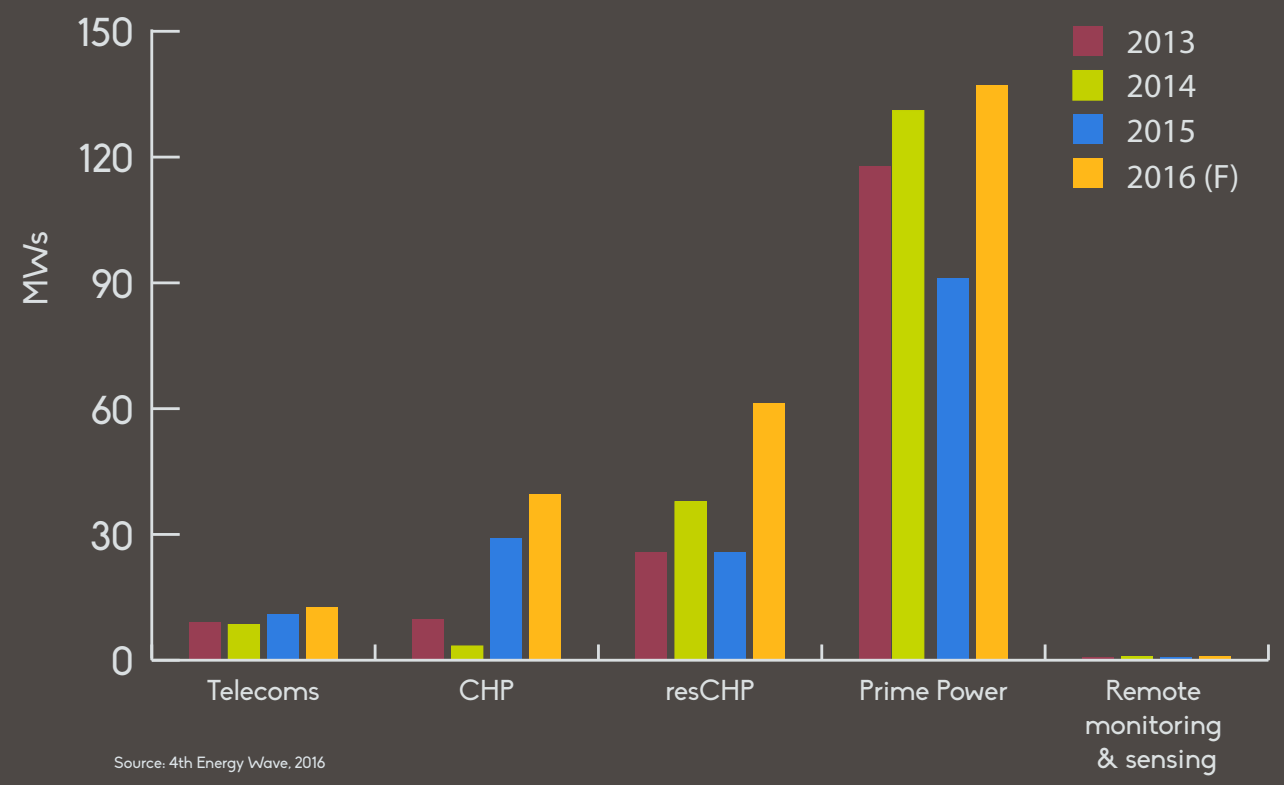
More than any of other two headline sectors, of transport and portable, the stationary sector is suffering from a lack of a concentrated, high volume, highly marketed, well-designed product push. And because of this, we are seeing a slowdown in interest in the sector, which is being translated into sluggish volume.

The innovation of moving to the Energy Services Company (ESCO) / PPA model continued to provide dividends in 2015, for companies well capitalised enough to go down this route. For a handful of companies, this transition away from selling technology to providing services is providing somewhat immediate benefits, and clearly, this is the area to watch. But companies wanting to enter this space need to be able to raise the capital, get the insurance and the regulatory clearance to become energy service providers. This is clearly not an insignificant undertaking and whilst profitable in the longer term, is unlikely to be an option for the majority of smaller stationary fuel cell companies, who will likely remain firmly a supply chain company.

This sluggishness is clear in chart 5.8. with minimal growth across the board.

Even with the switch to MWs shipped, which for the stationary sector at least is more normally the more attractive chart, we see growth, but at a very slow pace.
Table 5.1, on the next page, sets out each of the current stationary markets, which within a decade should be tens of MWs, or GWs of demand per year, if the stationary sector can up its game.

Chart 5.9: Global Stationary Fuel Cell Sector by MWs Shipped: 2013 – 2016 (F)



Source: 4th Energy Wave, 2016

	Country / Region with Increasing Policy Pressure	Country / Region with Decreasing Policy Pressure	What we could see in 2016	Company / companies to watch
CHP				
- resCHP	New York State	South Korea	A 3 – 5 kW system being targeted at NY State	Doosan Fuel Cell America, Sunfire, m Field
- Food and Drinks Industry	New York State		Increasing deployment of microgrids with fuel cells included covering facilities including farms	FuelCell Energy
- Office Buildings	New York State	Germany	Small handful of high PR units going into C100 cities	GE
- Commercial facilities (hotels etc.)	New York State	Germany	High end hotel chain openly talking about the potential of fuel cells	GE, FuelCell Energy
Prime Power				
- Datacentres	USA		Multi MW orders	Bloom Energy,
- Secure facilities	USA			Hydrogenics
- Generators	UK / London		Testing of units	SerEnergy, Company X in the UK, (possibly) Watt Fuel Cell
- Grid Support	USA	UK	Movement on another tens of MW project	FuelCell Energy, Hydrogenics, Dominovas Energy
- Nuclear waste clean up	Japan		Increased volume flow into Japan	Hydrogenics
- Oil and Gas Industry	Russia		The number of units going into oil the gas industry starting to bounce back.	Atrex Energy (formerly Acumentrics), SFC
- Distributed Energy	European Union			SerEnergy, ElectroPowerSystems, Sunfire
- Mining	South Africa, Chile		Another tranche of deployments into mines in South Africa	Doosan Fuel Cell America
Back Up Power				
- Telecoms	Indonesia		More focus on altering the business model to PPA type arrangements rather than direct sales	Intelligent Energy, Heliocentris, Altergy
- Railway Signalling	USA		Orders from the UK	Plug Power, Protonex (Ballard Power)

The other market that we expect to see added to this list within the next two to three years is power demand for water desalination.

One example of the potential high volume, high power demand markets is that of data centres. Although using fuel cells in this market has already been already tested in multiple locations, we have yet to see the volume order that would break it out of the 'prime power' category into its own.

The pressure on datacentres to adopt distributed power, and consume less water, is primarily an economic one, but with growing concern from governments. As energy demand grows from this sector, graphically shown in chart 5.10, pressure to ensure that the 'data centre best' curve is the one the industry follows will grow.

For context, it is worth taking into account that the IEA sees world energy demand potentially reaching 32,000 TWh per annum by 2030. So if we see power demand from datacentres reaching the 8,000 TWh per annum, if growth is left unchecked, then by 2030 this will represent 25% of global energy demand.

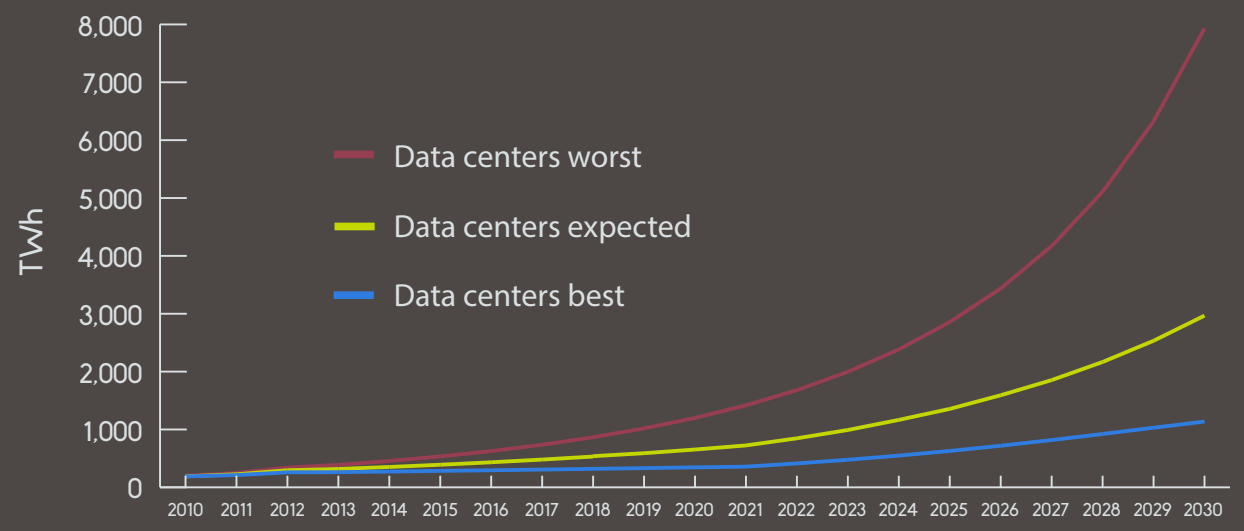
Transport

Planes, trains and automobiles.

Except now it's fuel cell planes, trains, automobiles, buses, bikes, ferries, trucks, vans and trams. It's also car clubs and integrated mobility. Diversification and growth.

The heavy-duty sector is covered later in this report in the special section, so this part of the Review is on the fuel cell car market. 2015 saw the launch of the newest fuel cell car, the Riversimple Rasa. Even from the image, you can see that this is not an average car. When you see it in person, you realise it is tiny and very elegant. But it is when you compare it to with say, the Mirai, then you see the difference.

Chart 5.10: Global Electricity usage (TWh) of Data Centers 2010-2030



Source: Huawei Technologies, Sweden

Image 5.1: Linde's Fuel Cell Bike, as Part of the Munich Mobility Programme BeeZero

Source: 4th Energy Wave, 2016

Toyota Mirai

- 100 kW fuel cell stack
- Range about 300 miles
- 4-seater
- Buy or lease
- Current cost (without subsidy) £66K in the UK, $58K in the USA.
- Availability: limited

Riversimple Rasa

- 8.5 kW fuel cell stack + ercapacitors
- Range about 300 miles
- 2-seater
- Customers will pay per mile used. No option to buy.
- Works with urbanites who don't own a car.
- Projected city use only
- Fully recyclable
- Availability: 2016 – first batch will be released in Britain

Tesla Model 3

- Lithium Ion Batteries
- 215 mile range
- Cost - $35k / £25k
- 5-seater
- Availability: Deliveries start in the US in late 2017

When you consider the rise of the urban car sharing movement, in the West at least, combined with peak cars, the demonisation of diesel and the increased awareness of the benefits of public transport, then targeting this market is a potentially very clever move.

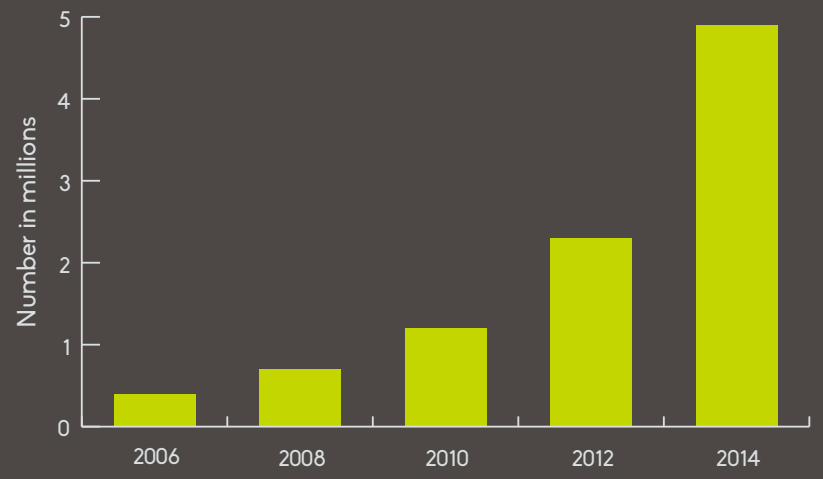
Riversimple is also braking the investment mold, and has launched a crowdfunding campaign. Instead of selling product, it has put up 7.5% of its equity. It is easy to be snippy about this being a small amount of its equity, but the amount raised will be the next chunk of funding to get the company the next step or two to market. So this reads as far more strategic than the naysayers would have you believe.

Aside from Riversimple, the importance of Japan, and the Japanese market to drive down costs in both the automotive and resCHP sectors, cannot be overestimated. As was mentioned earlier in this report, the Japanese targets for adoptions of fuel cell cars are:

- 40,000 fuel cell cars on the road in Japan by 2020, 200,000 by 2025, and 800,000 by 2030;
- Number of hydrogen refuelling stations to increase from the current 80 to 160 by FY 2020 and 320 by FY 2025;
- Reducing the cost of fuel cells to half of the current cost by 2020 and one quarter by 2025[5]

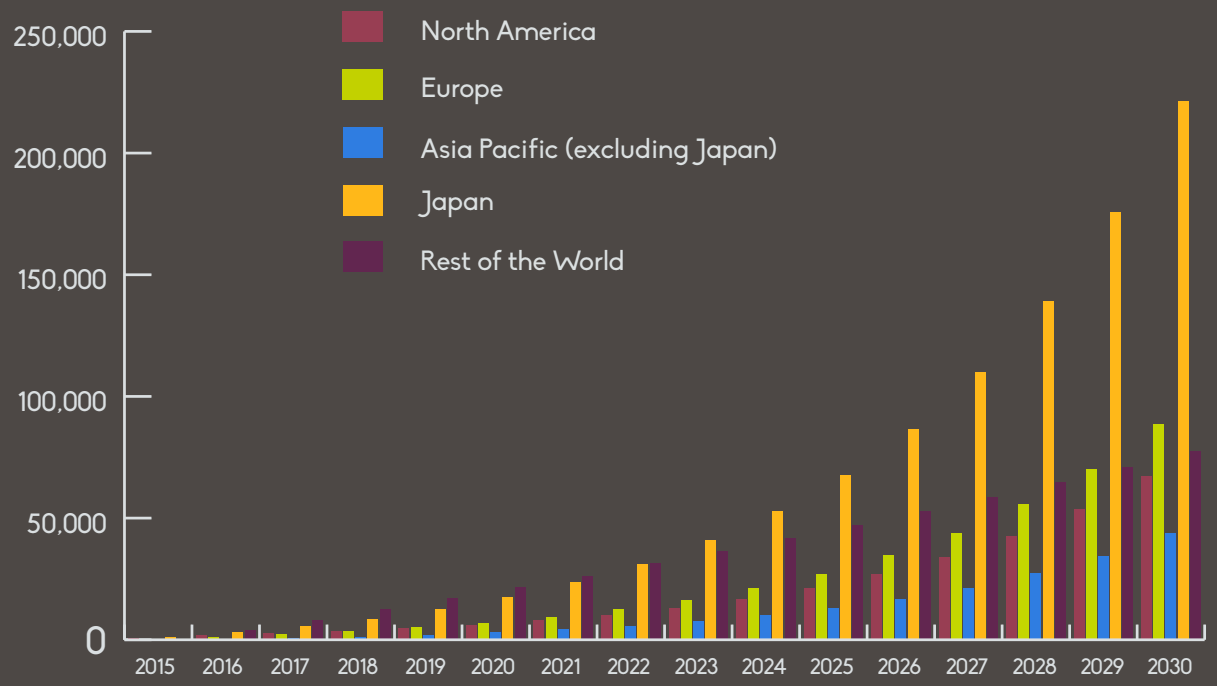
To put this 800,000 target in context though, below is the 4th Energy Wave forecast, under BAU assumptions for the fuel cell vehicle fleet out to 2030.

Chart 5.11: Number of Members of Car Sharing Schemes Worldwide



Source: Statistics, 2016

Chart 5.12: Global Fuel Cell Vehicle Adoption under BAU Assumptions, 2015 - 2030



Source: 4th Energy Wave, 2016

The axis is deliberately scaled to 800,000 cumulative to show the delta between current forecasts and this new target. What it clearly shows is that if Japan is to hits its targets, the BAU model needs to be thrown out. To do this, we need to see much more aggressive policy and actions by the auto makers in Japan to reach anything like this number.

Overall, we would suggest that the direct impact of these targets will be something of an investment and spending spree from the Japanese auto OEMs and supply chain, as it seeks to bring in and embed technology that can meet the cost targets, and by proxy, the adoption targets.

Also over the next few years, we will see a ramp up in fuel cell cars coming to market, more exciting new prototypes and concepts, and the growth in fuel cell car sharing services.

In terms of refuelling Japan, California, Germany, Norway and the UK are all increasingly ramping up deployment of hydrogen refuelling stations. It is now looking likely that Norway will be the first country to have all major cities covered with hydrogen refuelling stations. This is through the deal signed between Uno-X Hydrogen AS to install 20 hydrogen refuelling stations, covering all the major cities in Norway by 2020. Uno-X is a NEL ASA joint venture and a Norwegian affiliate of Praxair as a strategic alliance. Following the agreement, Praxair's Norwegian affiliate will hold 20 percent of Uno-X Hydrogen, with Uno-X Gruppen and NEL holding 41 percent and 39 percent, respectively.

Portable

2015 was a sluggish year for shipments the portable fuel cell sector.

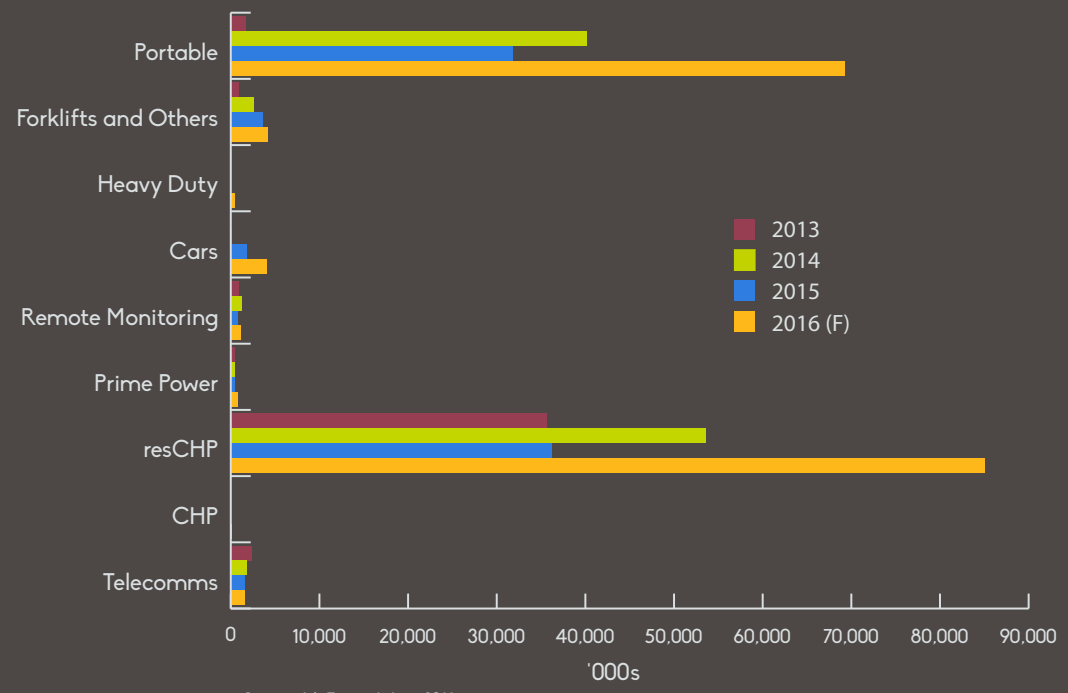
- Intelligent Energy stopped production of the UPP, and is moving to working on integrated fuel cells into a smart phone;
- The myFC JAQ grabbed a lot of headlines, rightly so, but is not due to start volume shipping till 2016;
- Neah Power continued to steadfastly not produce the fuel cell component of their portable electronics recharger;
- eZelleron raised a spectacular $1.5 million on crowdfunding site, Kickstarter, with the initial aim to have production of the Kraftwerk in December 2015. This has now been pushed out to 2017.

The upside in the portable sector is that in terms of company developments, both myFC and eZelleron have expanded overseas.

MyFC have created MyFC Asia, and MyFC China, with Novel Unicorn. The new company will target the Chinese market, with the portable fuel cell JAQ. MyFC Asia will initially be 70% owned by Novel Unicorn and 30% by MyFC Holding. When you take into account that, according to China Daily, only 51% of the Chinese population have a mobile phone, but that this is changing rapidly, and the push for greener products, the JAQ could well be the first fuel cell product to top annual sales of over 100,000 units. And if it does, don't be too surprised if a good chunk of this comes from the Chinese market.

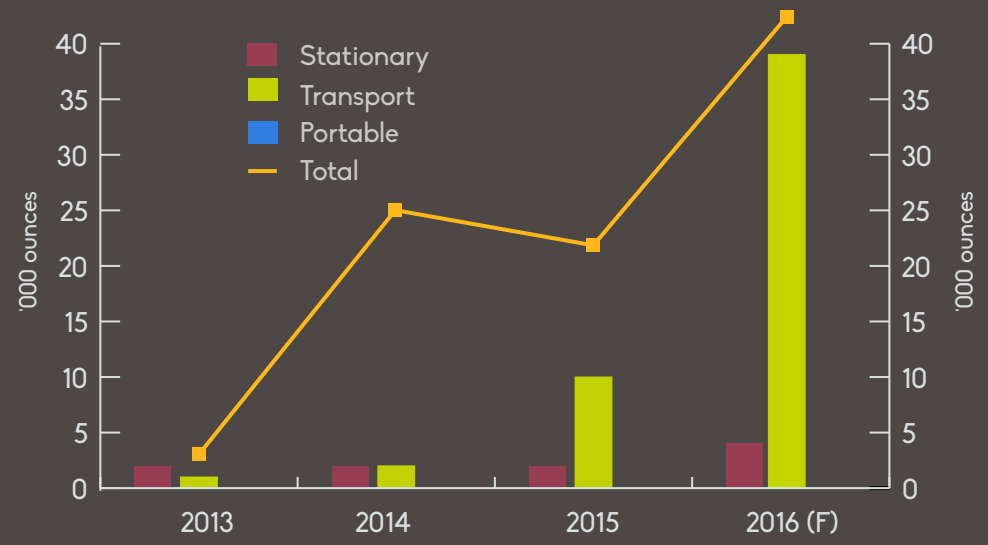
eZelleron on the other hand have gone West and opened up in Silicon Valley, USA. The German-based company gave the reason for the Silicon Valley move as follows: 'Unfortunately, looking for growth capital in Europe is still an impossible task', says the co-founder and COO, Martin Pentenrieder. 'The investment,

Chart 5.13: Deployment by Sector and Sub-Sector, Global Deployments by Systems: 2013 – 2016 (F)



Source: 4th Energy Wave, 2016

Chart 5.14: Global Platinum Demand from Fuel Cell Shipments: 2013 – 2016 (F)



Source: 4th Energy Wave, 2016

required for deep technology high-tech start-ups, are too progressive for most European investors.' SFC, the poster child for the portable fuel cell sector, also took a hit in 2015. As the company shifts to higher margin markets in defence and the oil and gas sector, both markets, which are dependent on strong economic growth and strong oil prices, saw unit sales drop in the recession. The company, which announced in 2015 that it was working with Russian giant Gazprom, is forecasting a return to growth in 2016.

Platinum

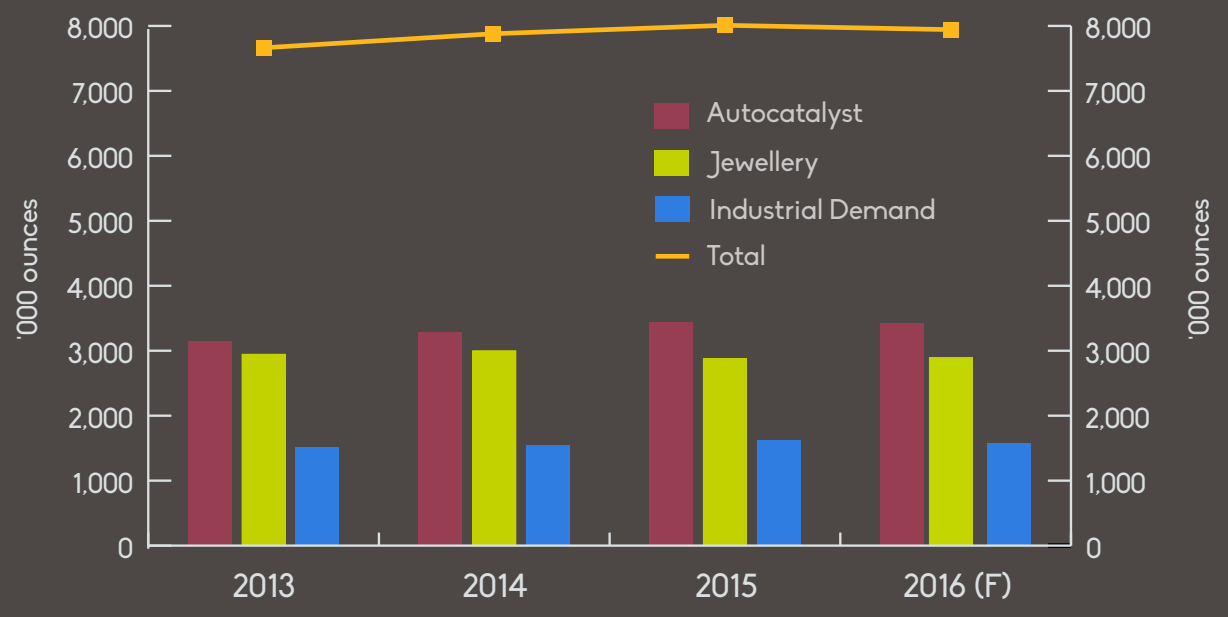
Overall platinum demand from fuel cells dropped to 22,000 ounces in 2015. And is forecast to rise to 43,000 ounces in 2016. The development of a million-ounce market from fuel cells, under current business as usual modelling, is currently well past the 2030 timeframe.

The overall global platinum market, without taking into account recycling, saw demand of 7.9 million ounces in 2015. So adding in the 22,000 ounces from the fuel cell sector does not cause any additional stress on the industry.

Costs

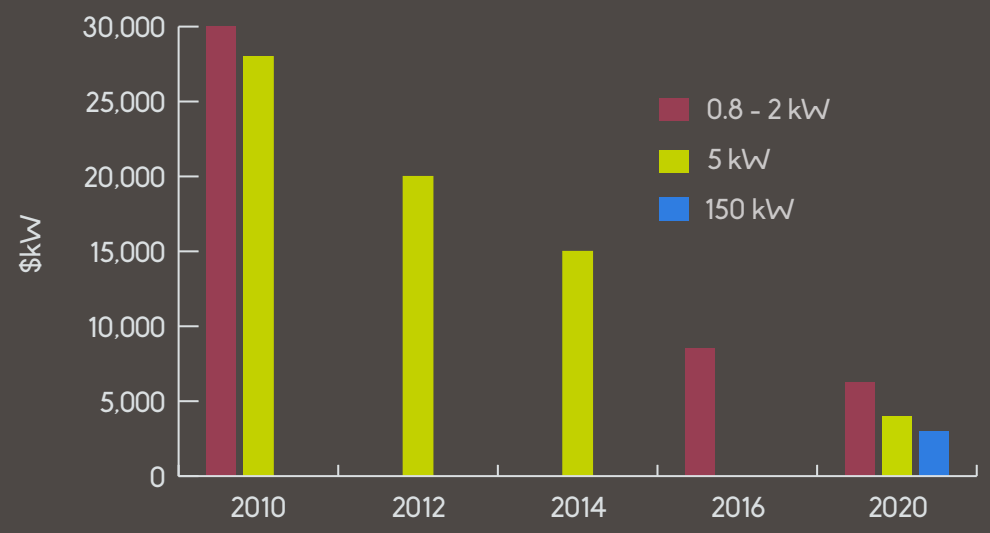
CAPEX costs of fuel cell systems are still high, but are being reduced. Using limited publically available data on current and historic costs, combined with internal information and projections on cost out, we can see from charts 5.17 and 5.18 that by 2020, costs of the larger PEM and SOFC systems (5 kW and over) are forecast to be below $5 per watt. Time to the $3 watt point, which appears to have been the economic tipping point for solar PV, is still some time away. Though with focused capital investment and market development, in the short term, the $3 per watt point could be seen in the short term after 2020.

Chart 5.15: Global Platinum Demand: 2013 – 2016 (F)



Source: SFA Oxford, 2016

Chart 5.16: PEM Historical and Forecast CAPEX Cost



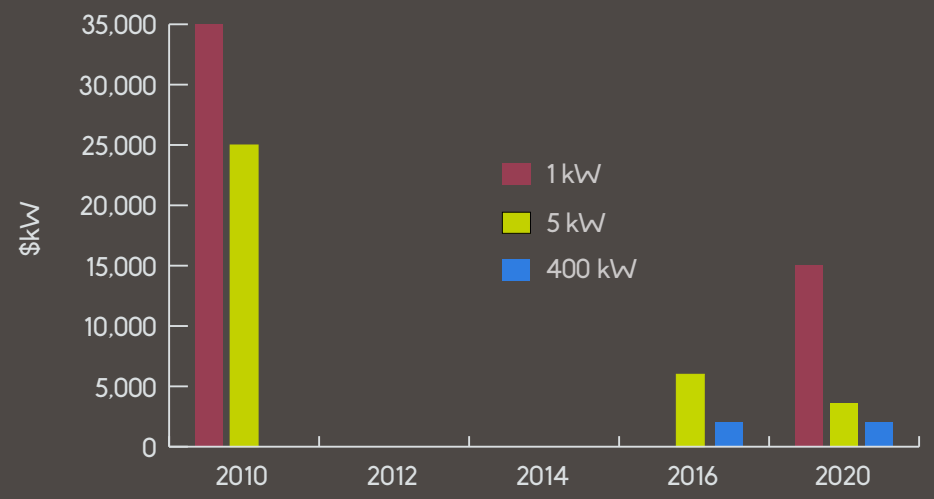
Source: 4th Energy Wave, 2016

Consolidation and Investment

2015 was a busy year for consolidation and buy-outs in the fuel cell sector. But it terms of investment, it was lowest in terms of vc capital flows for at least the last 6 years.

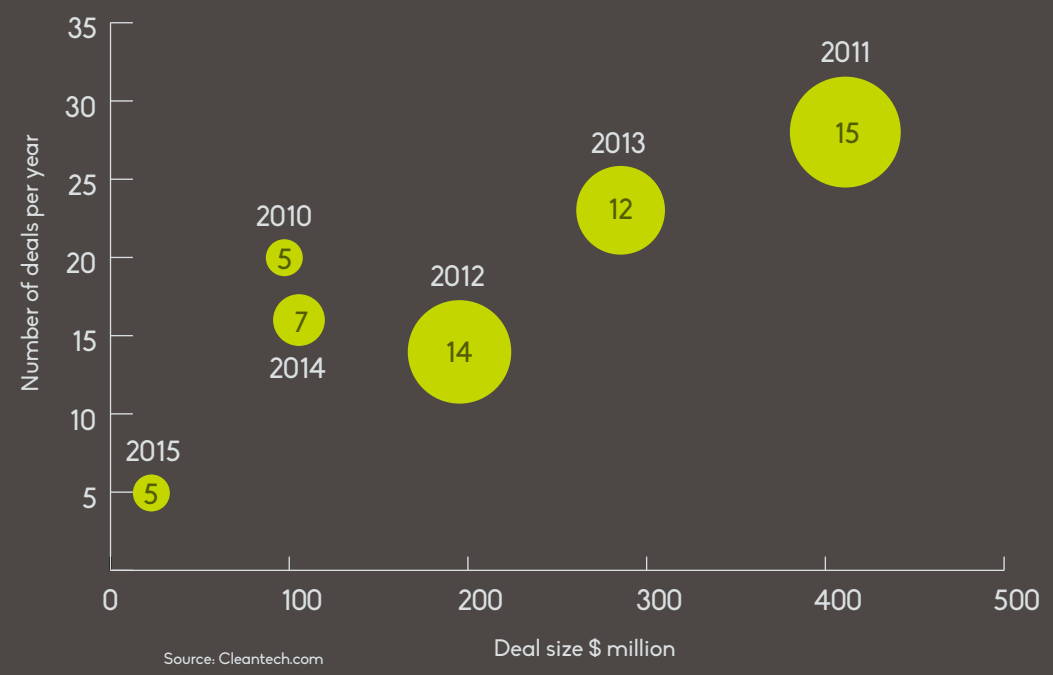
The data in chart 5.18 is taken from the dataset held by CleanTech.com. The bubbles represent the average deal size that year. What the chart shows is that according to the dataset there were only 5 announced deals in fuel cells and hydrogen in 2015 and the average deal size was as low as $5 million. This contrasts with 2011, when there was 28 deals and the average deal size was $15 million.

Chart 5.17: SOFC Historical and Forecast CAPEX Cost.



Source: 4th Energy Wave, 2016

Chart 5.18: Global Investment Trends in Fuel Cells and Hydrogen: 2011 – 2015



Source: Cleantech.com

In terms of consolidation, Table 5.1, below outlines the industry movements during 2015, and to date in 2016.

In terms of bankruptcy, it appears that Blue Hamster (Germany, telecoms) was the sole bankruptcy in 2015.

Table 5.1: Industry Consolidation

Buyer	Company Bought	Sector
Heliocentris	Acta	Electrolysis
Elvi	Electro Power Systems	Energy storage, stationary fuel cells
Elbit Systems	CellEra	Defence electronics
Trefor	IRD	Small portable / stationary fuel cells
Ballard Power	Protonex	Portable / military / SOFC fuel cells
CHEM	Ballard Power (telecoms)	Telecoms
Elcomax	Elcore	Residential fuel cells
Plug Power	Hypulsion	Forklifts / logistics vehicles
NACCO Materials Handling Group	Nuvera	Forklifts / logistics vehicles
Neah Power	Shoria	Battery company
Kolon?	Panasonic Electronics (fuel cell group)	

6. Special Section - Heavy Duty Fuel Cells

The breakout sector in 2015 was heavy-duty fuel cells for transport. This is not a new idea. Fuel Cell Today published a piece on fuel cells for trucks back in 2004, marine in 2004, and rail in 2005!

Eleven years later and the use in trucks, buses and rail is now high on the agenda. Like with many things though, last time round, the timing wasn't right. Not only was the technology not really ready, in terms of weight, power density, fuel, etc., but also the market conditions weren't ready.

Now though things are different. Different enough to kick-start a move to the adoption of new technologies into the sector? In specific areas and regions, yes, but in general, as a general mass market trend, it is still some way off.

This special section looks at the trucking market. It is not that buses are not interesting, especially after the South Korean 28,000 fuel cell bus announcement, but that information on fuel cell buses, challenges and potential, is already well published.

Trucks

Sleeper APUs

First, let's talk types of trucks. Yes, really. It's important.

To date, the work on using fuel cells in trucking has been to provide APUs for sleeper cabs, or to provide power for cooling to reefer trucks.

If we look at just sleeper cab trucks (Class 8 in the US and N3 in Europe), this is a growth market, but as with any growth market, faces challenges and opportunities for change.

The opportunities for the new technologies to make their way into this segment include:

- An aging Class 8 fleet in the US, with average age of vehicle now over 7 years;
- A stable diesel price, allowing fleet owners to plan for the future. Fuel currently makes up around 36 per cent of fleet managers costs;
- Increased focus on emissions from freight is pushing up interest in bolt on options, which do not require a new truck.

But, the flip side of this is the challenges are really high. These include:

- The truck retrofit market is where the volume opportunity lies. As with most industries that need some form of emissions removal, the problems do not stem from the new trucks, but the in-use fleet. With the number of on-road older vehicles running into the millions, the focus will increasingly be on cleaning up these vehicles. The challenge for any fuel cell design therefore is to produce a retrofit design that can be put into older vehicles. So far, no one is working on this challenge but is focusing on the much smaller new vehicle market.

  The scale of new vehicle market is highlighted in the chart below, which shows annual Class 8 truck sales in the US, alongside total new truck sales. According to the American Trucking Associations (ATA), the total Class 8 fleet in the US is some 2.3 million vehicles. With the average annual sales being between 200,000 and 250,000 per annum, simple back of the envelope maths shows that the average turnover time of the US fleet is in the 9-year timeframe.

- Cost. The trucking / freight industry in general is highly cost sensitive. Any increase in outlay or non-short-term payback will often be met with resistance due to issues of cash flow.

- Fragmented Industry. 90 per cent of trucking companies in the US have 6 trucks or less. This means that the point of sale has to be back up the chain to the truck manufacturers, but then this points back to new trucks, not retrofit.

- Policy. France and Belgium have implemented rulings, making it illegal for drivers to sleep in their cabs [6]. This has implications overall in Europe on the sleeping patterns of truckers.

- Size. In Europe, the maximum length of trucks includes the cab and the trailer. In America, the maximum length only applies to the trailer. So in Europe, the sleeper compartments, and related power requirements from an APU, are much smaller. The average power requirement in the US from a sleeper can be as high as 5 – 6 kW. In Europe, it is closer to 2 kW. So again, there is a region-by-region design requirement, which pushes up cost and lack of standardised product design.

As you can see from this short section, the Class 8 / N3 market is going to be very challenging for any fuel cell company to make a sustainable, long-term profitable business from.

If any company does focus heavily on this market, they will probably have a profile that will read something like this: they will focus on the US, with the bigger on-board space available in the rig, they will aim to form a JV with Freightliner, the majority supplier of Class 8 trucks to the US market, they will need to have good revenue streams from other markets, and will need to play nice with a Tier 2 component supplier into this market.

At present, this type of company is not an SME, not in need of short-term revenue from the market, likely to be US based, and likely to be plugged into developments in the Californian market.

[6] http://www.lloydsloadinglist.com/freight-directory/road/Haulier-outcry-over-French-truck-law/1335.htm#.Vml8GEqLTIU

Chart 6.1: US Class 8 and Class 1 – 7 Annual Truck Sales

Source: ATA, 2015

Cargo Trucks

The focus on logistics fleets is not new, and when the most common fuel for trucking is diesel then the pressure to find alternatives becomes clearer. Especially when this is combined with the potential for trucks and buses to be a significant contributor to greenhouse gas emissions by 2030. Electric, battery, trucks and fuel cells trucks are starting to be developed and delivered into the market, but it is very early in the overall developmental cycle for this option.

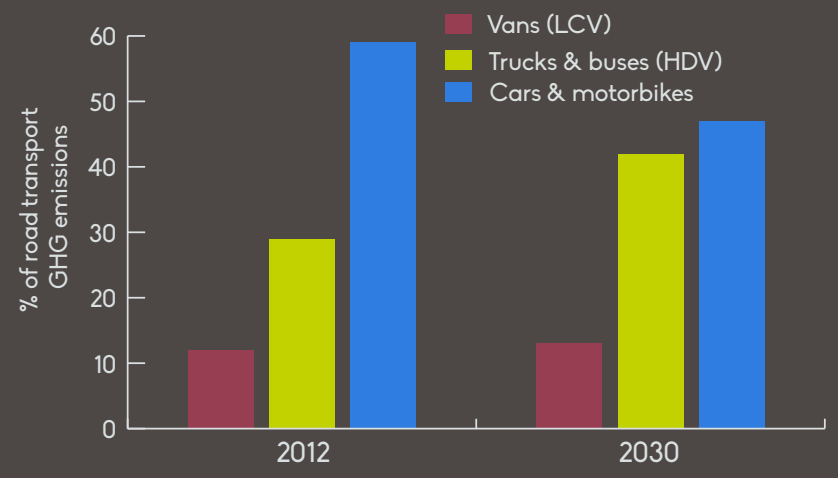
As with APUs, the entry point into the market is to work direct with one of the big OEMs. The three fuel cell companies that have so far come out of the closet and are openly working in this area are:

- Loop Energy (Canada), publically working with CRRC Corporation (China) and Peterbilt (USA).
- Hydrogenics (Canada), with its 60 kW 'Celerity' fuel cell. Likely to be working with Chinese partner on fuel cell trucks.
- Palcan (Canada), working with Dongfang (China) to deliver fuel cell trucks, utilizing methanol as a fuel.

Also, due to the move in Norway to ban the sale of petrol and diesel vehicles, ASKO, one of the largest transport companies in Norway, with 600 trucks on the roads throughout the country, has demonstrated 4 hydrogen fuelled trucks. It is not clear what the propulsion system of these vehicles are though.

Finally, who can forget the Daihatsu concept mini truck from 2013, the FC Deco Deck. Maybe like other vehicles, its time has now come. In summary, expect to see further announcements in this area in 2016, likely to centre around China, California and tie ups and developments with Tier 1 manufacturers.

Chart 6.2: EU Road Transport Emissions Profile: 2012 and 2030



Source: Transport and Environment dot Org

Image 6.2: The Daihatsu FC Deco Deck

Source: Daihatsu

The White Van Man

In the UK, the white delivery van is now so ubiquitous that the sector of short range (around 300 miles or less), small to medium weight delivery is simply known as White Van Man. In North America, its cousin is the 'U-Haul' trucks.

Whilst the vehicles themselves have no on-board power requirements as they travel into and out of city centres, they are increasingly the focus of major city planners. Whether it is emissions from diesel engines, or noise etc., this sector, alongside the trucking sector, will increasingly be the focus of the legislators. One example already in play is that the Mayor of London has already announced that in 2016, the freight sector, including short range delivery vehicles, will need to be increasingly zero emissions.

The only two options for these types of vehicles are:

- Pure fuel cell or battery EV. The downside to this is the cost and basically the availability. You cannot exactly rock up to the van dealer and buy a battery or fuel cell van off the shelf.

- Hybrid. Realistically, as the need for zero emissions will only be in the emission zone of London, even with a number of drop offs, this will be much less than 100 miles per day. This lends itself to some form of vehicle where it can run on the battery of fuel cell in the required areas, and then revert back to diesel outside. Again, the downside is exactly the same. Cost and availability.

So although there will be an increasing push for cleaning up their part of the freight sector, at the minute, battery EVs, with the current actual availability for vans, will likely take the edge.

That said, this is one area where it is clear as a bell as to how a new business model could break open this market.

Speciality Vehicles

Vehicles such as rubbish trucks, fire engines, mail vans, etc. all operate within city limits on a daily basis. Like delivery vans, they will increasingly be regulated on emissions and noise, and are also going to be covered by the London plan to reduce pollution from freight.

The difference for rubbish (garbage) trucks and fire engines is that they both have an on-board power requirement, which cycles up and down, in a regular use profile.

Again, although there is a very small number of companies developing product for this area (< 5 that we are aware of), this will likely gain in popularity, fast, as the market pull and funding money for vehicle development comes on-stream.

7. Data Tables

The following data tables present data from Fuel Cell Today [7] for 2009 to 2012, combined with primary data gathered by 4th Energy Wave for the 2013, 2014 and 2015 fuel cell markets.

Table 7.1: Global Fuel Cell Shipments by Sector: 2009 – 2015

Shipments	Units	2009	2010	2011	2012	2013	2014	2015
Portable	'000s	5.7	6.8	6.9	18.9	26.0	44.1	31.8
Stationary	'000s	6.7	8.3	16.1	24.1	38.7	56.5	39.0
Transport	'000s	2	2.6	1.6	2.7	2.8	4.3	5.4
Total	**'000s**	**14.4**	**17.7**	**24.6**	**45.7**	**67.5**	**104.9**	**76.2**

Table 7.2: Global Fuel Cell Shipments by Region of Manufacture: 2009 – 2015

		2009	2010	2011	2012	2013	2014	2015
Europe	'000s	4.4	4.8	3.9	9.7	8.7	24.6	7.0
N America	'000s	3.2	3.3	3.3	6.8	2.4	4.2	5.2
Asia	'000s	6.7	9.5	17	28	55.6	75.6	64.0
RoW	'000s	0.1	0.1	0.4	1.2	0.8	0.4	0.0
Total	**'000s**	**14.4**	**17.7**	**24.6**	**45.7**	**67.5**	**104.9**	**76.2**

Table 7.3: Global Fuel Cell Shipments by Electrolyte Type: 2009 – 2015

		2009	2010	2011	2012	2013	2014	2015
PEM	'000s	8.5	10.9	20.4	40.4	63.8	77.3	74.4
SOFC	'000s	0.1	0.1	0.6	2.3	0.7	0.9	0.9
Other	'000s	5.8	6.7	3.6	3	2.9	26.6	0.8
Total	**'000s**	**14.4**	**17.7**	**24.6**	**45.7**	**67.5**	**104.9**	**76.2**

[7] Fuel Cell Today, Johnson Matthey, 'The Fuel Cell Industry Review, 2013'

Table 7.4: MWs Fuel Cell Shipped by Sector: 2009 – 2015

MWs	Units	2009	2010	2011	2012	2013	2014	2015
Portable	MWs	1.5	0.4	0.4	0.5	0.2	0.9	0.1
Stationary	MWs	35.4	35	81.4	124.9	168.4	180.2	157.4
Transport	MWs	49.6	55.8	27.6	41.3	11.9	40.7	178.1
Total	**MWs**	**86.5**	**91.2**	**109.4**	**166.7**	**180.5**	**221.8**	**335.6**

Table 7.5: MWs Fuel Cell Shipped by Region of Manufacture: 2009 – 2015

		2009	2010	2011	2012	2013	2014	2015
Europe	MWs	2.9	5.8	9.4	17.3	2.8	3.3	5.7
N America	MWs	37.6	42.5	59.6	61.5	117.8	107.9	127.9
Asia	MWs	45.3	42.5	39.6	86.1	56.1	110.6	198.3
RoW	MWs	0.7	0.4	0.8	1.8	3.8	0.0	3.7
Total	**MWs**	**86.5**	**91.2**	**109.4**	**166.7**	**180.5**	**221.8**	**335.6**

Table 7.6: MWs Fuel Cell Shipped by Electrolyte Type: 2009 – 2015

		2009	2010	2011	2012	2013	2014	2015
PEM	MWs	60	67.7	49.2	68.3	43.2	84.5	215.4
SOFC	MWs	1.1	6.7	10.6	26.9	48.5	56.3	70.5
Other	MWs	25.4	16.8	49.6	71.5	88.7	80.7	49.8
Total	MWs	86.5	91.2	109.4	166.7	180.5	221.8	335.6


Copyright: FuelCell Energy

8. Selected Company Financials

FuelCell Energy (April-to-April reporting cycle), Ballard Power (December-to-December), Plug Power (April-to- April), Hydrogenics (December-to-December), and Intelligent Energy (December-to-December) between them represent the overall health of the non-Asian based fuel cell sector. Together, they represent well over 50% of North American and European commercial revenue, they are the best-known listed pure-play fuel cell (and hydrogen) companies, and as such, are a bellwether for the global industry.

When picking apart the financial and yearly results, there a couple of things to take into account:

1. The results shown here are not levelled out to the calendar year 2015.

2. The results shown here are taken directly from the 2015 and 2014 annual 40K, and for Plug Power, the 8K reports are also used.

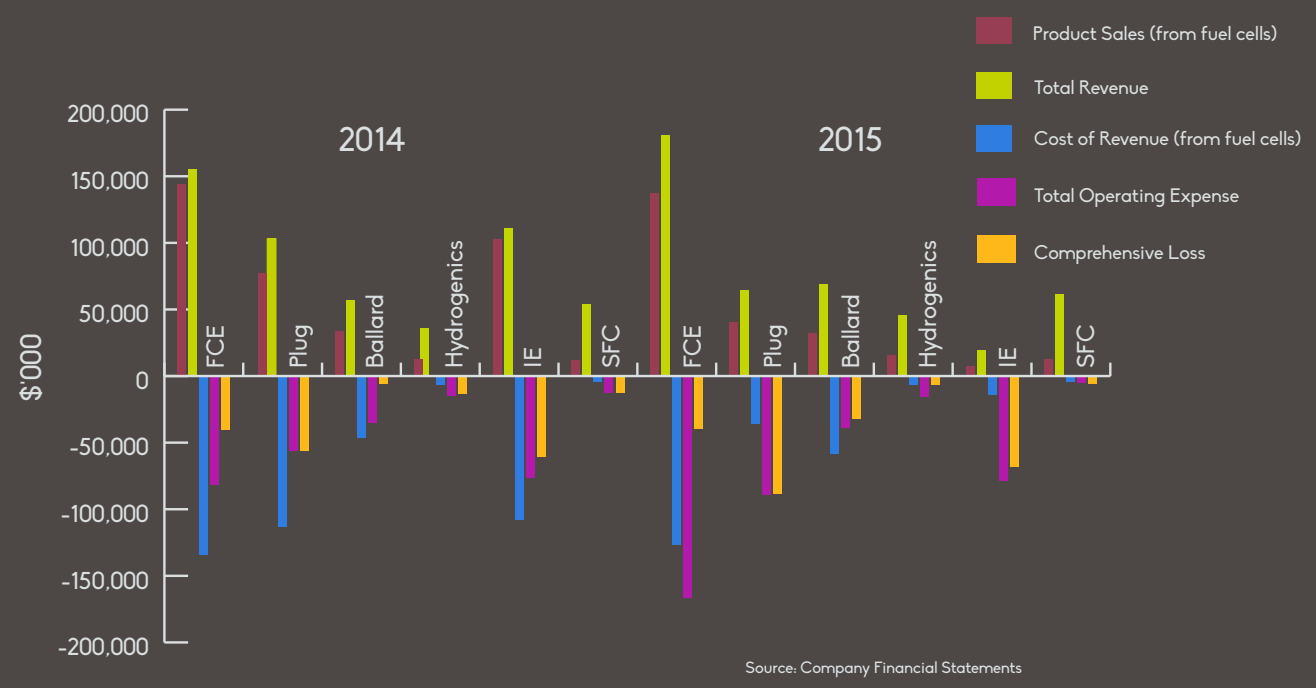
3. As Intelligent Energy results only go back two years, 2015 and 2014, the results here are kept to these two years. The Fuel Cell Annual Review will take the amalgamated results back another year to 2013, but will be shown in a way so specific companies cannot be broken out.

4. The overall Hydrogenics results are for both fuel cell and hydrogen groups, but the product revenue sales and headcount are for the fuel cell group only.

5. All charts go back in time, not forward. So they start in 2015 and go back to 2014.

6. All charts in this section are generated direct from company financial reports.

Chart 8.1: Overall Edited Financial Performance



Source: Company Financial Statements

Overall Results

Between them, these five companies posted revenues for 2015 of $469 million. Of these product sales, in others, revenue from fuel cells shipped was $355 million. Overall, this is up from the 2014 results, which saw fuel cell revenue at $232 million. If the overall 2015 revenue results are in the region of $3.5 billion, as our initial back of the envelope suggests, this puts the pure-play non-Asian sector firmly in its place, showing that there really is significant room to improve!

The chart also very clearly highlights the continued gap between revenue and costs. The comprehensive loss number represents the biggest issue. This is, in reality, the number the company has to make up before it hits profit. The good news is that all companies looked at there, apart from Hydrogenics, are reducing losses and, by implication, are moving towards profitability.

It is too simplistic to say from this that Hydrogenics is the outlier. All companies have had a year of 'stuff' happening to them. Whilst each company will be looked at individually later on, the biggest 'stuff' award goes to Ballard, which, reading between the lines, is in the process of, once again, reinventing itself. This time, as a supplier to the heavy-duty vehicle industry. Implications of this later on.

Moving on to the cost of sales of fuel cell units; the gap between cost to make and price they can sell at. If the cost to sell is higher than the cost to make then, at its more basic, the company is making a loss per unit sold. The more they sell, the higher the loss. As the sector moves to profitability, step 1 is to make a profit per unit sold. FuelCell Energy and Hydrogenics posted a (small) profit per unit sold in 2015. Ballard Power saw the biggest loss per unit, though this is substantially down from 2014.

In the sprint for the first to profitability, Ballard could be said to be in the lead, with the strongest cost out. But the margins per unit sold are still very poor, and with the transition to a heavy-duty supplier, their overall results going forward will be heavily predicated on how quickly they can shift R&D programmes into revenue-generating product.

Chart 8.2: Revenue from Sales and Loss Cost from Sales

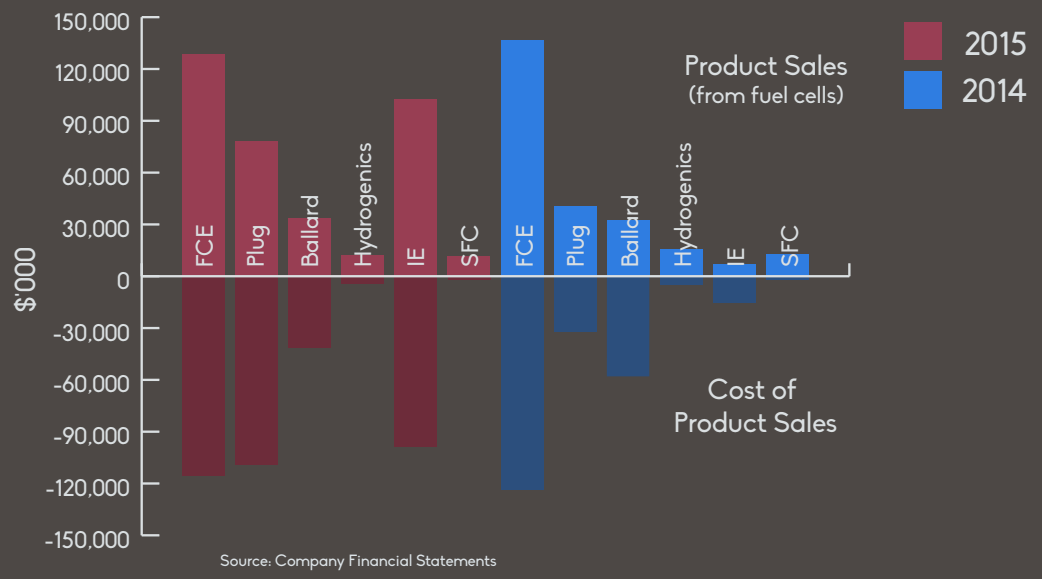
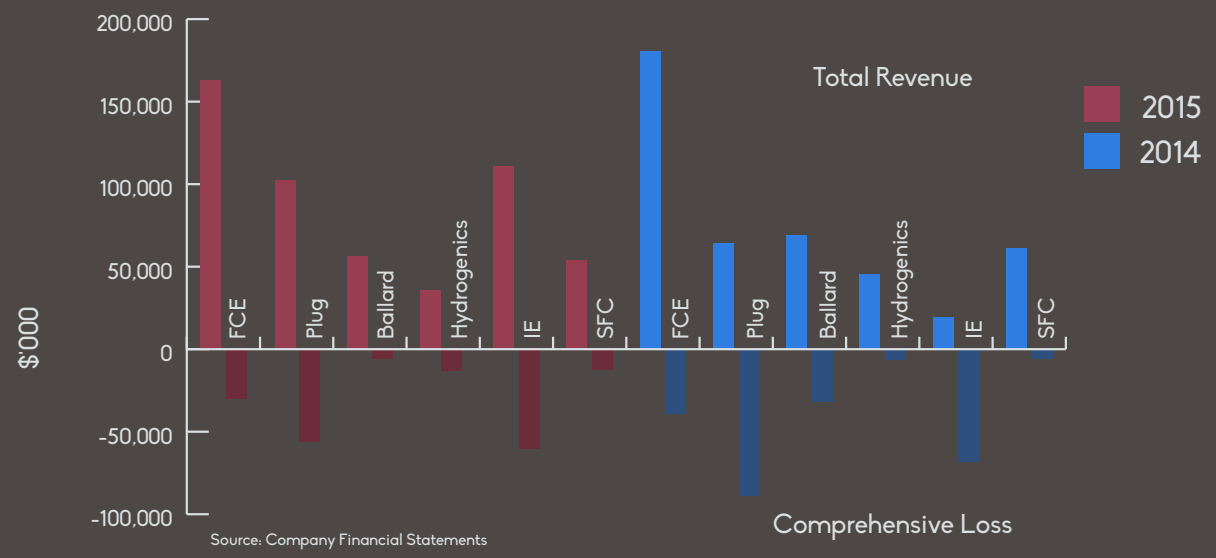


Chart 8.3: Overall Revenue and Comprehensive Loss



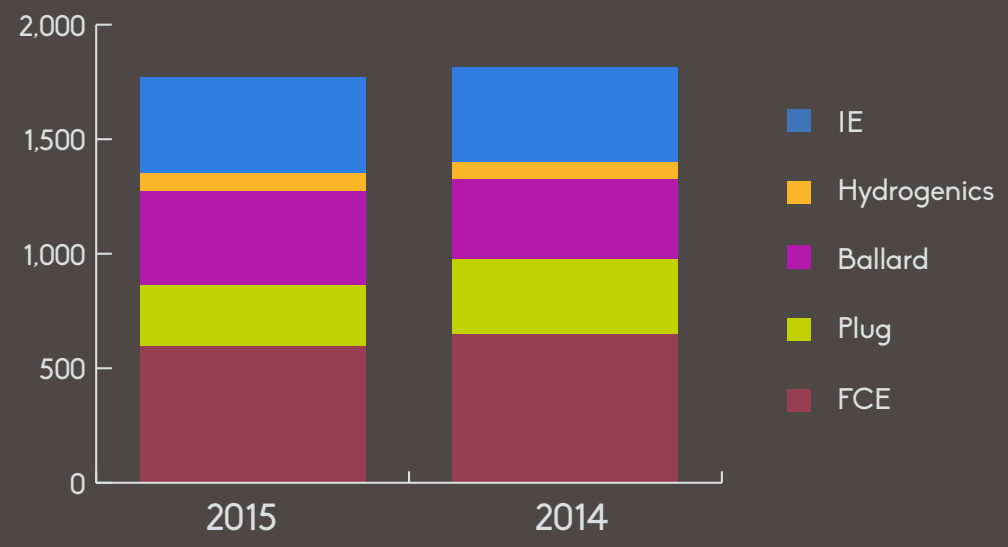
Looking at the head count, what is interesting is that FuelCell Energy and Plug Power shrunk in terms of overall full time staff levels. This is in contradiction to the fuss, in the UK at least, when Intelligent Energy was seen to be laying off staff. When a company has provided location information for the employee's year-on-year, it is clear that, so far, at least, there is no transfer of staff into Asia, specifically China. Intelligent Energy has the biggest overseas presence, as measured by this metric, with a strong office in Singapore and India. With the growth in regions pushing to the home of fuel cell manufacturing, this is the most politically sensitive of all the metrics, and after profit, will be the one most closely followed.

What is interesting is the actual size of these companies. They are small! Between them, they are less than 1,800 people. When you take into consideration that they all, in one way or another, represent their own stack and system companies (apart from the 'current' plug-Ballard tie up), this shows the potential for growth.

When you compare this with Tesla Motors, which in June 2015 had over 12,000 full time employees, you can starkly see the difference in scale. The question has to be asked is are they actually big enough to be sustainable? Staff equates to costs. But staff can also equate to sales. More boots on the ground and the bigger the pipeline. FuelCell Energy, for example, has less than five European sales staff. That's less than five people to cover the EU (28 countries) and Russia. Not a big patch then! But to staff up will clearly require more investment in all of these companies, so it is a Catch-22.

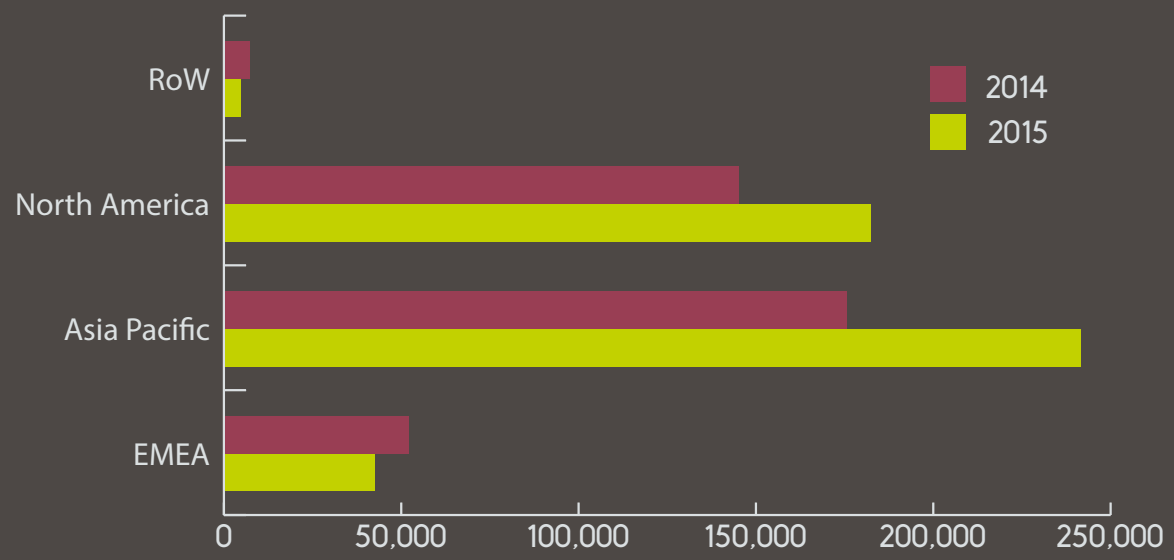
Finally, in this first section, if we look at geographical split of sales, it becomes really, really clear that North America and Asia is where the revenue is coming from. Here, we include India in Asia Pacific.

Chart 8.4: Global Full Time Staff in the Selected Companies, 2015 and 2014



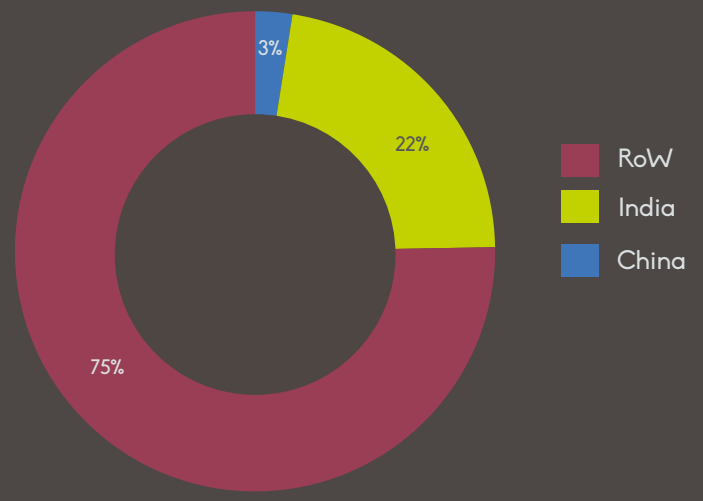
Source: Company Financial Statements

Chart 8.5: Global Revenue by Geography for Selected Companies, 2015 and 2014



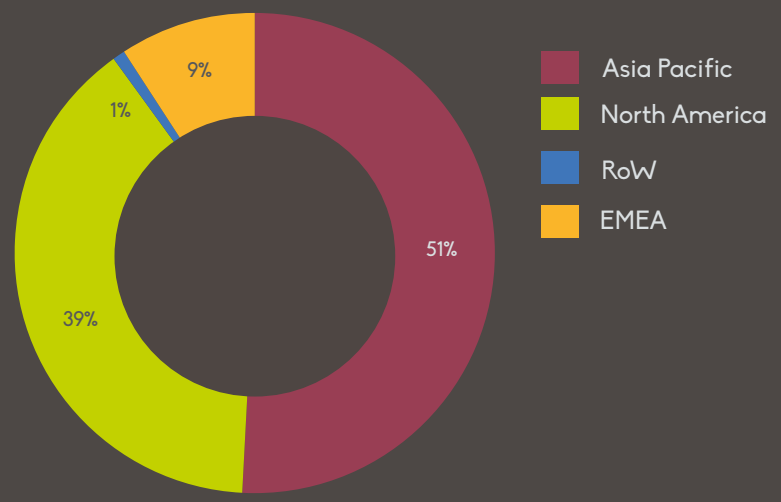
Source: Company Financial Statements

Chart 8.7: Global Revenue by Split Out by China, India and RoW for Selected Companies, 2015



Source: Company Financial Statements

Chart 8.6: Global Revenue by Geography for Selected Companies, 2015



Source: Company Financial Statements

What we can also say about this chart is that for all companies, apart from Plug Power, the value of the export market is growing. Intelligent Energy has the least income from its home geography, whilst FuelCell Energy and Ballard come in at a close second and third. In terms of overall trade then this is could be argued to be a healthy picture, with global trade being critical to the growth of the overall industry. But, as will be discussed later, in reality, there is far, far too much concentration on key areas for Intelligent Energy, Ballard and FuelCell Energy to be comfortable.

What this overall chart does hide though is the rise of India. China and India are coming out of the shadows as adopter nations, and from talks with a number of start-ups, it will only be a couple of years before India becomes a manufacturing hub. Not through rhetoric, but action.

Fuel Cell Energy

FuelCell Energy posted revenues of $163 million, down from $180 million in 2014. Alongside this, the company saw a reduction in MWs, shipped down to 65 MWs. The company is clearly still very much linked to the growth and success of POSCO Power, which represented 67% of all revenue in 2015. Up, worryingly, from 54% in 2013. Six customers represented 94% of all revenue.

The concern in focusing on this chart is the reliance on POSCO Energy. With the current deal due to be completed in the medium term, it is clear that the company is focusing on building up the pipeline of deals in the US, and potentially Europe.

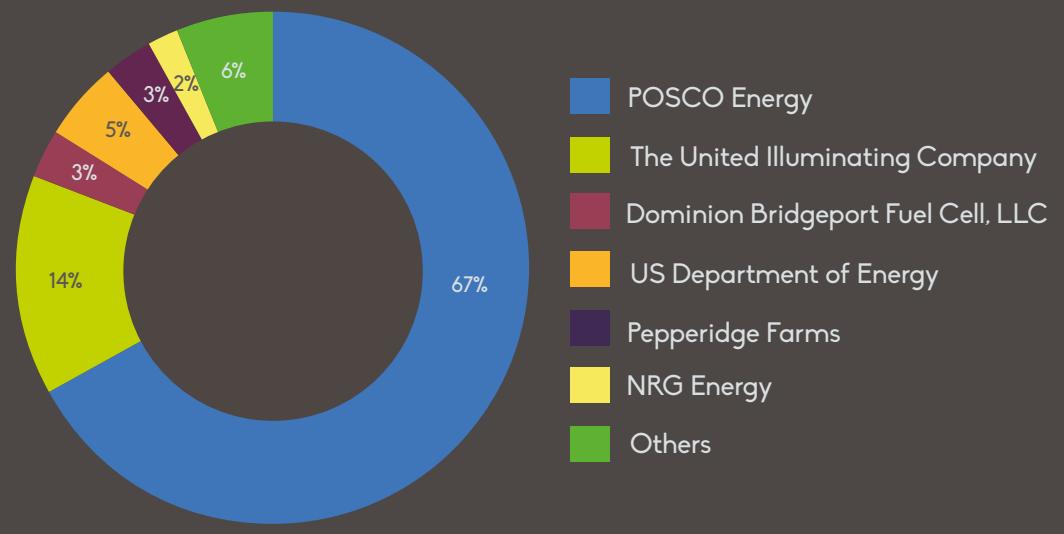
The company has suffered from a very slow ramp-up in Europe, and this is unlikely to change within the next couple of years. Because of this, the importance of the US will grow, unless they can find another majority customer, or unless POSCO continue to place volume orders.

Interestingly, for FCE at least, the company is reaching a tipping point whereby the revenue from the running of fuel cell power plants outweighs the revenue from the sale of fuel cells. In 2015, power plant revenue was $19.6 million and fuel cell sales were $24.5 million[8]. With the ramping up of the 69.9 MW Beacon Falls, Connecticut power plant, 4th is forecasting, to reverse by the end of 2016, power plant revenues taking the majority share of the two.

In terms of price competiveness, the company has stated that to produce power for prices that are below typical grid prices, without incentives, annual global production of approximately 210 MW is needed. Taking into account planned expansion of manufacturing facilities in the US and South Korea, the company will have access to 440 MWs of annual capacity by the end of 2017.

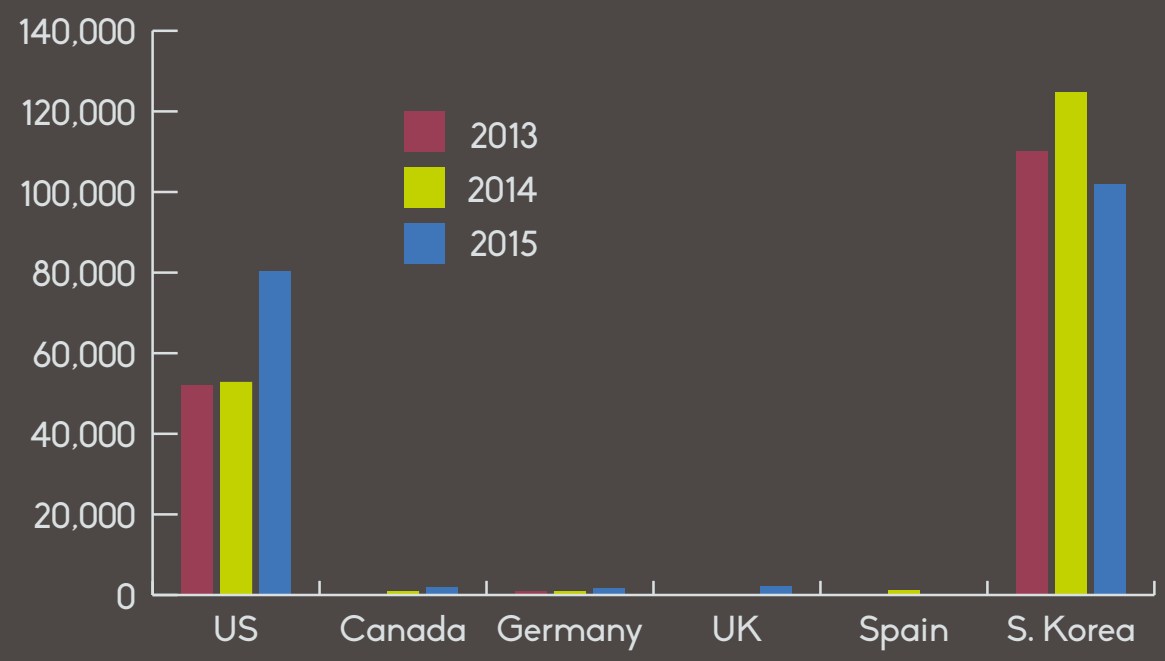
[8] Revenue from the sale of kits to POSCO power was $84.5 million

Chart 8.8: FuelCell Energy 2015 Global Customer Mix



Source: Company Financial Statements

Chart 8.9: FuelCell Energy Sales by Geography: 2015 – 2013



Source: Company Financial Statements

FuelCell Energy's route to profitability is very closely pegged to scale up in manufacturing. As a company, although they are still working hard on cost out through engineering, the majority of the cost out is based on scaling up. Profit, the company is forecasting, will be seen at an annual production of 100 MWs per annum, from the US site. To get to this though, the company will really need to ramp up its sales pipeline in the US. This is tied to available cash and finance for projects and this could lead to more capital raising in 2016.

So for 2016, expect to see a focus on finance raising for new power plant projects, the expected breaking ground on the expansion of manufacturing capacity, build up in sales team in the US, and a lot of positioning in Europe.

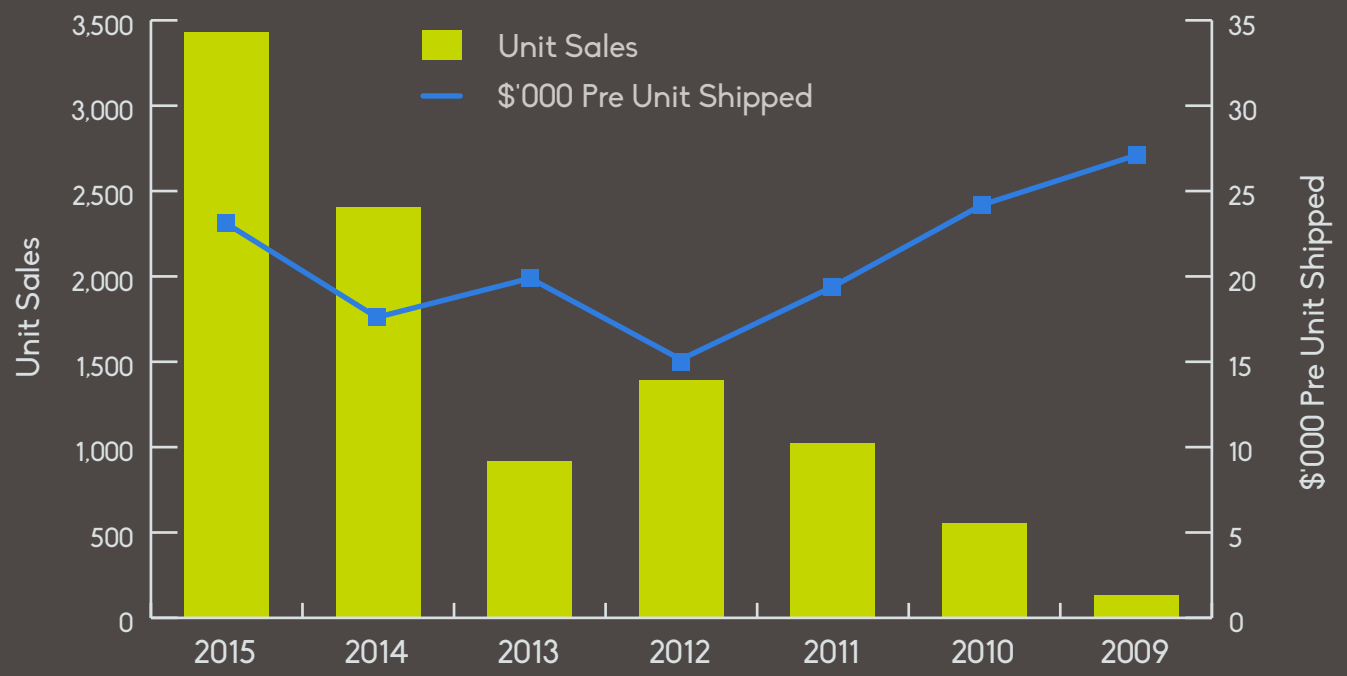
Plug Power

On this year's annual conference call, Plug Power highlighted that there are design concerns in stacks, leading to premature failures. This, they claim, is due to a (unnamed) supply chain stack partner. The knock-on impact of this is fairly severe, and will impact Plug Power's revenues for some years to come, as they stated that two-thirds of the current fleet will have expected costs that exceed the residual service revenues. So two-thirds of the fleet will cost more to run than they earn for the rest of the service life.

The positive milestone in the company though is that during the last financial year, the company deployed its 10,000 fuel cell forklift, and has, it claims, 10,300 in the field at the time of writing of the financial report.

If we look back at the historical GenDrive shipments, as shown in Chart 10, we see them increasing in two clear phases, 2009 – 2012, and then again in 2013 – 2015. But when you look at revenue, measured in thousands of dollars per unit shipped[9], we see a much odder trend. Instead of going down year-on-year, as would be expected through cost out etc., it has jumped back up in 2015.

Chart 8.10: Plug Power's GenDrive Shipments and $000 per Revenue of Unit Shipped, 2015 – 2009



Source: Company Financial Statements

These two headlines show that Plug, whilst growing, is still experiencing teething problems in an emergent sector. The supply chain issues starkly highlight the impact of bad components that are out of the control of the system partner. It is no wonder then that the company is so keen to shift to using its own stacks, from the ReliOn part of the group, and move away from the reliance on external providers.

The focus of the company is clearly on the supply chain, and the de-risking of it, and de-risking adoption for the customer by providing finance options, and maintenance options. Digging through the report, is it interesting, and a sign of confidence in their systems, that customers can opt to maintain the unit themselves. The GenFund product, which is the finance PPA arm of the company, was formed in Q3, 2015, and was set up to provide project funding for the fuel cell product and hydrogen refuelling. As part of this, the company very recently raised a $30 million loan facility, pushing it further into the red.

[9] This is not the price, and was calculated by simply dividing reported product revenue by annual shipments.

The risks for the company, worryingly, seem to be outweighing the positives in this year's annual report.

1. Setting aside the stack quality issue, Plug, like FuelCell Energy, are heavily weighted to one customer. FuelCell Energy gets a lot of flak for their revenue reliance on POSCO Power, but interestingly, there is almost no equivalent for Plug. The reality is that in 2015, 56.7% of consolidated revenue for Plug Power came from one customer – Walmart. Not only are the implications of this clear, but the annual report is clear, in that it states that 'a loss or decline in business with this customer could have adverse impact on our business, financial condition and results of operation'.

2. Also, in terms of risk, Plug states that they are concerned over the potential loss of a supply chain partner, so investing in alternative designs to allow them to use their own components. This R&D effort is very clearly shown in the massive step up in the company's R&D spend, from $6.5 million in 2014 to an eye-watering $14.9 million in 2015.

3. The company has stated that any loss of government incentive will have a negative impact on sales. With the US investment tax credit set to run out by the end of 2016, this could really undermine next year's results.

4. Even though Plug have now spent over two years trying to develop a European market for its products, and now owns a 100% share of HyPulsion, sales of the systems are still 99% predominated on the North American market. And within this, the USA has the majority share.

5. ReliOn – what is clear from the investor presentations and the year-end results is that ReliOn is still a tiny minority of income. In one presentation, Andy Marsh, the CEO, said that by the end of this financial year (2016), they were expecting this to have changed. As overall, the fuel cell telecoms market is still really not taking off, then unless he has a proven pipeline in this area, the worry is that this statement either implies over optimism on their part, or some form of restructuring.

As with any financial report, the devil really is in the detail, and the one nugget in the Plug filling that made me look at it three times was that, for the backlog, some clients have an agreed upon delivery time of… 10 years. 2025. This type of deal cannot be common as, due to the risk profile, finance for a project of 10 years hence is close to impossible.

Finally on Plug Power, one statistic to make you wince is that by the end of their financial year 2015, the company had an accumulate deficit of $993.9 million. So in lay terms, pretty much a billion dollars. Of the companies outlined in this report, the deck just seems to be stacking up more against Plug than the others right now. This is in sharp contradiction with some of the press statements that are being made about Plug at the minute. That it is forecast to be profitable in 2016. That this is the year they are going to make it big. We can only wait and see.

Ballard Power

In 2015, Ballard Power posted revenues of $56 million, down from $68.7 million in 2014. Within this, sales of actual product was $34 million, with R&D revenue making up a significant percentage of the difference. Engineering services, or rent-a-brain, is still a highly profitable area for Ballard.
Ballard is going through a major shift in focus, as can be seen in the product breakout chart opposite.

What is clear from this chart is the rapid decline in sales from the telecom sector. This is not a Ballard Power phenomena as, aside from Intelligent Energy, there is no fuel cell company post year-on-year growth in this area. Linked into this drop in sales saw the exit of three C-level execs, each of which was a major promoter of this area.

Note than in early 2016 CHEM bought the telecoms unit from Ballard Power.

Portable power was the acquisition of Protonex, a really odd purchase for Ballard, which traditionally has no interest in either the military or SOFC sector. We can only assume it is linked to Ballard's development deal with start-up, Ardica. Protonex have a depth of history in surviving in these areas, as well as limited, booked revenue stream. So Ballard, potentially, bought support for Ardica, as well as a revenue stream.

It is the shift to heavy duty that is fascinating. As a company that has only dabbled in this area for the past decade, to make a commitment to growing this sector is clearly linked to the number of deals the company secured in China during 2015.

Note, in 2013, that the South African revenue comes from the Anglo Pt development deal to produce methanol-powered 5 kW for off-grid communities. Also, the Taiwan revenue in 2014 was a telecom deal, which is now complete.

A recap of the Chinese deals are worth a run through, as there were multiple, and have fairly long-running implications for the company.

1. Guangdong Synergy Hydrogen Power Technology Co., Ltd. ('Synergy') – equipment supply agreement, valued at $12 million, to provide FCvelocity™- 9 SSL fuel cell stacks for range extension applications in commercial vehicles in China. Ballard expects to deliver the stacks in 2016 and 2017. Synergy will collaborate with Dongfeng Xiangyangtouring Car Co., Ltd. ('DFAC'), which is part of Dongfeng Motor Corporation.

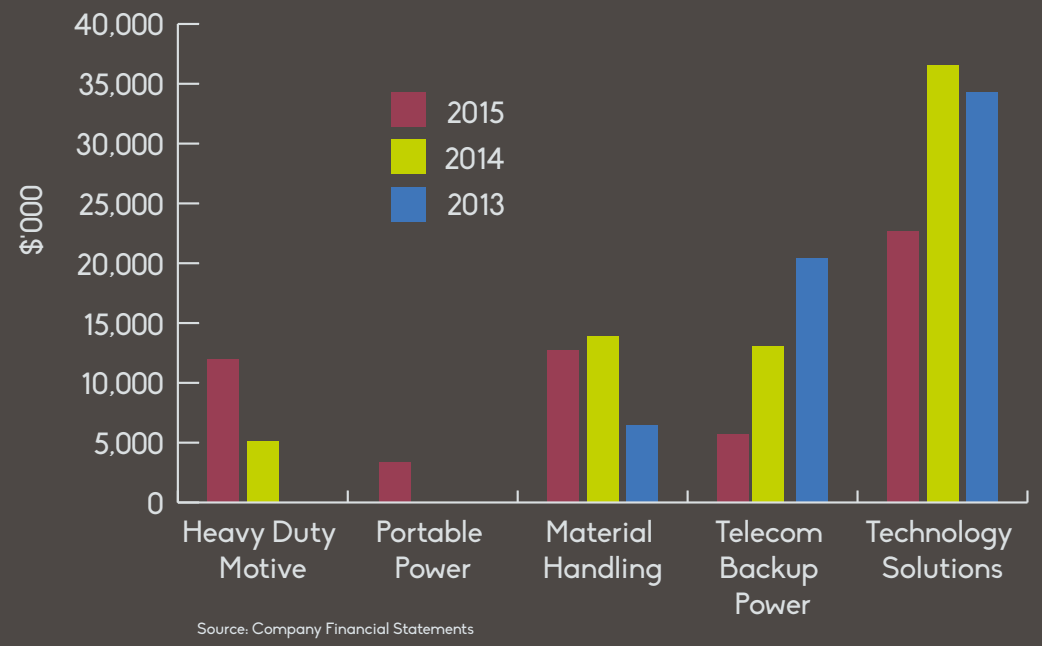
2. Tangshan Railway Vehicle Company Limited ('TRC') – development agreement, with a value of approximately $3 million, for the development of a new fuel cell module that will be designed to meet the requirements of tram or Modern Ground Rail Transit Equipment applications. The initial prototype is slated for delivery in 2016.

3. CRRC Qingdao Sifang Company, Ltd. (CRRC Sifang) – joint development agreement and a supply agreement to develop and commercialise a fuel cell engine specifically designed for integration into low-floor trams manufactured by CRRC.
The agreements include delivery expected in 2016 of ten customised FCvelocity modules and have an initial expected value of approximately $6 million. An initial deployment of eight fuel cell-powered trams is planned by CRRC Sifang and the City of Foshan on the Gaoming Line, starting in 2017.

4. Synergy (deal 2) – to provide fuel cell power products and technology solutions in support of the planned deployment of approximately 300 fuel cell-powered buses in the cities of Foshan and Yunfu. The agreement has an estimated initial value of approximately $17 million expected through 2016. Critically, this deal includes technology license for localisation of assembly, supply of proprietary fuel cell stacks. So opening of manufacturing in China.

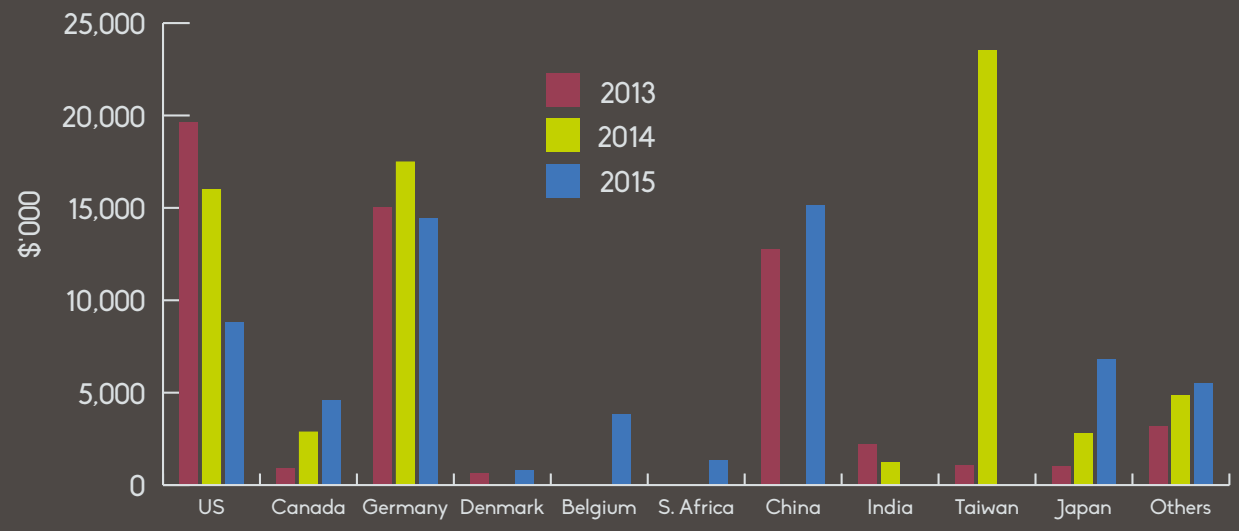
5. Nantong Zehe New Energy Technology Co., Ltd. ('Nantong Zehe') and Synergy (deal 3) – to provide fuel cell power products and technology solutions to support the planned deployment of an initial 33 fuel cell-powered buses. The agreements have an estimated value of approximately $10 million, the majority of which was recognised in 2015.

Chart 8.11: Global Revenue by Market Area, 2015 – 2013



Source: Company Financial Statements

Chart 8.12: Ballard Revenue Geographical Split: 2015 – 2013



Source: Company Financial Statements

The two key points in this rundown are:

1. The importance of Synergy (Guangdong Synergy Hydrogen Power Technology Co., Ltd.) to Ballard. This company, which appears to have no website, should not be confused with the Taiwan company, YC Synergy. And;

2. The move of Ballard to start production in China, based on these deals.

So in 2016, along with the selling off of the telecoms arm of the company, we are forecasting for Ballard the opening up of an office and facility in China, with the transfer of staff from Canada, layoffs in Canada, and the acquisition of another small fuel cell company to complement Protonex.

Hydrogenics

Hydrogenics continues to see significantly more revenue from the sale of electrolysers than fuel cells, as shown in Chart 8.12.

According to the company annual report, the reduction in revenue in 2015 was primarily due to the weakening euro to dollar, and then a reduction in sales.

The company's push for Power-to-Gas has seen them land a number of deals. The improvement from 2013 on is not due to one factor, but a combination of increased sales of indoor-based UPS systems, combined with the deal with Kolon, which saw a 1 MW unit shipped in 2015.

The Kolon deal, which is being discussed as potentially seeing a follow-on order for a further 50 MWs, would certainly help balance the books between hydrogen and fuel cell revenue.

Hydrogenics have also been making a strong play for the heavy-duty vehicle market, with the headline-grabbing 200 fuel cell units for Alstom (Europe) for passenger rail applications. The first prototype has already been shipped, so it looks like this is moving fast (no pun intended). With both Hydrogenics and Ballard Power making a strong play for this market, we could arguably see Hydrogenics taking market lead in Europe, Ballard in China, and we would suggest Hydrogenics in North America, simply because of (suggested) better relations.

In terms of the (hydrogen) onsite generation system, what was interesting to watch in 2015 was the increase in the 'we are first' rhetoric from a number of companies. Whilst, to be honest, most of them were wrong and showed a woeful lack of understanding of the actual electrolyser market, Hydrogenics' claim to be the only company with a single MW PEM electrolyser stack seems to be spot on. The company now has both PEM and AFC electrolysers, and is selling both for different markets.

The new market to appear in 2015 takes some head twisting to follow. It is the cleanup of radioactive contaminated water.

The accident at the Fukushima Daiichi nuclear plant is producing large quantities of tritiated water [10] . Tritiated water is radioactive water where the normal hydrogen atoms are replaced by tritium, otherwise known as hydrogen-three. The electrolysis of the tritiated light water produces (clean) hydrogen and tritium gas. The tritium gas is then caught on a catalyst layer and is collected as a waste product of radioactive sludge.

So the process does not remove all the radioactive material, but makes it less harmful, and in what is thought to be a more manageable form, due to it being concentrated. If this works, and it should be remembered that this process is still theoretical, then the market for this, in Japan, is large. Scary large. With the Japanese push for a hydrogen economy, the really odd by-product of these hellish happenings could be that they are able to produce large amounts of useable hydrogen from it.

Kurion, Inc., who bought the 0.5 MW electrolyser off Hydrogenics, has applied for the patent for this process [11].

The electrolysis process is not the only design to stabilise the radioactive water and at the same time as this demonstration project, Russia's Atomproekt has also designed a system and is planning on demonstrating it as well.

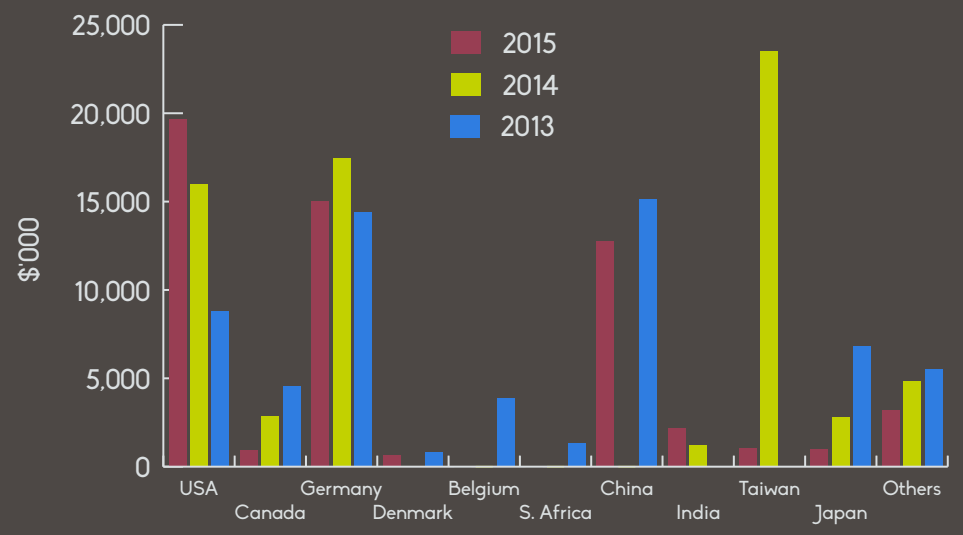
In terms of costs, Hydrogenics, like every other company with new product development lines, saw an increase in R&D costs, but compared with Ballard, the change has been minor, at an increase of $0.7 million over the 2014 level.

Looking forward for 2016, expect to see a step up in marketing for the heavy-duty units, especially on the east and west coast of the USA, and Europe, a push for more usage of systems in areas with waste hydrogen and, potentially, the creation of a combined turnkey offering of hydrogen generation, storage and fuel cell package. This has been tested, in a somewhat modular fashion, but it makes sense now to see this launched as an overall product offering. For the (hydrogen) onsite generation site, another multiple MWs of power-to-gas projects in Europe and more PR for the Japanese nuclear reactor project.

Costs for Hydrogenics are key, as they are with other companies, but Hydrogenics is very aggressive with its cost-out programme, and we could see some public figures during 2016 showing the impact of hydrogen pricing on profitability.

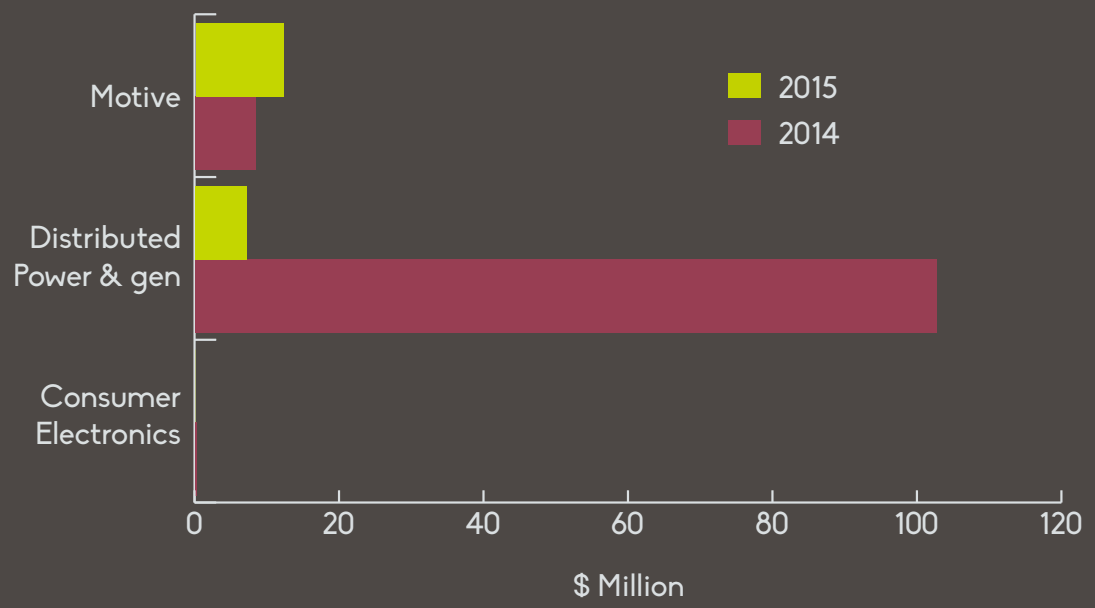
[10] Background on this can be found at http://www.meti.go.jp/earthquake/nuclear/pdf/140428/140428_01n.pdf
[11] For reference, this patent number is: US20130336870 A1.

Chart 8.12: Evolution of Hydrogenics Revenue by Hydrogen and Fuel Cell Sales, 2015 – 2009



Source: Company Financial Statements

Chart 8.13: Intelligent Energy Revenue by Product Group, 2015 – 2014



Source: Company Financial Statements

Intelligent Energy

Intelligent Energy pulled off something of a rabbit from a hat last financial year, with the announcing of the deal to take over the power management rights of 27,400 telecom towers in India, from GTL. Of these, over 10,000 of them will be fuel cell-powered. What is critical in the agreement, and overlooked, is that the deal is fully expected to see the build out of fuel cell manufacturing in India.

With the company focused on building up for this deal, securing the supply chain and manufacturing for scale up, it is unlikely that we will see another deal of this for IE in 2016. What this has done though is prove that the model for telecoms is the same as for prime power – provide a service, instead of a technology, and the market follows. This is a very big departure for IE as remember, as a company, it was set up to license its stack design and had no plans to manufacture, never mind become a power management company! But kudos to the company for moving in this direction and seeing the revenue flow to back them up.

Although power electronics was only a tiny blip in 2015, at $0.14 million and nothing in 2014, we are looking to see this jump in 2016, with the announcements of a deal to embed the company's technology into a smartphone. Is it Apple? The company is referred to as an 'emerging smartphone OEM', so it is likely worth looking to India again to see who is making gains.

Of the companies looked at in this special, IE is by far the smallest in terms of revenue, but is well staffed. FuelCell Energy was a 2015 revenue of $129 million and has a staff headcount just under the 600 mark. IE with a 2015 revenue of $113 million is at 422.

9. About *4th Energy Wave* and Legal Disclaimer

4th Energy Wave is a fully independent, distributed energy strategy, analysis and advisory firm. At present, the company has deep expertise in fuel cells, hydrogen and flow batteries.

Our mission is to work with any stakeholder interested in the emerging distributed economy, in both energy and transport, helping you see and understand opportunities and threats. Helping you develop and execute on your business plans. Helping you develop an understanding of how policy is changing, the ebb and flow of the capital markets and the growing export markets.

4th Energy Wave is a completely self-funded, commercial enterprise and is not backed by government or private funding.

4th Energy Wave is the only analyst house in the world to hold complete datasets on the development of the fuel cell sector and has regular access to confidential information from companies around the world. This is what makes us unique.

For more information and to discuss how we can help you, please contact me at:

Kerry-ann@4thenergywave.com

Appendix A

Japanese Company Fuel Cell Commercialisation Plans

Name of Company	Technology	Market	Unit size (kW)	Target launch date	Any other useful info
Mitsubishi Hitachi Power Systems	DMFC? (using highly concentrated methane)	Industrial		In development- no date announced	µDeveloping the worldµs most efficient fuel cellµ
Nichias		Residential			Expanding sales off µRoslim Boardµ which is an inorganic thermal insulation board easily processed and manipulated for high temperature operation for use in FCs.
Toda Kogyo Corp.					Increasing production capacity of FC catalysts to eight times that of current capacity. Their production system will be upgraded to meet demands of FC manufacturers who want to reduce costs of FCs aiming to cut catalyst cost to half.
Kyoto University	SOFC			FY 2018	Doing research and development of technology to use ammonia.
Tokyo Gas and Panasonic		Residential		Apr 15	New Ene-Farm has been developed. Cheaper than current model by reducing the number of parts and amounts of precious metal while keeping the basic performance such as generation efficiency.
Panasonic and Toho Gas		Residential		Apr 15	New product requires 30% less installation area compared to existing model.
Metawater	DMFC? (using sewage sludge)	Industrial (sewage treatment plant)	105 kW		Sewage plant plans to reduce its maintenance costs by selling electricity.
FC-R&D	PEM	Commercial			FC generation system, µZEEP 24µ which uses an originally developed hydrogen storage alloy, which eliminates the need of a compressor.
Bloom Energy Japan	SOFC	Large scale commercial	1,200 kW		Largest scale output in Japan.
Toshiba FC Power Systems		Commercial and Agriculture			Next generation pure hydrogen FC system will be tested in Yamaguchi Prefecture.

Name of Company	Technology	Market	Unit size (kW)	Target launch date	Any other useful info
Tokyo Gas and Panasonic		Residential		Apr 15	New fourth generation Ene-Farm to be released in April 2015.
Saibu Gas and Panasonic		Residential		Apr 15	New Ene-Farm to be released in April 2015. Reduced price by reducing number of parts.
Iwatani & Others	Directly injecting hydrogen	Agriculture		on market	First cogeneration system to supply heat and power solely using hydrogen.
FCO Power	SOFC	Residential		2020	Specifically made thinner for home FC systems. Reduction in volume to less than a quarter than that of conventional products.
Hydrogenics			33 kW	In a few years	Accelerating its deployment of an FC business in the Japanese market.
Toshiba Fuel Cell Systems		Commercial (refuelling station)		Further development after experimental operation	This FC system uses hydrogen as fuel, and supplies electricity and hot water w/o producing CO2. Currently an experimental operation at Iwatani.
Gifu University	DMFC?	Target is commercial		Have to resolve issues first- scaling-up and reducing costs.	Have succeeded in generating power and phosphorus from livestock waste water, inc. pig waste using a microbial FC system. This is the first time phosphorus has been collected by a microbial FC.
Kyocera	SOFC	Residential and commercial		FY2016	An FC system is planned to be developed using expertise from their experience of cell stack production. An experiment is planned to start in this term (article from May 1, 2015).
Miura	SOFC	Residential, small-scale commercial and factories	5 kW	FY 2017	Will promote product as independent cogeneration system to provide electricity and heat.
NEDO					New research and development projects were launched for full FCV market growth. Aim is to drastically improve performance, cost and productivity of FCs. These projects will work on the development of process technology to significantly reduce production time and basic technologies such as investigation of the reaction mechanism of FCs and the creation of new material concepts with Japanese expertise.
Osaka Gas	SOFC	Residential			Working together for commercialisation of smart house with FCs and a micro EV as core, they will examine specifications of the microEV, which is to be charged from excess power of FCs as well as issues of power supply from EV to home (V2H). Each firm will use results to develop products and these firms plan to offer a new product (living environment).

Name of Company	Technology	Market	Unit size (kW)	Target launch date	Any other useful info
Panasonic		Residential and home appliances		2030	Firm is working on development of an FC system using hydrogen directly at the same time. Firm considers photocatalytic technology as the core to be more appealing to consumers. Have developed an original µniobium nitride catalystµwhich works with visible rays in sunlight.
UEC	PEM				Have succeeded on high-resolution, 2-dimensional imaging of platinum catalyst degradation in a polymer electrolyte full cell in a simulated operating state. This method can be used for development of highly functional catalysts for PEFCs.
METI	IGFC (Integrated coal gasification fuel cell combined cycle)			2025	METI has a draft roadmap to commercialise highly efficient thermal power station tech with lower CO2 emissions. IGFC is a combination of coal gasification technology and fuel cells and an ultimate future tech still under development.
Gunma University	DMFC				Have developed a highly active electrode catalyst for DMFCs. Carbon nano-fibre is soaked in a solution of titanium oxide precursor and then oxidised to become a titania coated carbon nano-fibre. This nano-fibre is used to support metal particles for this new catalyst. Increases activity with reduced need for platinum.
Fuji Electric	SOFC and PAFC	Business			Product range under development.
Kyoto University	SOFC	Residential	1 kW	2020	Have developed an FC to generate power using a reaction of ammonia and oxygen in the air.
Mitsubishi Gas Chemical Company	DMFC	Portable backup power sources	250 W to 500 W		
Tokyo Gas and Kyushu University	SOFC			2025	Have developed a method to significantly improve generation efficiency of SOFCs. Oxide ions are replaced with protons when cell stacks are arranged in a series. This method improves the generation efficiency form 45% to 55% LHV to over 80%.
Hokkaido Gas			200 to 700 W	Oct 15	Introduce new Ene-Farm for cold climates into market.
Arcadia		Emergency preparation			Have developed a cell using aluminium as the fuel. They succeeded to produce electricity stably for several days by using a special solvent.
NEDO	MFC (microbial fuel cell)				Project aims to build a system to treat waste water from a chemical plant such as a resin factory.

Name of Company	Technology	Market	Unit size (kW)	Target launch date	Any other useful info
Osaki CoolGen	IGFC			2021	Project in Hiroshima Prefecture will start phase 2 in FY 2016.
NEDO	IGFC			2025	Starting development of clean-up technology of coal gasification for highly efficient coal thermal generation. Will develop a technology to precisely remove poisons in coal gas, which reduce FC performance.
Primix					They have established a lab to improve production technology of electrode plates. Aim to make the leading production centre of new electrode plates.
Biocoke Lab				Nov 15	Small FC system planned to be produced and sold from November.
Hokkaido Gas		Residential			Can operate in a very cold outdoor environment of -20C.
NGK	SOFC	Residential and Business and Industrial			
Atsumitec	SOFC	Automotive	1 W/cm3		Developing a power generation system using exhaust gas and heat. SOFCs and thermoelectric conversion element are combined to achieve better generation efficiency.
Mitsubishi Hitachi Power Systems	SOFC and micro turbines	Aerospace, Gas, Industrial, Commercial and Power stations			FC combined generation and control system µDIASYS Netmation 4Sµwon a Good Design Award for 2015. FC combined generation system is a combo of SOFC and micro turbines to achieve highly efficient generation and significant reduction in CO2 emissions.
University of Electro - Communications	PEM				Have developed a highly functional and durable catalyst for cathodes of PEFCs. The catalyst exhibits five to eight times more catalytic reaction in mass than conventional platinum catalysts, and over double of that of platinum cobalt catalysts.
Toshiba FC Power Systems		Residential		Be in houses available Jan 2016	First natural gas Ene-Farm for apartment units has been delivered. The features are 95% total efficiency, the worldµs highest level.
Toyota		Automotive			New FCV concept, which functions as a generator during parking and can feed its power to the grid in the community. Also, once the car has passed its time, the FCs can be removed and used as a generator.

Name of Company	Technology	Market	Unit size (kW)	Target launch date	Any other useful info
Kyushu University	PEM	Automotive			Have developed a method to use a catalyst using hydrogenase produced by microbes for both electrodes. Raises possibility to produce FCs w/o platinum.
Kyocera	SOFC	Commercial	3 kW	2016	
Toshiba		Government - emergency use		Mar 16	µH2Oneµis a new product that is self-contained and produces its own hydrogen for power production.
Aquafairy		Government - emergency use	30 W		Developed FC system to produce hydrogen in-situ for power generation. Key feature is portability.
Tatsumi Chuo Management Laboratory		Government - emergency use		Now going to Fukushima Prefecture and available wider in 2017.	Magnesium air batteries for independent operation during disasters. For use in vending machines, computers, cell phones and TVs.
Biocoke Lab			1,000 kW	testing in 2019	
NEDO	SOFC	Commercial	5 kW	2020	Starting development of stationary FCs for commercial facilities and plants. Will combine FCs and gas turbines.
Kyushu University	PEM			2020	Have improved the durability of a catalyst by over 120 times for PEFCs. Allows a significant reduction in costs.
Mitsubishi Gas Chemical Company	DMFC	Government - emergency use			Their FCs use a LIB to stabilise output. Will offer portable and stationary types.
Aquafairy	Calcium hydride	Government - emergency use, Leisure	30 W	Jan 16	Developing an FC system that continuously operates at low-output.
Osaka Gas	SOFC	Residential		Spring 2016	New Ene-Farm, of which generation efficiency is over 50%. It can use a smaller hot water tank.