Shell Chemicals

"What does the future hold for the C6 aromatics chain?"

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Sven Royall

Sven Royall joined Shell Chemicals UK in October 1979 with a degree in Natural Sciences (Cambridge) and a PhD in Chemistry (London). After early assignments in the Agrochemicals business - mainly working in Latin America but also including a four year posting to Thailand - Sven spent six years in the Natural Gas business. His last three years in that business were spent working from Malaysia.

In April 1996, Sven returned to the UK to manage the SM/PO, styrenics and PET businesses in Asia, Latin America, Middle East and Africa. In 1998, he was appointed Vice President Aromatics, based in Singapore. In July 2000 Sven transferred to the UK as Vice President Commercial Operations, with global responsibility for logistics, supply chain and customer centres.

From March 2003, Sven held the role of Vice President for Lower Olefins Americas and for global C4/5s, based in Houston, returning to London in November 2003 to assume the position of Executive Vice President Strategy, Portfolio & Sustainable Development. On 1 January 2005, he assumed the position of Vice President Strategy, Acquisitions and Divestments. In this role, Sven was also responsible for activities in the areas of Health, Safety, Security and Environment (HSSE), Sustainable Development (SD) and External Affairs.

Sven took up the position of Vice President Customer Services & Intermediates on 1 May 2006 before becoming Vice President Global Intermediates on 1 August 2008.

After two tough years for the C6 aromatics value chain, my aim today is to try to offer some optimism about the long-term future of this business. And while for many of us business conditions remain difficult, there is a ground swell of opinion throughout the industry that better times are coming.

As most of you know, Shell is one of the world's major aromatics producers and a significant supplier of benzene, styrene and phenol-acetone, the key building blocks for the C6 chain. Having over many years built a world-scale, world-class manufacturing network, we intend to sustain and strengthen our global position.

So why are we optimistic?

Well, mainly, because further along the C6 chain our major customers and their customers are expressing confidence that the materials and products made from or with aromatics will continue to be in demand, with new applications driving growth in a number of markets.

There are numerous and complex challenges to be met, some relating to competition, others to supply, cost or sustainability issues. But there are also significant opportunities for future growth if the supply chain remains flexible, competitive and creative.

My intention is to take a broad brush and paint an impressionistic overview of the outlook for the C6 aromatics chain in 2011 and beyond. I'll look at demand drivers, review issues and challenges, then offer a brief summary of Shell's strategy for staying competitive before concluding.

Demand drivers

Today, aromatics are the precursors for an incredibly diverse range of everyday and essential plastics, fibres, foams and resins that are used in automotive manufacturing, construction, clothing, appliances, IT equipment, cleaning products and pharmaceuticals. New uses and applications continue to be developed. What's more, many of these products can enhance energy economy – by providing insulation or weight reduction, or both – which also helps reduce CO_2 emissions.

Like most petrochemicals, aromatics suffered major demand disruptions in the wake of the global financial and economic meltdown, which occurred in late 2008. Global styrene producers, for example, are still grappling with average industry operating rates around 82%, the lowest since 1990. And while phenol operating rates have perked up this year, last year they averaged around 75%.

Thankfully, industry indicators through 2010 suggest strengthening demand.

> "There is a ground swell of opinion throughout the industry that better times are coming"

Let's take a closer look at current and future demand for benzene and its derivatives.

In 2009, global benzene demand was around 41 million tonnes, of which 4.5 million tonnes were traded.

Demand drivers: Benzene usage (slide 1, page 13)

Currently, styrene production accounts for 52% of this, with main downstream uses in polystyrene, synthetic rubbers and plastics for applications ranging from household appliances and white goods, to IT products, automotive parts and insulation products for the construction sector.

Around 20% of benzene is used – via cumene and phenol – to produce both phenolic resins, used to make furniture and construction boards, and polycarbonates, which have wide industrial applications and considerable growth potential.

Another 12% is used for cyclohexane to make nylon, primarily for sports and leisure products. About 3% is used in detergent surfactants.

"There are significant opportunities for future growth if the supply chain remains flexible, competitive and creative."

Since late 2008, two key C6 end-use markets – automotive manufacturing and construction – have been in a deep trough. But it is in these two key end-use markets, which are now slowly recovering, where much of the future growth in C6 value chain demand is likely to emerge.

In large part, this will be because C6-derived products are well-suited to meet the needs of a low-carbon age. Their light-weight and insulating properties can help reduce energy consumption and lower CO_2, while their "processibility" is enabling designers to engineer a variety of stronger, more flexible parts and products that meet the needs of a wide range of manufacturing industries.

Given the importance of the styrenics chain for benzene, let's take a closer look at what is likely to drive future demand.

EPS Insulation & Packaging (slide 2, page 13)

We see good long-term prospects for EPS due to its excellent insulating properties. In a world seeking a major reduction in its carbon footprint, we expect renewed demand growth in the construction sector – in both new builds and refurbishments.

Not only does EPS insulation significantly reduce heat lost by buildings in cold climates, lowering energy demand for heating, in hot climates it help keep buildings cool, reducing energy usage for air-conditioning.

It is estimated that the energy used to produce polystyrene foam insulation for a typical house is recovered after only one year through energy savings.

With buildings accounting for up to 40% of energy use globally, the potential contribution of insulation to energy efficiency, and therefore lower CO_2 emissions, is significant. Some estimates suggest that 20% of current world energy consumption could be saved if all new buildings were energy efficient.

At this point, I should also mention polyurethane foams, which are widely used for insulation in both construction and domestic appliances such as refrigerators. Benzene is used in the production of polyols, an essential ingredient in PU manufacturing, of which Shell is a major producer.

EPS and PU compare favourably to mineral products (slide 3, page 14)

The performance of these chemical insulation products compares favourably to mineral products like Rockwool. Carbon intensity data for insulation panels made from EPS, standard polyurethane and Rockwool, calculated for Synbra by a life cycle tool developed by Akzo Nobel, show that both EPS and polyurethane production results in less than half the carbon footprint (expressed as CO_2 equivalent per m^2 of insulation panel with Rc 5) compared to Rockwool.

"...both EPS and polyurethane production results in less than half the carbon footprint compared to Rockwool."

According to the July 2009 International Chemicals Councils Association report, Innovations for Greenhouse Gas Reduction, insulation of buildings using chemicals industry products – primarily EPS, extruded polystyrene and polyurethane – was almost 2.1 gigatonnes of CO2 equivalent in 2005. This equates to 40% of the total CO2 emissions savings enabled by chemical industry products.

Staying on the low-carbon track, another source of optimism is the fact that the automotive industry's use of polymers and composite materials has been rising steadily for over 40 years. A wide variety of styrenic polymers and polyurethanes are all widely used in automotive applications.

The plastic car (slide 4, page 14)

In 2009, an American Chemistry Council report estimated that the use of plastics and polymer composites in a typical passenger car rose from 27kg to over 150kg in the 40-year period to 2007.

Just 15 years ago, a leading automotive OEM executive was telling his and our industry that steel is for cars, aluminium is for aeroplanes, and plastics are for toys.

Yet the ACC now reckons that by the end of this decade it is quite possible "the automotive industry and society will recognise plastics as a preferred material solution that meets, and in many cases is the benchmark for, automotive performance and sustainability requirements."

Why? Because these products – many of them from the C6 value chain – offer a wide range of desirable characteristics, including strength, processability, light weight, resistance to chemicals, corrosion and harsh environments, thermal and electrical insulation, thermal and electrical conductivity, transparency, translucence, opacity, size and shape, and cost-effectiveness.

According to the ACC, over 50% of a typical car's volume comprises polymers and composites, but only 10% of the weight. What's more, they estimate that plastics – through "light-weighting" – help reduce energy consumption in the US passenger vehicle fleet by 88 million barrels of oil equivalent (BOE) each year, preventing 30 million tons of CO2 emissions.

Recently Shell's Group CEO Peter Voser suggested that "between now and 2050, one billion new vehicles will come on to the world's roads, mostly in Asia, more than doubling today's total." That's a lot of cars needing a lot of plastics.

There is also increasing interest in the strength and safety qualities of automotive plastics, highlighted by the development of heavily plastics- and composite-reliant aeroplanes. Plastics also offer significantly increased design and engineering flexibility over metals and glass, while impact-resistant and lighter weight plastics/composite materials offer better passenger protection and safety.

But what, you may ask, does this mean for the C6 chain specifically?

Well, at Shell we estimate that the proportion of C6 value chain products going into the automotive sector is currently around 15% globally, with virtually no difference between the regions.

A good example of a benzene-derived product that is winning a bigger share of the weight and performance market is polycarbonate.

Polycarbonate in Automotive & Construction (slide 5, page 15)

Already the largest volume engineering plastic, polycarbonate has enjoyed strong demand growth due to its combination of strength, light weight, thermal stability and – for some applications – excellent polymer clarity.

Global polycarbonate demand hit 3 million tonnes in 2009, and is growing at 6%/year.

Although demand growth in CDs and optical media has slowed, applications in automotive components, electronics and sheeting/film are increasing rapidly.

Automotive glazing demand is growing particularly fast. Polycarbonate is already used in headlamp, fog lamp and tailgate lenses, roof modules and fixed side windows in cars and trucks.

Development of scratch-resistant multi-layer polycarbonates is expected to drive wider use in both automotive and construction sector applications. PC offers weight savings over glass, more design options and much easier handling.

Some manufacturers are using polycarbonate rear windows, and are optimistic that it may soon be used in windscreens. It is already widely used in motorcycle windshields due to light weight and safety factors.

I'll come back to polycarbonate later on when I talk about Shell's strategy for aromatics. For now, the message is that there are good on-going demand prospects for the C6 value chain, but the players along the value chain will need to work together to develop the products that take advantage of the performance and design properties of C6-based products, and particularly those addressing solutions for a low-carbon future.

There are others reasons to look on the bright side.

Substitution of PS by PP seems to have reached a plateau, and estimates suggest global styrene demand will grow around 3% per annum to 2020.

> "…estimates suggest global styrene demand will grow around 3% per annum to 2020."

Reports from Asia confirm that further PS substitution is no longer an issue. There are on-going challenges for PS in North America and Europe, where perhaps up to one third of each market could be vulnerable to PP, but only with increased investment in production capacity for the latter. Substitution is not a threat to construction market-focused PS products – particularly insulation – where long-term demand outlook is good in both new build and refurbishment. There are other uses – such as snap-off multipacks for foods such as yoghurts – where PS is clearly the material of choice.

So, my overall message on C6 demand outlook is that there are reasons for optimism because the styrenic and phenolic products have the properties and potential to meet both low-carbon needs and – with innovation and creativity, which are the defining characteristics for many of our customers – to spread into new applications.

For the period 2011-2014, Shell and CMAI estimate potential annual benzene demand growth of 3.9%, which is underpinned by derivates demand growth, including 3.6% for styrene, 5.1% for cumene/phenol (3.5%) and aniline (4%).

Challenges

Now, having offered reasons for optimism in the long-term demand outlook for the C6 value chain, there are also some challenges.

Let's start with benzene supply and price volatility.

Those unfortunate enough to have heard my 2005 ICIS Aromatics speech may recall me suggesting that two significant on-going issues for the C6 value chain would be benzene supply and price volatility. Time has certainly validated that assertion.

Since around 2005, after the steady closure or mothballing of many of the toluene hydrodealkylation units that once provided "on purpose" production and "swing capacity", benzene output has been mainly determined by gasoline manufacture and naphtha cracking, both of which generate benzene as a by-product.

Before 2005, on-purpose swing capacity could add 20% to other benzene production. Today, it is nominally about 4%, but practically non-existent.

Back in that 2005 speech, I speculated whether the severe reduction in swing capacity would – at some point – create the need for new, on-purpose benzene supply if incremental fatal supply was unavailable. Well, to-date, it hasn't, and the jury is still out on if and when that may happen.

New benzene capacity has come on stream, but only as by-product of other manufacturing processes. In Asia Pacific, new steam crackers and aromatics plants will have added around 4.5 million tonnes of benzene capacity by 2015, while between in the same period the Middle East is expected to have added 1.2 million tonnes, three quarters of which will be refinery derived.

In both North America and Europe, benzene capacity expansion has been limited by the lack of demand growth for ethylene and para-xylene, although some 600,000 tonne/year additional benzene has been released in response to the MSAT regulations, stipulating a reduction in benzene levels in gasoline.

In Central and Eastern Europe, capacity addition is limited as both regions currently have surplus benzene.

Supply of aromatics feed has also been impacted by a number of factors including the shift towards lighter cracker diets, the relatively poor demand for polyolefins through late 2008 and 2009, and falls in gasoline demand. All of these have reduced supply of pygas and reformate.

Current estimates suggest that benzene capacity may rise by just over 2% a year, but annual demand growth will be about 3%.

One of the consequences of the loss of swing capacity is that benzene supply has shown a tendency to very quickly move from short to long or vice versa, depending on demand for olefins and transport fuels.

In combination with high and fluctuating crude prices, the knock-on effect has been to make benzene prices much more volatile.

Price volatility has made life very difficult for all of us throughout the value chain as we try to plan ahead and stay competitive while managing key materials costs that can vary by up to 30% month to month.

One of the ways the industry has dealt with this volatility is by moving away from quarterly pricing to monthly adjustments. While monthly pricing doesn't fully mitigate price volatility, it does afford more rapid correction to upstream cost drivers such as crude and naphtha prices and enables much more rapid adjustments in cash management.

Another consequence of the trend towards lighter cracker feed-slates is less C4 production, which has impacted butadiene costs for ABS producers.

Earlier this year, European butadiene prices rose higher than ethylene for the first time ever, and US prices jumped by nearly 50% between January and July. In large part, this is due to liquids cracking struggling to compete with ethane-based US and Middle East crackers, cutting availability of butadiene, which is dependent on heavy liquid feedstock. As a result, butadiene is very tight in the US.

To date, increased butadiene prices have however not impacted ABS/SBR demand. There are several reasons for this. Due to its performance and processing properties ABS is not easily substitutable – by alternatives such as PP or high impact PS – and it still has a cost advantage over polycarbonate. Butadiene is also a relatively small cost component of ABS – at about 15%. And finally, ABS end-uses tend to be in high-price products – ranging from automotive parts to musical instruments, golf club heads to luggage – where materials are only a small proportion of total costs.

Another issue impacting the C6 chain is differences in regional ethylene pricing.

Regional C2 issues (slide 6, page 15)

Until two or three years ago, relatively high ethane prices were seriously undermining the competitiveness of US styrene production. However, with a significant fall in ethane costs, US competitiveness has completely turned around, enabling US styrene producers to revitalise some under-used capacity and to export significant tonnages to Europe.

Regional styrene & phenol supply issues (slide 7, page 16)

Globally, styrene is currently long. With CMAI calculating average industry operating rates at 82%, I'm sure we all long for the golden days of 2004, when they were close to 95%.

The good news for styrene is that only between 1-1.5 million tonnes of new capacity is announced to come on stream after 2010, which is equivalent to demand growth for just one year. Operating rates are expected to recover steadily through 2011 and beyond.

Currently, virtually all Middle Eastern styrene is absorbed by Asia Pacific, primarily China, while some European demand is being met by US imports. However, should China ever reach its self-sufficiency target, then low-cost Middle East production could heap pressures on European producers.

Like styrene, phenol has also taken a hammering over the past two years. At one point, global industry average operating rates fell close to 75%, but in 2010 demand has been more buoyant. Over the longer term, phenol demand is expected to grow by around 5% a year, mainly on increased demand for BPA for polycarbonate and epoxy resins. But new capacity coming on stream will mean fierce competition.

HSE-related challenges will require close monitoring. The potential hazards of benzene and its derivatives are known and recognised by industry and regulators alike, but our excellent record of safety and stewardship through production and distribution to downstream manufacturing, and end-use utility, means broad acceptance for the risk management of C6 derivatives.

For the industry, the best response to HSE concerns is to continue our close engagement with ongoing and long-term research into the potential hazards and risks relating to our products. Industry organisations like CEFIC in Europe and ACC in the US play a key role in developing a sound understanding of these hazards and risks and advising on responses the industry should take. Shell fully subscribes to the positions that these organisations have taken in terms of the potential issues related to styrene and other products of the C6 chain. It is essential that we continue to press the case for a science-based response to regulation, and to promote the beneficial societal impacts of our products.

Having looked at some of the challenges and issues facing the C6 chain, I want to provide a brief overview of Shell's aromatics operations and our strategy for remaining competitive at the start of the C6 value chain.

Shell: staying competitive in the C6 chain

Shell global C6 footprint (slide 8, page 16)

As you can see, Shell's global C6 manufacturing network is closely aligned with refining to maximise the oil-chemical advantage.

Our chemicals businesses are focused on upgrading hydrocarbons in close integration with upstream and refining, but we are not involved further down the value chain.

For aromatics, our strategy is quite simple: optimise the integration advantages of being a member of a global energy major. Be a low-cost global producer with world-scale, world-class manufacturing assets, and a leading reliable supplier strengthening long-term relationships with our customers. And finally to continue to target outstanding HSSE performance, including product stewardship, in all our activities.

We all know remaining competitive is essential to sustainable success, so I want to finish by looking at four areas of activity within Shell, because I think they will mirror the industry-wide pursuit of competitiveness.

Let's start with restructuring.

We are already seeing widespread and on-going industry restructuring as some plants – mainly older, small-scale units – are closed, while some long-established players like Dow have sold their businesses or – like BASF – are putting them into new, stand-alone structures.

Shell has been reducing its refining footprint worldwide and we have recently announced plans to close one of our Rheinland crackers by 2012, which will impact aromatics production in Europe. However, with the opening of our new complex in Singapore, we have increased benzene production in Asia Pacific, reflecting demand growth in that region.

Staying competitive: integration & low-cost feedstock (slide 9, page 17)

As I mentioned earlier, Shell has for many years pursued a manufacturing strategy based on **low-cost feedstock and close integration** with upstream and refining activities to optimise both upstream/chemicals and oil/chemicals advantage.

This means concentrating our asset base in major regional hubs to ensure we can optimise feedstock through hydrocarbon upgrading and benefit from on-site integration.

Shell has recently completed its largest-ever petrochemicals investment in Singapore – a new world-scale cracker located on Singapore's Bukom Island and one of the world's largest MEG plants on Jurong Island. The new plants are strategically located to take advantage of existing infrastructure and to ensure that maximum benefits are achieved by integrating the petrochemical site with Shell's largest global refinery on Bukom Island.

Within Shell, we think we have combined most of these advantages at the Moerdijk facility in the Netherlands and at Deer Park, in the USA.

At Moerdijk, the new benzene unit is world-scale, integrated with the cracker, and almost all of the output is consumed on-site in the styrene unit.

At our Deer Park manufacturing hub in the US, we have world-scale phenol production supplied from on-site propylene and benzene feeds. Cumene and phenol-acetone production are also co-located, and we have extensive pipeline distribution to customers.

Finding smarter, more efficient routes to existing products drives **innovation and technology** at Shell. We always seek to enhance production process efficiency, and wherever possible focus development on "game-changing" technologies.

Since introducing our proprietary SMPO production process, Shell has maintained its technology leadership, and we are constantly seeking to boost its competitiveness.

More recently, while pursuing this agenda, Shell technologists in the US and The Netherlands have developed advantaged, phosgene-free process chemistry with the potential to create a more sustainable route to producing diphenyl carbonate, a key raw material for polycarbonates used in everything from space helmets and laptop computers to car headlights and mobile phones. We are currently evaluating the technology with our customers, but the early indications are very positive.

Leadership in HSSE is important to both Shell and to our customers, particularly when transporting and processing potentially hazardous products. Like most of you, Shell is constantly looking to raise performance, reduce our environmental footprint and to co-operate with customers along the supply chain to enhance our overall stewardship of aromatics.

As individual companies and members of the chemical industry, it is essential that we all retain the trust of regulators and society at large. That's why Shell has maintained a high-profile and leadership position in response to the EU's REACH initiative. While accepting that the registration process has been a challenge, I think co-operation within product groups such as aromatics has been exceptional and provides testimony to how seriously we take our responsibilities.

You may also have heard about Shell's efforts to provide better metrics for our own carbon footprint, which we are also sharing with customers on request. There is no doubt that consumers are increasingly interested in the lifecycle carbon footprint of the products they use, and certainly some of the major retail chains are indicating that their purchasing choices are likely to favour suppliers who can track these metrics. Similar trends are also emerging in the automotive sector.

Conclusion

So, as I draw to a close, I hope I have offered a plausible and reasonably upbeat outlook for the C6 value chain.

As the western world emerges from the ravages of recession, we expect to see a sustained upturn in overall demand and an increase in demand for products such as insulating materials and low-weight, high-strength products for the automotive sector that I outlined earlier.

The aromatics value chain will only survive if our customers thrive. So it is imperative that producers' strategies are aligned with the growth strategies of their customers. This could take the form of growing in new markets, assisting in new formulations of products, being proactive in the management of inventories, etc. In short, the value chain needs to be customer focused.

To remain competitive, new and existing capacity will fare best if it has some inherent advantages, such as access to low-cost feedstock, safe and reliable assets, economies of scale, site integration with upstream and downstream plants, and technology and customer linkages.

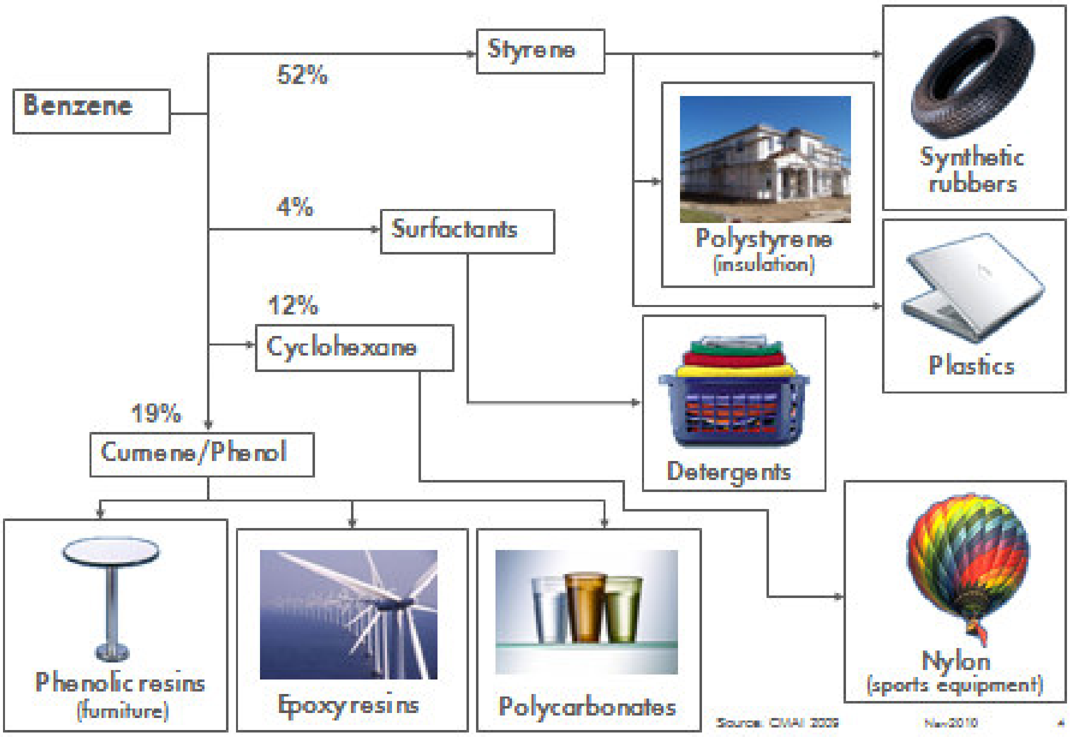
"Shell sees its future as a leading global merchant supplier of benzene, styrene and phenol. "

As far as Shell is concerned, being at the start of the C6 value chain is a logical location for an integrated energy group. Having long since withdrawn from the downstream sector of the C6 value chain, we have no intention of returning. For our joint venture partners and customers who do have downstream businesses, our message is clear: Shell sees its future as a leading global merchant supplier of benzene, styrene and phenol.

As for future C6 investments, well, wherever there's an integrated refinery and petrochemicals complex, there's always an option for more aromatics.

Thank you.

DEMAND DRIVERS: MAIN BENZENE USE FEEDSTOCK FOR STYRENE



Source: CMAI 2009 Nov2010 4

EPS IN PACKAGING AND CONSTRUCTION

Use of EPS in construction (2010-2014 3.67% AAGR in Europe)	**Insulation:** Floor, ceiling and wall insulation, mobile homes **Other:** Floatation devices, road construction, landfills, finishing systems (panels, fences, etc.)    
Other uses (2010-2014 3.82% AAGR in Europe)	Safety helmets, water treatment units 

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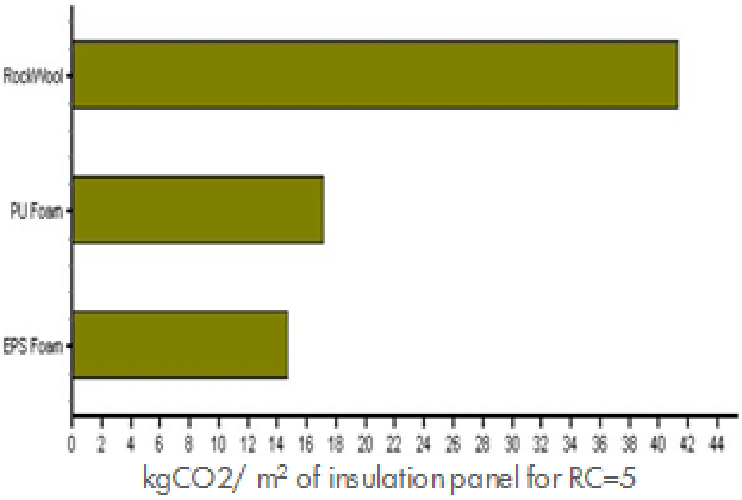
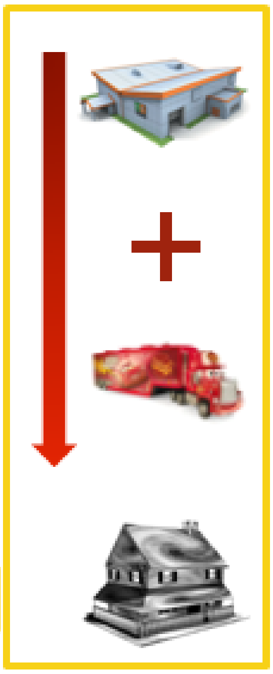
EPS AND PU COMPARE FAVOURABLY TO MINERAL PRODUCTS





The EPS and PU production process (normalised for the same insulation value per m²) results in less than half the carbon footprint compared to Rockwool

Rc=5

Source: Life Cycle Assessment Cradle-to-Gate compliant with ISO 14 040 and 14 044 standard, calculated for Symbro by a life cycle tool developed by Akzo Nobel Sustainable Development group, October 8, 2010
Assumptions: Rc=5, Dutch power footprint, Life time 40 years use, Global Warming Potential years

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C6 AUTOMOTIVE PARTS – THE PLASTIC CAR?

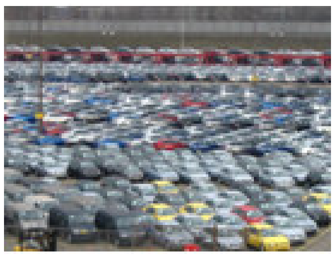
Dramatic increase of plastics and polymer composites in passenger cars -- ACC

1967 ~27kg plastic/car

2007 ~150kg plastic/car

1bln new vehicles will come on to the world's roads from now to 2050 -- Peter Voser, Shell

2050 – How to sustain?!



Distinguished characters of C6 chain products

Strength, lightweight, resistance, insulation, transparency…

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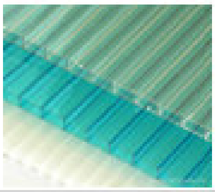
POLYCARBONATE AUTO & CONSTRUCTION USES

Use of polycarbonate in automotive components	**Automotive Glazing** Headlamp, fog lamp, tailgate lenses, roof modules, fixed side windows   
Use of polycarbonate in construction sector	**Construction material** Glazing, Sheeting, Greenhouse, Ceiling....   
Distinguishing characters of PC	Strength, Light Weight, Thermal Stability, excellent Polymer Clarity, etc.

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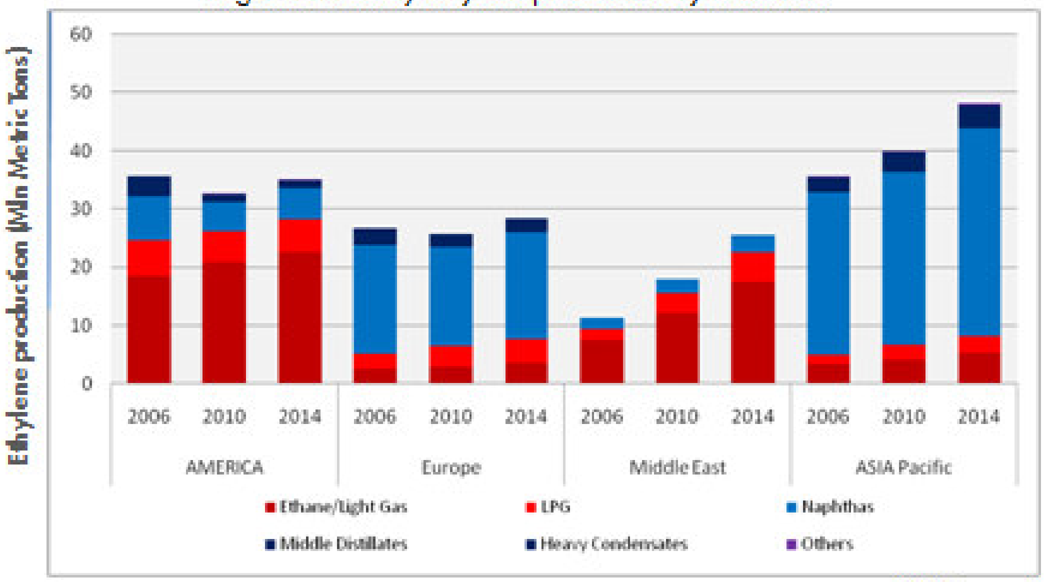
REGIONAL C2 ISSUES

- Liquid cracking to decline to minimum levels in North America
- ME advantaged ethane/LPG investments continue but are not enough

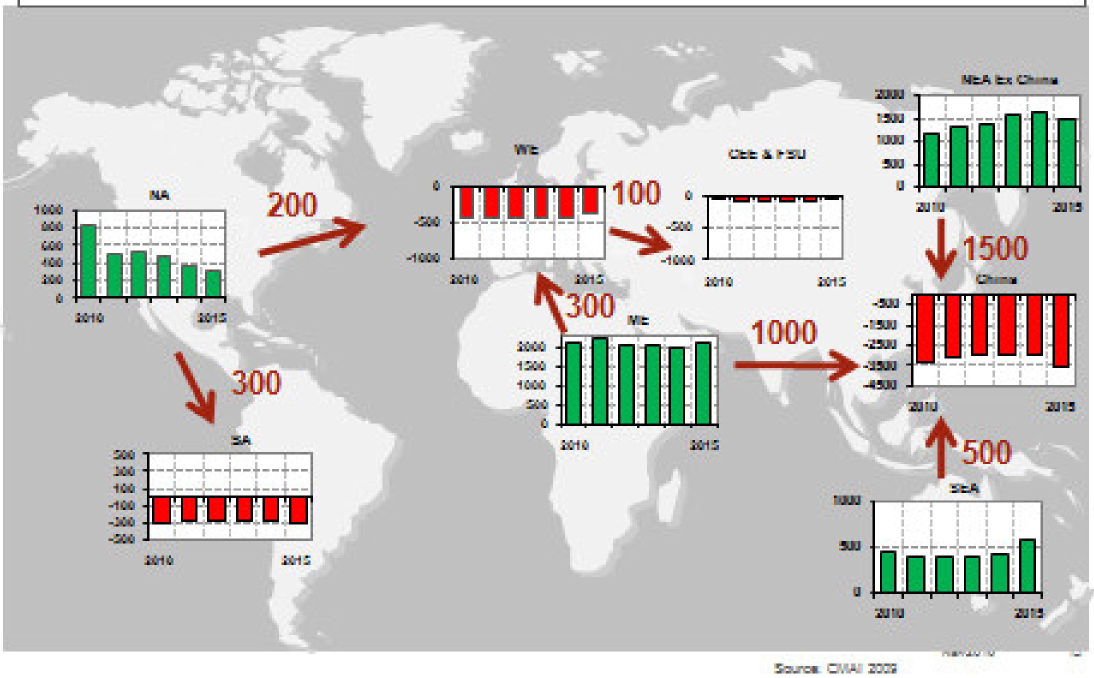
Regional industry ethylene production by feedstock



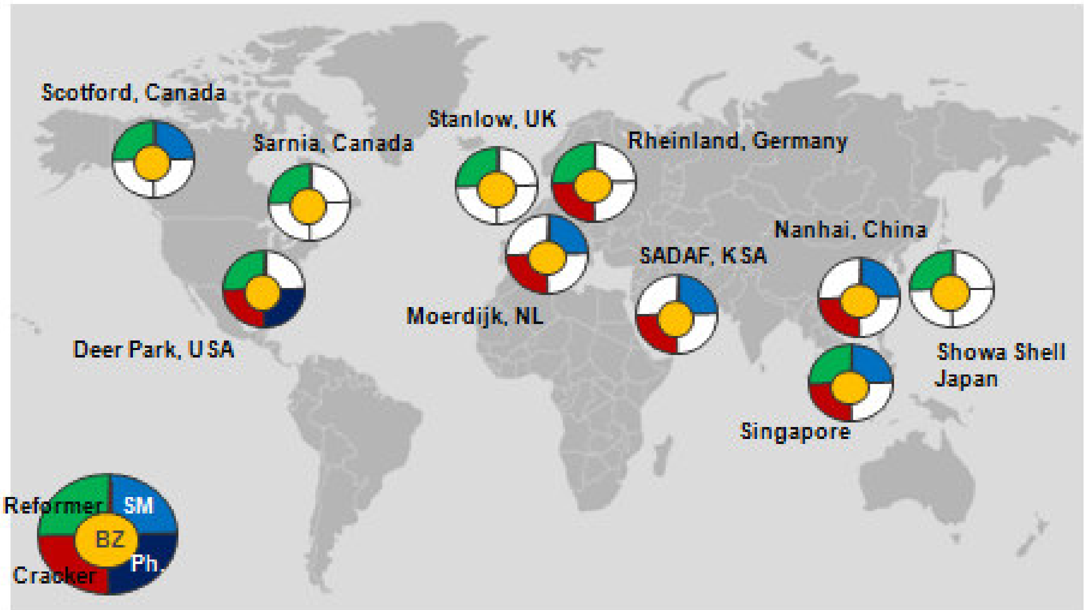
Nov 2010 12

SUPPLY ISSUES FOR STYRENE AND PHENOL

- Lower costs allow NA to export some 200 kta to EU on opportunistic basis



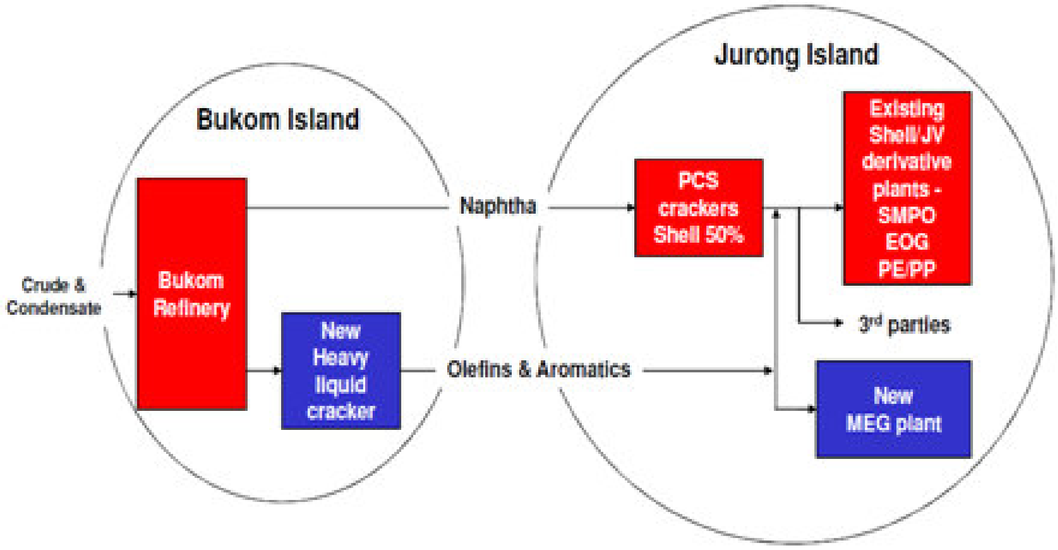
SHELL GLOBAL C6 CHAIN FOOTPRINT



Shell has aromatics units in all regions, with styrene capacities totalling 3 mln tons.

STAYING COMPETITIVE

- Integration and low-cost feedstock



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