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Industrial Gases

Growth Potential Explored: Upgrading Linde To Buy

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- **Linde Upgraded to Buy** — We believe a relative rerating of industrial gas companies is likely to be supported by the superior visibility and quality of their long-term EPS growth potential. However, within these stocks we believe the greatest upside is for Linde, which has the lowest valuation metrics of the group and the highest EM exposure. It is the market leader in four of the growth regions of China, South East Asia, India and Eastern Europe and it is number two in Latin America. Linde should deliver above market EPS growth and an improving ROCE trend. We upgrade Linde to Buy and raise its target price to €140 (from €120) to reflect our upgraded view of the quality of its growth potential.

- **Air Liquide's target price increased to €100** — We see upside to Air Liquide's share price but not of sufficient magnitude to warrant a Buy. We lift our target price to €100 (from €95) to better reflect its growth potential and reiterate our Neutral recommendation.

- **Energy is critical growth driver** — Growing demand for economical, clean energy is a global megatrend, which we expect will be critical driver for industrial gas companies in the medium to long term. High energy costs and the clean fuel drive are creating new markets like coal gasification which consume vast quantities of industrial gases.

- **Emerging markets represent 80% of incremental growth** — Ongoing industrialisation and rising energy costs in most emerging regions means energy conservation and efficiency improvement should be a major source of growth in gas need. Demand from these countries for industrial gases is also driven by the need to develop energy alternatives to crude oil, to improve manufacturing processes and use local energy (very often coal) resources more efficiently. China is a key growth region.

- **Demand should rise at roughly 2x GDP** — driven by Energy and EM megatrends. This pace of growth is consistent with the historical trends of industrial gas market. We estimate the market will be worth c$93bn by 2013, up c26% from 2010 levels, driven mainly by demand from emerging economics.

- **Economic Crisis in Europe likely only to slow growth in 2012** — The European credit crisis will likely adversely impact GDP growth and put pressure on volumes. We expect Linde and Air Liquide to see some adverse consequences so we believe EPS is still set to grow in 2012 but looks likely to be below the longer term trend growth. However, the driving force of the expansion of both companies will be new tonnage schemes starting up mainly to support the energy megatrends and mainly in emerging regions, in our view.

	Rating		Target Price		Current Year Earnings Estimates		Next Year Earnings Estimates	
Ticker	Old	New	Old	New	Old	New	Old	New
AIRP.PA	2	2	€95.00	€100.00	€5.45	€5.45	€5.69	€5.69
LING.DE	2	1	€120.00	€140.00	€7.51	€7.51	€7.99	€8.08

See Appendix A-1 for Analyst Certification, Important Disclosures and non-US research analyst disclosures.

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Industrial Gases: A Structural Growth Market

80% of growth from EM

We have analysed the prospects for industrial gases, which may prove something of a beacon of light in the gathering gloom of developed market economic prospects. Seismic shifts in the way industrial activity is structured are underway. Sustainability, securing energy security and improving energy efficiency are critical factors forcing change and the industrial gas companies are feeling its positive effects on their growth potential. For example, high energy costs are creating new markets like coal gasification which consumes vast quantities of industrial gases and the clean fuel drive is substantially increasing hydrogen demand globally. The opportunities within the energy and environment segments are the primary drivers of growth and we estimate that c.80% of this will come in emerging regions.

Gas stocks look relative safe havens

The continuing reductions to GDP growth estimates for 2012 have increased the downside risk to the outlook for industrial earnings. Within this context, we believe the gas stocks look like relative safe havens. We believe the superior EPS growth of the industrial gas companies will be a differentiating feature of the mid term. Valuations of the gas stocks partly reflect this outlook, but there is an inherent insurance policy in these shares in our view; they should continue to make relative progress even if GDP growth proves to be weaker than expected. We believe this should be a key part of the investment decision as this current cycle matures. We have analysed the past 152 quarters, in which broader markets have given negative return of c5% or more for 19 quarters. In these tough economic times, industrial gases have outperformed the market 13 times, indicating the resilient nature of their business.

Sustainable growth and good visibility

This research, we hope, will show the scale of growth potential available to the industrial gas companies by virtue of the growth resulting from the energy and environment megatrends. The scale and sustainability of this growth appear to be impressive and is written up in detail within the appendix section. It should enable both Air Liquide and Linde to deliver high single-digit EPS growth on average over the next five years, although a slower pace of progress is likely in 2012 due to the European economic crisis.

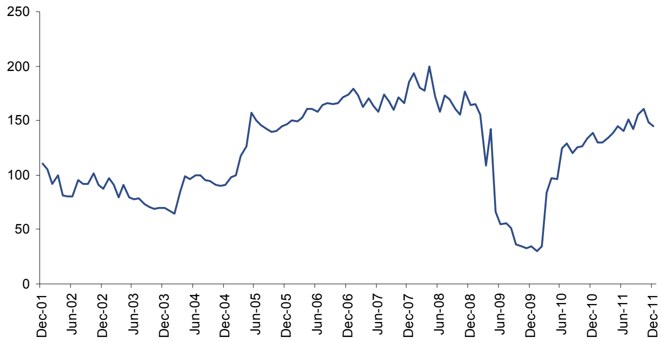
Linde Buy; Air Liquide Neutral

On the back of this research, we have upgraded Linde to Buy (from Neutral) on the back of increased estimates and a higher price target. We have also increased our target price for Air Liquide. The increases are driven by our more positive conviction about the long-term growth potential of the industrial gas space and the ability of these companies to capture this growth. We set this out in considerable detail in the Appendix. Linde is the most lowly valued of the Gases group but is also the market leader in four of the five key growth regions (China, South East Asia, India and Eastern Europe – it is number two in Latin America). The high valuation metrics and higher exposure in European market looks a drag on Air Liquide for time being, thus we remain neutral on stock for next twelve months. We reiterate our positive stances on Praxair (PX.N; US$103.53; 1) and Air Products (APD.N; US$83.22; 1).

Linde Upgraded to Buy

Linde has the lowest valuation metrics of the group, its EPS growth looks competitive, and its ROIC is rising post the BOC acquisition. Our DCF analysis points to the company being worth c.€140, based on a small discount to the price generated by our valuation analysis to reflect the usual risks associated with this sort of analysis. Using the same methodology and approach for Air Liquide, the upside potential was not quite enough to warrant a Buy recommendation.

Figure 1. Air Liquide PE relative to DJ Stoxx, Dec 01-Dec11

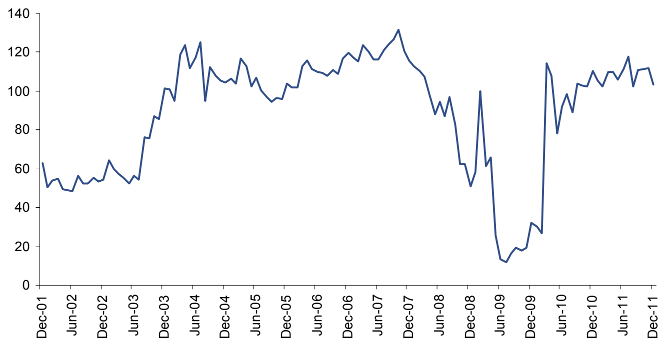


Source: DataStream and Citi Investment Research & Analysis

Figure 2. Linde PE relative to DJ Stoxx, Dec 01-Dec11

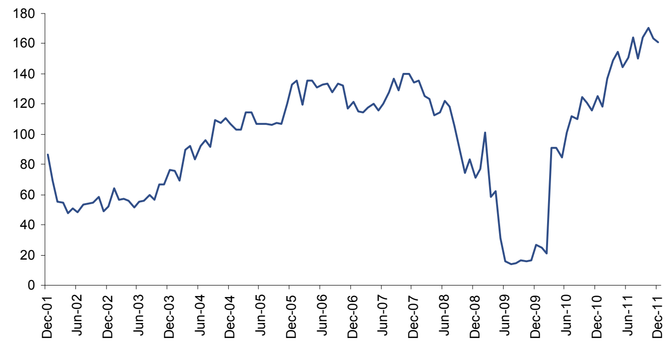
Source: DataStream and Citi Investment Research & Analysis

Figure 3. Air Products PE relative S&P 500, Dec 01-Dec11



Source: DataStream and Citi Investment Research & Analysis

Figure 4. Praxair PE relative to S&P 500, Dec 01-Dec11



Source: DataStream and Citi Investment Research & Analysis

The valuations of these stocks are well above the sector average (of a PE of 15.0x for 2012e), but we see this as fully justified by the superior earnings quality and high volume growth visibility.

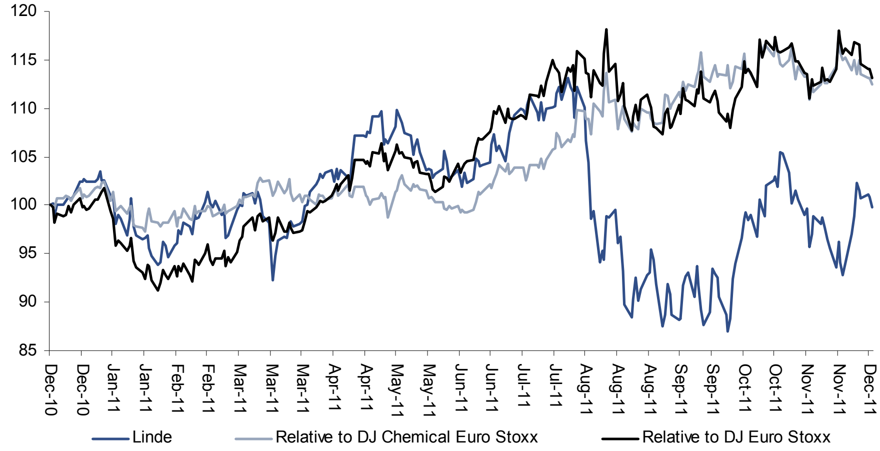
Figure 5. Industrial Gas Companies, 2012E Valuation Metrics

	Air Liquide	Air Prods & Chem	Linde	Praxair	Average
P/E	16.0x	13.3x	13.6x	16.9x	**15.0x**
EV/Sales	2.1x	2.2x	1.6x	3.1x	**2.2x**
EV/EBITDA	8.3x	9.0x	7.3x	9.9x	**8.6x**
NOPLAT	1869	1242	1463	2050	**1656**
EV/NOPLAT	16.7x	19.4x	16.1x	18.8x	**17.7x**
EV/CE	2.3x	2.2x	2.1x	2.5x	**2.3x**
FCF yield	3.9%	2.3%	5.6%	2.9%	**3.7%**
Div yield	3.0%	3.1%	2.2%	2.1%	**2.6%**
ROCE	13.9%	11.1%	13.3%	13.2%	**12.9%**

Source: Citi Investment Research and Analysis, as at Dec 08 2011

Indeed, the deepening macro credit crisis in Europe and the impact of high energy prices point to a potentially significant challenge to the earnings outlook generally. The Gas companies would be somewhat exposed to these macro factors, but to an extent well below the market average due to the contractual nature of the business and the secular growth drivers (and new contracts set to come on stream by all four players in 2012).

Figure 6. Linde Share price and relative in past year



Source: DataStream

The shares have outperformed the Chemicals sector and European markets by c13% over the past year. The volatility of its share price has been below the market average since the “sub-prime” crisis emerged in the summer of 2008.

With below-average valuation metrics, upside potential versus our DCF-based view of its fair value, and competitive earnings growth potential, we believe the shares have above-average performance prospects over the next twelve months.

Target Price for Air Liquide increased to €100

Air Liquide’s valuation is higher (see Figure 5) than that for Linde and we see slightly lower EPS growth over the medium term. While the long-term growth drivers mean we can be more confident about its potential and believe this warrants a higher target price, given the already high valuation, the upside we see is not quite consistent with a Buy rating.

Key Growth Drivers: Energy and EM

Clean fuels, energy, electronics and healthcare are main drivers

Environmental and economical energy (clean fuels, lower emissions from industrial processes, lowering unit energy consumption by increasing fuel efficiency, etc.) are medium to long-term key drivers of demand. Healthcare and electronics too remain significant factors contributing to growth for this sub-sector. Asia has also been a key driver. All of these have long been discussed and contribute to our confidence that the industrial gas players are able to deliver consistent (currency adjusted) EPS growth. We explore these growth drivers in detail in the Appendix. It is this review of the markets and the strong demand for gases that the need for clean and secure energy creates that underpins our confidence in the growth of the Gases sub-sector.

EM growth should ensure gases demand rises by 2x GDP

Emerging markets are set to dominate growth in the next five years, evident from their GDP growth rates (c.6% vs c.3% global growth rate, i.e. c.2x global growth). Demand from these countries for industrial gases is driven by the need to develop energy alternatives to crude oil, boost energy efficiency, improve manufacturing processes, reduce the impact of industrial activity on the environment and the need to use available energy (very often coal) resources more efficiently. In other words, our analysis indicates that we can be confident that the demand for industrial gases and services will increase by about 2x GDP for the next five years, driven by needs in emerging markets.

Rerating potential greatest for Linde

For developed nations, we believe growth will be delinked to GDP as healthcare and environmental concerns will be the driving force in these regions. Furthermore, beyond our current forecasting period (the next five years), there is a good chance that the pace of growth will accelerate, and possibly significantly so, driven by clean fuel initiatives and carbon sequestration. While this is hard to quantify, the long-term sustainability of the growth potential is a key positive factor for sentiment towards the gas stocks. A rerating of these companies is possible supported by the superior visibility and quality of long-term EPS growth potential. However, **within these stocks we believe the greatest rerating potential is for Linde**.

Oxygen and hydrogen are growth engines

Demand for **oxygen and hydrogen** is expected to be key driver for industrial gas companies for this decade driven by megatrends of **growing clean energy requirements and emerging region industrialisation**. Hydrogen to ensure clean fuels is also a key driver. **Energy economics**, driven by rising energy prices and increasing disparity between oil and coal, is a major contributor of current demand growth as very large coal-to-fuels and coal-to-chemicals projects are built, mainly in China. Industrialisation of emerging markets, driven by sectors like steel, metal fabrication and petrochemicals, will continue to create growth opportunities. Healthcare is expected to drive demand for developed nations with the increasingly ageing population of Europe and increasing obesity levels worldwide.

Outsourcing trends to continue

Another important aspect of this demand trend is growth in large scale business which is tonnage based on long-term take-or-pay contracts. Large scale industries have the option to espouse captive gas plants or can outsource this to industrial gas companies, which maintain and operate the plants and provide gas under long-term contracts. We believe the **outsourcing trend will continue, with the Middle East and China the prime locations where change is underway**. The increasing cost of capital and need to focus on core businesses are encouraging customers to outsource large-scale needs to industrial gas producers.

1. Hydrogen — Double-digit growth to continue

Environmental legislation and the rising proportion of heavier crudes as a proportion of global supply are creating hydrogen demand

The most important end use for hydrogen that the industrial gas companies serve is its use in upgrading fuel by the refining industry. Throughout the refining process, hydrogen is both produced and consumed. The applications are reducing the sulphur content in fuels **(environmental megatrend)** and increasing the proportion of petrol/gasoline from heavy crudes **(energy economics)**. The US accounts for c63% of market share while the rest of the demand is from Europe and Asia. While the market for hydrogen is expected to grow by **c7%-8% CAGR**, we expect the industrial gas companies' share of this market **will double** as additional hydrogen demand will be **increasingly outsourced.** Currently c15% of Hydrogen demand is met through merchant hydrogen, up from c11% in 2005. We believe total **outsourcing** for the industry will increase to **c22%** by 2015. This should result in market growth for industrial gases at c**15%** CAGR 2010-15e.

Figure 7. Hydrogen Production- Tcf/yr

	2005	2010	2015e	CAGR 2010-15e
Worldwide Hydrogen Production[1]	**9.6**	**13.0**	**18.7**	**7.5%**
Worldwide Merchant Production	1.0	2.0	4.0	15.1%
% outsourced	10.8%	15.4%	21.6%	
U.S. Hydrogen Production	**6.4**	**8.4**	**11.2**	**6.0%**
U.S. Merchant Production	0.7	1.3	2.2	12.3%
% outsourced	10.3%	15.0%	20.0%	
RoW Hydrogen Production	**3.2**	**4.7**	**8.2**	**12.0%**
U.S. Merchant Production	0.4	0.8	1.8	19.2%
% outsourced	11.7%	16.1%	22.0%	

Source: Hydrogen Analysis Resource Center, Citi Investment Research and Analysis; 1)-Excludes hydrogen production from syngas, byproduct gases, and on-site plants not owned and operated by the end-user.

Key points we considered for calculation growth prospects for hydrogen:

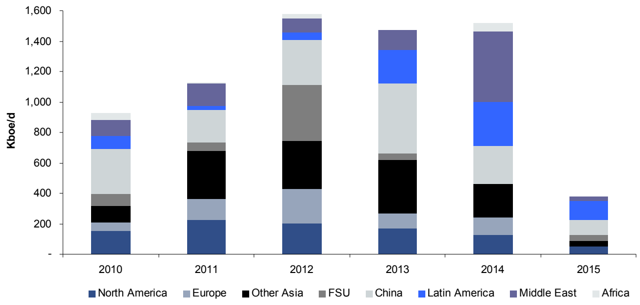
- **Heavy oil arbitrage:** On average, heavy crude is c15% cheaper than premium light crude like Brent. Combined with low natural gas prices in US, upgrading a heavy bbl using hydrogen can add c$10/bbl to gross margins of refineries. Valero is already upgrading its capacities in 2013; we believe other companies will follow.

IEA estimates c6mb/d of upgrade capacity and c6.3mb/d of desulphurisation capacity will be added in next five years

- **Increasing heavy and sour crude slate:** World crude slate is increasingly becoming heavier. To process this crude, new upgrading capacities will be required which the IEA forecasts will be around c6mb/d (c6% of total refinery capacity worldwide). We believe this megatrend can increase demand for **merchant hydrogen by c3.8bcf/d** (c70% of existing merchant hydrogen market).

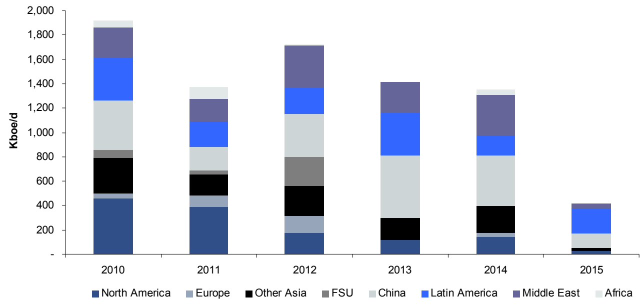
- **Stringent emission norms:** Automobile emission controls are increasingly becoming stringent with increasing focus on environment. The IEA forecasts c6.3mb/d of additional hydrotreating capacity will come on-stream in the next five years. We estimate that this megatrend can increase demand for **merchant hydrogen by c1.1bcf/d**. (c20% of existing merchant hydrogen market).

Figure 8. Upgrading Capacity Additions



Source: IEA, Citi Investment Research and Analysis

Figure 9. Desulphurisation Capacity Additions



Source: IEA, Citi Investment Research and Analysis

2. Steel — Asian demand and capacity upgrades

The Chinese government plans to consolidate the fragmented Chinese market by achieving 70% of its domestic production through China's top 10 mills by 2020. This will involve closure of c26mn tonnes of old, inefficient plants and replacing them with new efficient capacity. While underlying demand for steel industry from emerging markets is c5.3%, we believe China efficiency will drive demand for oxygen at a much faster pace, delivering **c8%-12% annual** growth for next five years. This is effectively all tonnage business, so it very high quality no matter how economies develop over the period.

Apart from new additions, industrial gas companies are also gaining share in old captive market

Apart from Chinese demand, India is increasing becoming an important market for steel. With growing infrastructure demand, India is looking to add large scale capacities. Air Liquide and **Linde in particular** are front runners in Indian market, with major projects lined up in next 2-3 years. Most of the projects involve long-term supply contracts, thus building a long-term business for industrial gas companies. For example, Linde stuck a deal with Tata Steel to supply a new ASU and also **acquire its old plants** for a long-term supply and maintenance contract.

Figure 10. Major ASU projects for steel industry undertaken by Air Liquide and Linde in emerging markets

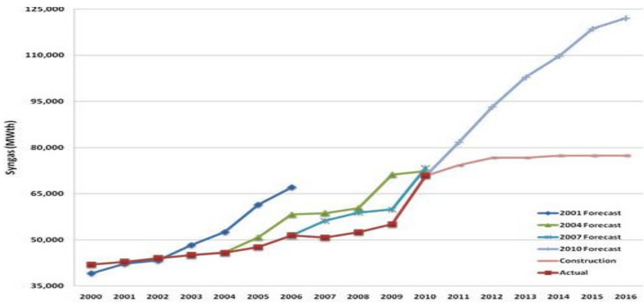
Company	Region	Steel grouo	ASU capacity - TPD	Capex - €Mn	Startup	Description
Air Liquide	China	Bohai Steel Group	2200	55	Q2 2011	Long-term contract with Bohai to supply oxygen to its plant in Hebei province
Air Liquide	China	Jianbang Group	800	20	Q2 2011	Long-term contract with Jianbang Group to supply oxygen to its plant in Shanxi Province
Air Liquide	China	Dongnei group	800	25	Q3 2011	Extension of contract signed with Dongnei Group in 2007
Air Liquide	Russia	Severstal	2000	50	Q4 2011	Air Liquide in JV with Severstal to upgrade capacity based at Cherevopets. It will bring the total production capacity of ASU on this site to 5,000 tpd
Air Liquide	China	Xilin Steel Group	1200	40	Q1 2012	Strategic investment into leading northeastern industrial region of China
Air Liquide	India	RINL	1800	70	Q4 2012	Long-term contract with RINL for its steel plant expansion from 3 to 6.3mn tonnes. Air Liquide also will produce other liquid gases from this plant to meet the needs of the industrial and medical customers in the region.
Air Liquide	Ukraine	Metinvest	1700	100	Q2 2014	Long-term contract with Metinvest for its I&SW facility in the Donetsk region. Air Liquide will also supply liquid gases to other industries in Ukraine
Linde	Kazakhstan	ArcelorMittal	2000	95	Q2 2012	Long-term contract with ArcelorMittal Temirtau to supply the Temirtau steelworks with oxygen and nitrogen gas
Linde	India	Tata Steel	2550	90	Q4 2012	One of the largest ASU for Tata steel plant in Jamshedpur. Under contract, Linde will acquire the existing ASUs of TATA Group (c1475tpd)
Linde	India	SAIL	1706	72	Q4 2012	BOC India (Linde Group subsidiary) will supply 2600 tpd by installing 2 ASU at the site. BOC will also produce nearly 400 tonnes of additional liquid products for local industrial demand
Linde	Indonesia	Posco	3000	88	Q4 2013	To supply 2000 tpd of oxygen for 3mn MT steel plant in the Celegon area, west of Jakarta. Linde will also supply liquid products for industrial demand

Source: Citi Investment Research and Analysis, press releases and other web sources

3. Gasification — Coal economics to drive demand

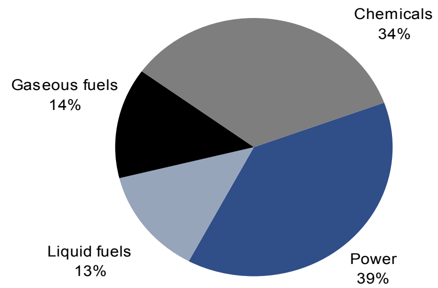
The gasification market is one of the most important growth drivers for industrial gases. Coal to chemicals and coal to liquids have increasingly become commercially viable in the US and China, driven by cheap coal versus crude oil. We believe the market for ASU plants alone will be **around c€3.5-€4.8bn** in next five years. Moreover, an increase in carrier gas demand in emerging markets provides a good expansion base for industrial gas companies for specialty gases, which we forecast will grow at c9% CAGR 2011-15e.

Figure 11. World gasification planned growth forecast



Source: US DoE

Figure 12. Planned capacity by product and end use



Source: Citi Investment Research and Analysis, DOE

In the longer term we believe coal gasification for power plants may become the most important growth driver for industrial gas companies. Currently power plants account for c40% of total gasification projects lined up in next five years, despite the fact that these power projects are not commercially viable. Most of these projects forms part of environment research study and demonstrate new technologies developed in the field of carbon capture and sequestration (CCS). Industrial gas companies in alliance with various government agencies are putting efforts into various research to commercialise coal gasification techniques for power plants. This includes efforts to improve the efficiency and scale of existing ASU technology and new ways to produce cheaper oxygen in large quantities, required for coal gasification. We believe successful commercialisation of this technology will provide a significant opportunity for industrial gases. Just to give an idea of scale, if c10% of existing coal-based power generation capacity is converted to oxy-combustion, it would require **c1,450 new ASUs** with an average capacity of 3000tpd of oxygen (or about 30x the current capacity of the global oxygen leader, Air Liquide).

4. Electronics — 9% growth p.a. over the next five years

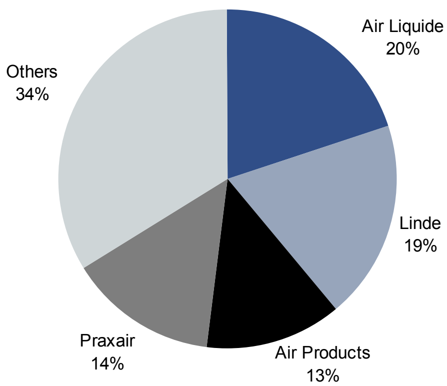
The trend growth for electronics is slowing, but we estimate this will still **average 9% p.a**. over the medium term. The good news is that globalisation, the broadening of applications (away from just PCs and now including LCD panels), and the declining impact of new software innovations in provoking cyclical demand are all leading to less volatility. On the downside, many of the specialty gases are commodity oriented and profitability has been disappointing. However, for the Industrial gas companies the expansion of capacity in Asia, notably in China and Japan (also Korea), has led to a significant increase in carrier gas demand, which should support growth in 2012 and beyond.

5. Geographical presence matters

The industrial gas sector is a highly consolidated market with the top four companies accounting for **c66%** market share worldwide. Linde has been the key driver of this consolidation process for about the last ten years with its acquisitions of Aga in 2000 and BOC in 2006. Air Liquide has also been active, buying Messer assets, increasing its stake in Asian activities, and making several healthcare and engineering acquisitions. The US companies have mostly picked up the pieces that were divested from the merged companies. For example, Praxair acquired part of Messer's German assets and Air Products bought BOC's Polish subsidiary.

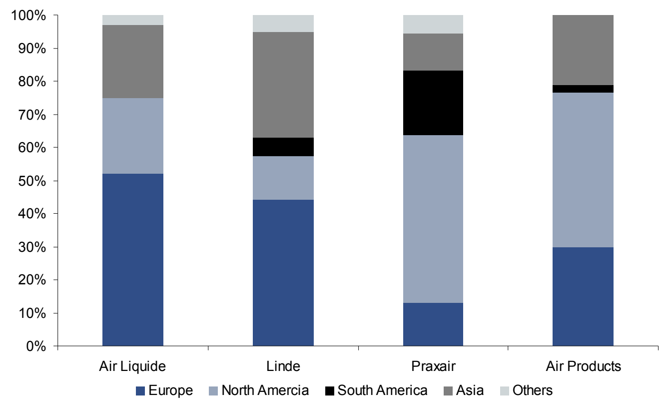
We believe after this consolidation phase, it is time to reap the benefit of consolidation in the form of efficiency/synergy gains and better market exposure. The current turmoil in European markets and stagnant US economy means in these markets growth will likely only come from selected niches that can still grow in challenging conditions, i.e. healthcare and environment. Strong growth is only likely in emerging regions and here the market position of the sector is robust, notably Linde’s. This combination should mean the gases market available to the Gas stocks (the outsourced component) will grow at 2x GDP.

Figure 13. Breakdown of Global Industrial Gas market by producer



Source: Company Reports and Citi Investment Research and Analysis

Figure 14. Geographical breakup of revenue of top four players



Source: Company Reports and Citi Investment Research and Analysis

Playing on the geographical theme, we believe Linde has a key advantage with the highest exposure (c32% of total sales) to Asia among the four big players. From a defensive perspective, Praxair seems to score well with only c13% of sales exposure in Europe. Another important factor for future geographical growth is future capex. We believe the major players are well set to capture growth from these emerging markets. With existing capex levels, we believe industrial gas companies should be able to at least maintain their market share. On this basis, we estimate the industrial gas market should be around c$93 by 2013e, growing at rate of c8.0% CAGR2010-13e.

Figure 15. Sales and Market share of the big four Industrial Gas producers (US$ in Millions)

	2009	2010	2011E	2012E	2013E
Market share of top four	66%	66%	66%	66%	66%
Air Liquide Gas sales	14215	15768	17950	17899	19256
Growth		10.9%	13.8%	-0.3%	7.6%
Linde Gas Sales	12457	13569	15475	15796	16981
Growth		8.9%	14.0%	2.1%	7.5%
Praxair	8956	10116	11331	12534	13861
Growth		13.0%	12.0%	10.6%	10.6%
Air Products	8256	9026	10082	10841	11754
Growth		9.3%	11.7%	7.5%	8.4%
Total Market -USD Mn	**66998**	**74014**	**83088**	**86208**	**93151**
Growth		**10.5%**	**12.3%**	**3.8%**	**8.1%**

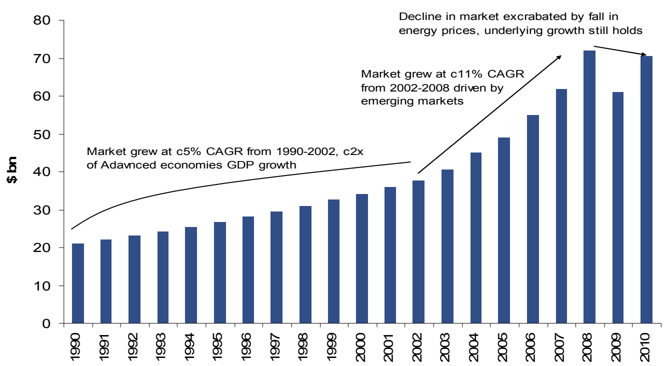
Source: Company reports, Citi Investment Research and Analysis

6. EM supports c.8% compound growth

The industrial gas market has historically grown at 2x GDP. In 1990-2002, industrial gas markets witnessed growth of c5% CAGR, c2x of the advanced economies' GDP. These markets accounted for c90% or more of the sector's growth during this period. From 2002 the focus shifted to emerging markets, with c70% of new growth coming from these markets and c30% of growth witnessed from advanced economies. Thus the industrial gas market grew more rapidly at c11% CAGR 2002-08, capturing the growth of emerging markets and maintaining their c2x relationship with GDP. We estimate the market will be worth c$93bn by 2013, up c26% from 2010 levels, driven by demand from emerging economics.

The strength of the industrial gas market also lies in its broad portfolio of end customers. Developed market growth is oriented around health, hydrogen, environment, hospitality and food (and in Japan electronics). In developing markets, it is focused around metal fabrication, primary metals, electronics and hydrogen. The majority of this addition to market size will be from large scale industries, adding further reliability and stability to future earnings.

Figure 16. Industrial gas market - $ bn



Source: IMF, Citi Investment Research and Analysis

Figure 17. Growth driven by refining, energy and metals

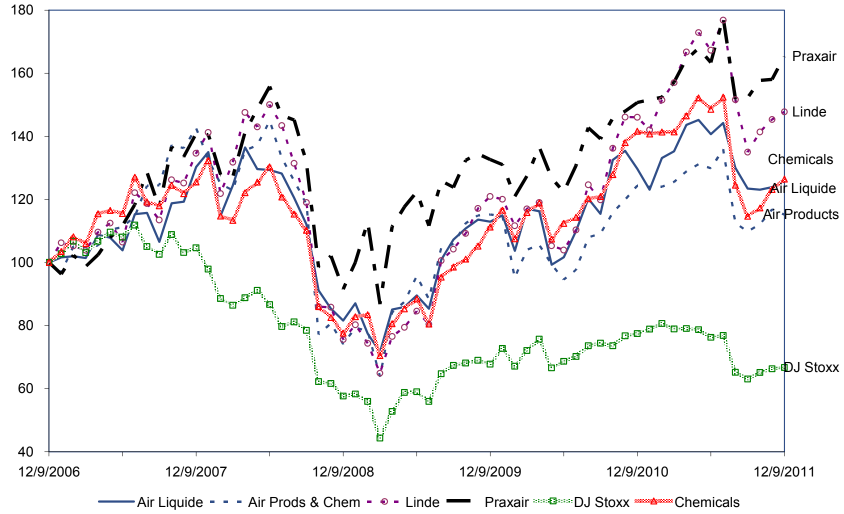
Sector	2010	2015e	CAGR 2010-15e	Component of growth 2010-15e
Metal Fabrication	17000	21000	4.3%	11%
Refining	12000	24000	14.9%	34%
Chemicals	8200	12000	7.9%	11%
Electronics	6300	9700	9.0%	10%
Food	5,700	7,000	4.2%	4%
Healthcare	5,000	6,700	6.0%	5%
Primary metals	8000	12500	9.3%	13%
Gasification	2000	4500	17.6%	7%
Others	6800	8600	4.8%	5%
Total	**71000**	**106000**	**8.3%**	**100%**

Source: Company data, Citi Investment Research and Analysis

Share Price Performance

5-year share performance converted into US$ with Dec 2006=100. Praxair and Linde have been the strongest performers, notably in 1H 2008, followed by sustained recovery from 2009. However, all the stocks have outperformed the index on a five-year view.

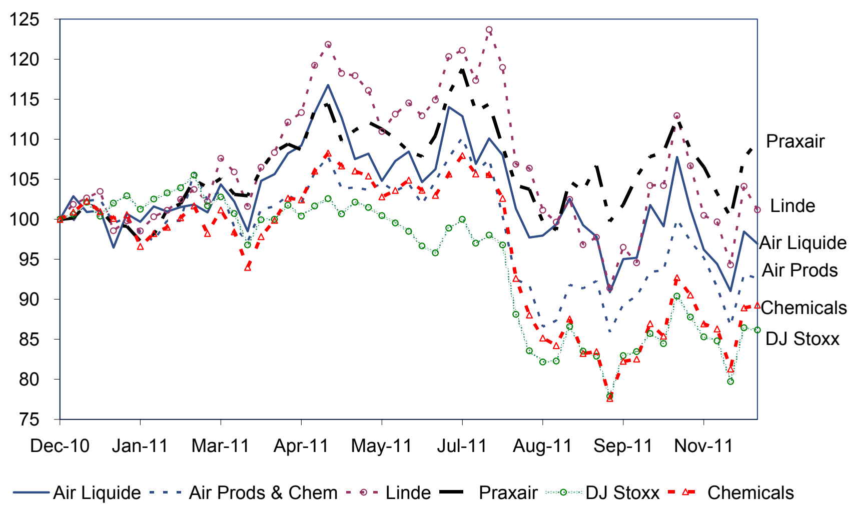
Figure 18. 5-year Share Price Performance (USD: Dec 2006 = 100)



Source: Powered by dataCentral

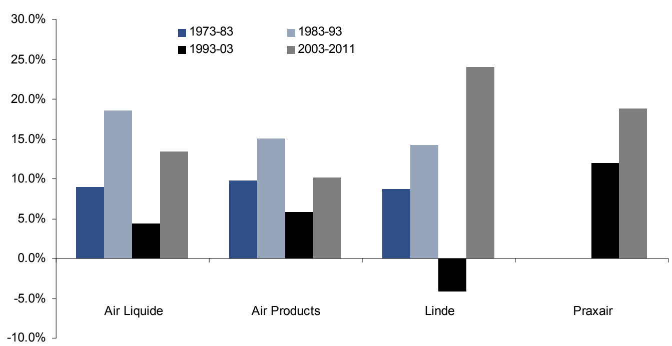
1-year share performance: in US$ and 1y=100. Chemicals have followed index. The relative performance of gas stocks have tended to improve since mid-2011.

Figure 19. 1-year Share Price Performance (USD: Dec 2010 = 100)



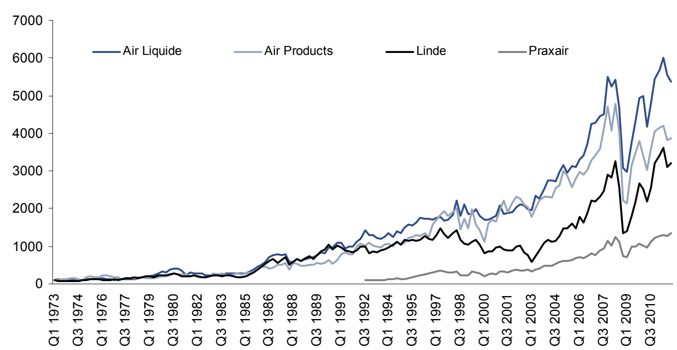
Source: Powered by dataCentral

Figure 20. Annualized return for every 10 year holding period



Source: DataStream, 2003-11 CAGR return is for 8 years

Figure 21. Share Price Performance Since Q1 1973 (rebased to 100 in USD)

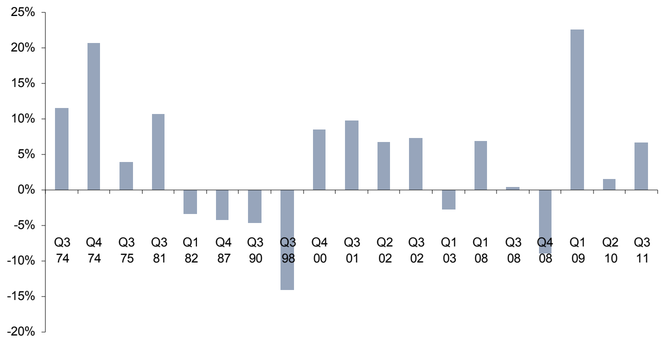


Source: DataStream, Praxair rebased from 1992, its time of listing

Industrial gas companies have consistently generated value for their shareholders and have outperformed broader markets for the last four decades. Their outperformance has been outstanding in recent times, led by Linde and Praxair.

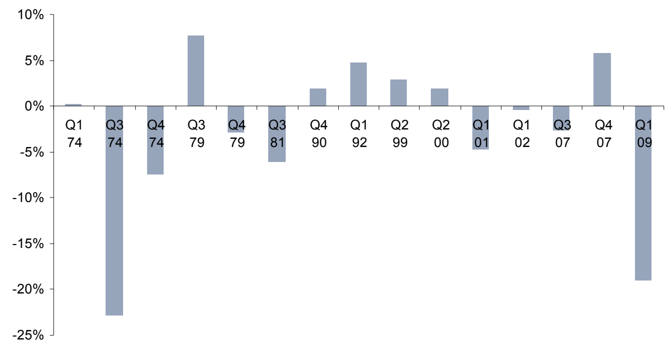
In Figure 22 we highlight that the outperformance of industrial gas shares tends to coincide with periods of marked underperformance of the market. We analysed data for the past 38 years to provide some empirical evidence. Out of past 152 quarters, broader markets have given a negative return of c5% or more for 19 quarters. In these tough economic times, industrial gases have outperformed the market 13 times. Similarly we compare strong outperformance periods (c10% or more) for industrial gas companies and the corresponding performance of the market. Out of 15 such quarters in the past 38 years, broader markets have given negative returns seven times and the average decline of the market was c9%.

Figure 22. Average industrial gas performance during periods of average EU, US market negative returns (-5% or more)



Source: DataStream and Citi Investment Research and Analysis

Figure 23. Average EU, US market performance during periods of industrial gas outperformance (c10% or more)



Source: DataStream and Citi Investment Research and Analysis

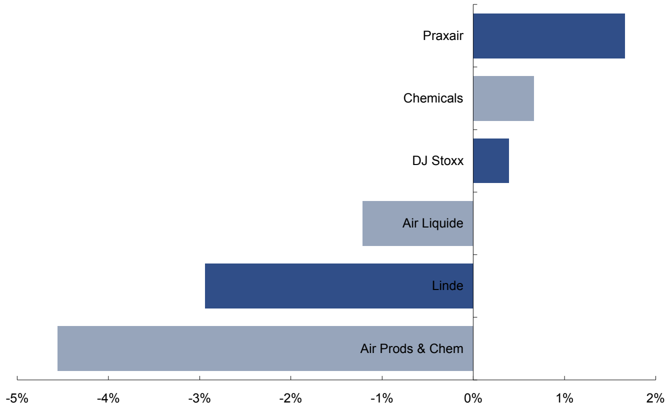
Markets are volatile and generally weak at present, with a negative outlook for 2012. This probably suggests the industrial gas shares have an above-average chance of outperforming.

Figure 24. Periods of Industrial Gases Outperformance and Market negative returns (companies relative outperformance to indices)

Period	Air Liquide	Linde	Praxair	Air Products	Avg EU & US	Comment
Q1 74	34%	9%		23%	0%	Property and Banking Crisis
Q3 74	14%	21%		-1%	-23%	Linde and Air liquide outperformed market strongly
Q4 74	29%	31%		2%	-7%	
Q3 75	5%	13%		-6%	-10%	
Q3 79	16%	15%		7%	8%	Air liquide and Linde outperformed market in recovery mode as well
Q4 79	25%	8%		5%	-3%	
Q3 81	34%	6%		-8%	-6%	Remains defensive sector during high oil price inspired recession
Q1 82	-3%	-5%		-3%	-8%	
Q4 87	-1%	-4%		-8%	-26%	
Q3 90	4%	-9%		-9%	-8%	
Q4 90	10%	8%		18%	2%	
Q1 92	8%	5%		19%	5%	
Q2 92	0%	3%		4%	5%	
Q3 98	-10%	-8%		-17%	-12%	
Q2 99	-1%	7%	44%	27%	3%	
Q2 00	5%	12%	14%	31%	2%	
Q4 00	12%	20%	-5%	7%	-9%	
Q1 01	19%	8%	41%	27%	-5%	
Q2 01	-2%	0%	3%	12%	-4%	
Q3 01	16%	12%	10%	1%	-14%	
Q1 02	8%	13%	11%	8%	0%	Linde and Air Liquide outperform market
Q2 02	8%	7%	2%	9%	-8%	
Q3 02	13%	-7%	16%	7%	-13%	
Q1 03	10%	-17%	0%	-4%	-9%	
Q3 07	4%	9%	9%	18%	-3%	
Q4 07	13%	9%	16%	11%	6%	
Q1 08	10%	12%	5%	0%	-14%	
Q3 08	10%	1%	-2%	-7%	-15%	Industrial gas companies continue to outperform market in last crisis
Q4 08	9%	-13%	-8%	-23%	-34%	
Q1 09	15%	24%	27%	25%	-19%	
Q2 10	1%	6%	2%	-3%	-13%	
Q3 11	16%	7%	5%	-2%	-14%	Industrial gas companies continue to outperform market in current crisis

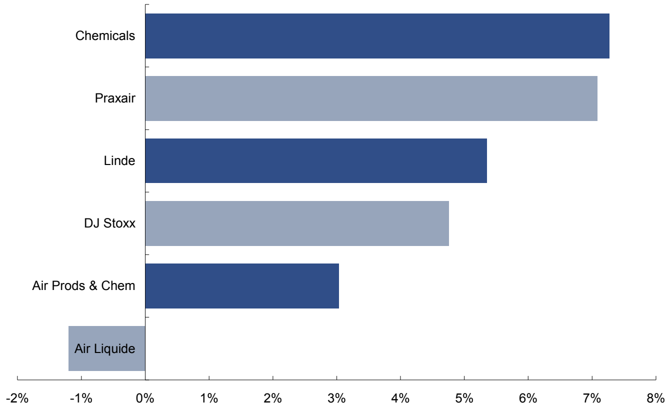
Source: Datastream, Citi Investment Research and Analysis

Figure 25. One-Month – Industrial Gases Performance (in USD)



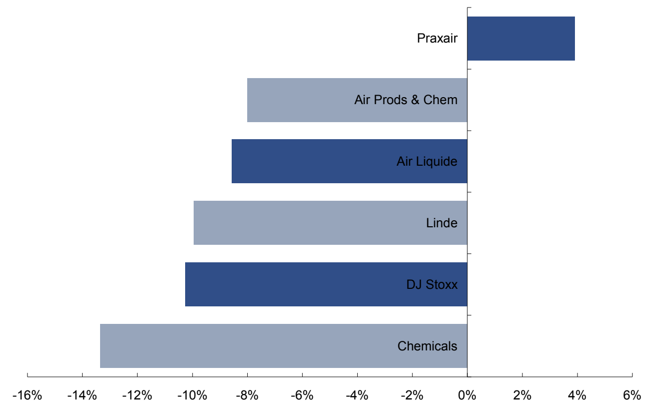
Source: Powered by dataCentral

Figure 26. Three-Month – Industrial Gases Performance (in USD)



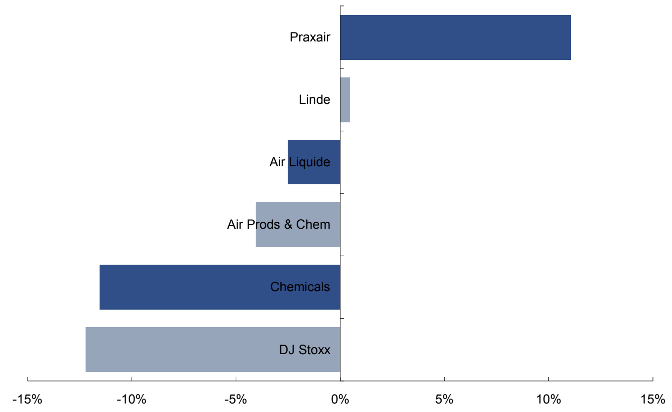
Source: Powered by dataCentral

Figure 27. Six-Month – Industrial Gases Performance (in USD)



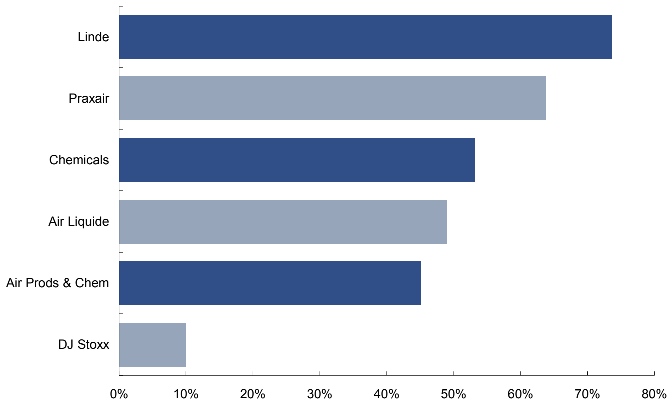
Source: Powered by dataCentral

Figure 28. 1-Year – Industrial Gases Performance (in USD)



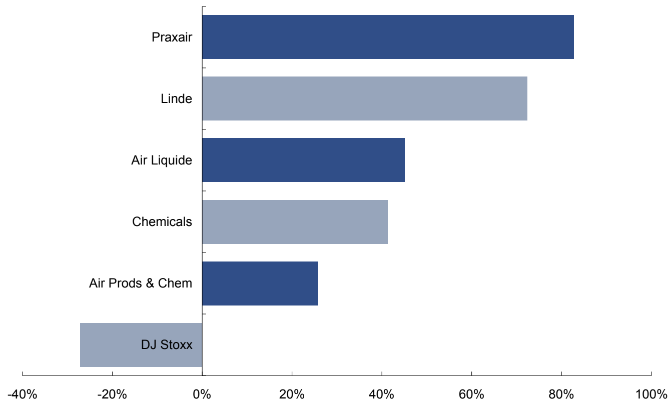
Source: Powered by dataCentral

Figure 29. 3-Year – Industrial Gases Performance (in USD)



Source: Powered by dataCentral

Figure 30. Five-Year – Industrial Gases Performance (in USD)



Source: Powered by dataCentral

Valuation

Valuation comparisons need to be put in the context of profitability. On first look, Air Products looks cheapest on P/E but has relatively low ROCE, thus we believe its lower valuation reflects concerns on profitability. On average, Linde looks the most lowly valued compared with its profitability and growth prospects. On similar terms, Praxair looks expensive (c11% to group on relative basis), with ROCE in line with the group. Air Liquide valuation is broadly in line with the group, but remains the leader in terms of ROCE. We believe its superior profitability prospects should command a premium.

The gases used to trade at a discount to S&P 500 in the 1990s, but now trade at a premium to the market. We believe this premium is justified due to their steady cash flows, high returns and attractive reinvestment opportunities.

- The European Chemical sector trades at a PE for 2012E of 10.4x and the US sector at 11.1x. The gas stocks are at a modest premium to their respective markets.
- Looking at 2012E EV/EBITDA, Europe trades at 6.8x and the US at 6.9x. Here Linde is broadly in line, and the rest are at a modest premium.
- The low FCF yields reflect the high capex of the companies, which is the key underpinning factor behind our growth projections.

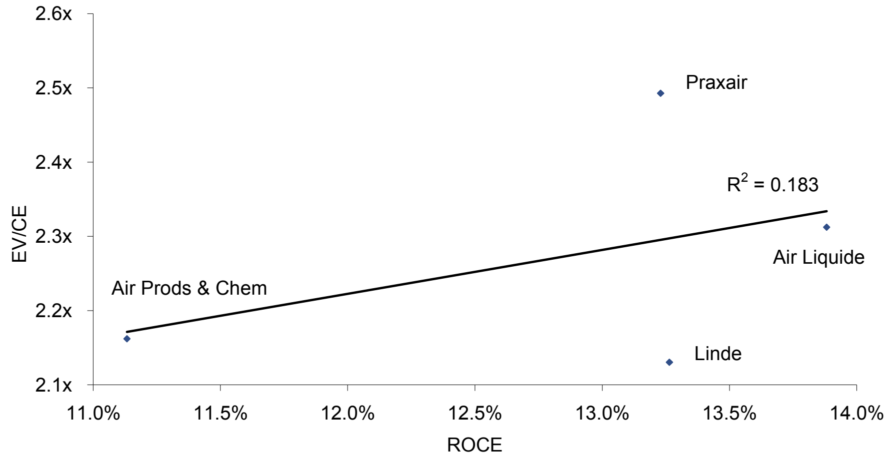
Figure 31. Industrial Gas Companies, 2012E Valuation Metrics

	Air Liquide	Air Prods & Chem	Linde	Praxair	Average
P/E	16.0x	13.3x	13.6x	16.9x	**15.0x**
EV/Sales	2.1x	2.2x	1.6x	3.1x	**2.2x**
EV/EBITDA	8.3x	9.0x	7.3x	9.9x	**8.6x**
NOPLAT	1869	1242	1463	2050	**1656**
EV/NOPLAT	16.7x	19.4x	16.1x	18.8x	**17.7x**
EV/CE	2.3x	2.2x	2.1x	2.5x	**2.3x**
FCF yield	3.9%	2.3%	5.6%	2.9%	**3.7%**
Div yield	3.0%	3.1%	2.2%	2.1%	**2.6%**
ROCE	13.9%	11.1%	13.3%	13.2%	**12.9%**

Source: Citi Investment Research and Analysis, as at 8 Dec 2011

We use EV/CE versus ROCE for a snapshot comparator analysis, but with the denominator the same on both axes, the issue is the relative position on the linear regression line. In this case Linde stands out as the cheapest of the bunch. With only four data points, however, it is wrong to draw too many conclusions from this type of regression analysis.

Figure 32. EV/CE vs ROCE, 2012E



Source: Powered by dataCentral

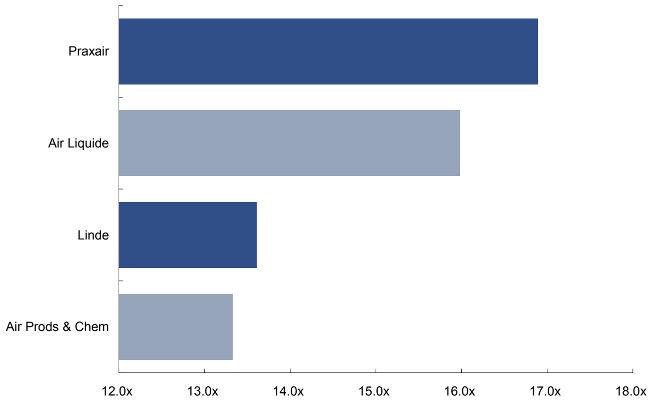
Figure 33. Value per share implied by Line of Best Fit based on 2012E Forecasts (local currency)

	Air Liquide	**Air Prods & Chem**	**Linde**	**Praxair**
ROCE	14%	11%	13%	13%
Valuation on line of best fit of industrial gases	2.3x	2.2x	2.3x	2.3x
Capital employed	13,467	11,157	11,029	15,499
Implied EV	31,429	24,225	25,337	35,574
Debt and Equivalents	5,548	6,736	4,698	6,837
Shares out in 2007	282	212	171	307
Implied value of equity per share	92	83	121	93
Upside to current price	**1%**	**1%**	**10%**	**-10%**

Source: dataCentral

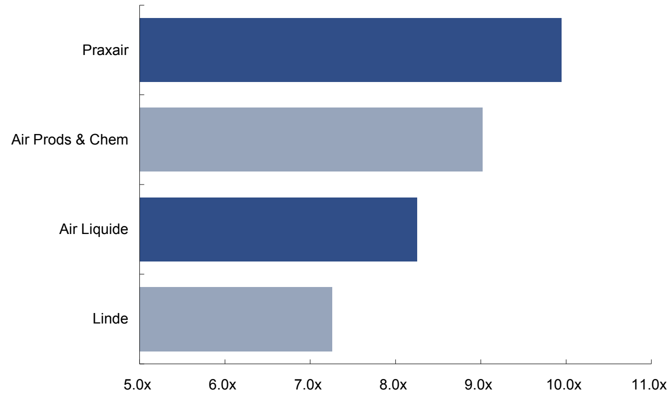
Other Valuation Metrics

Figure 34. 2012E P/E



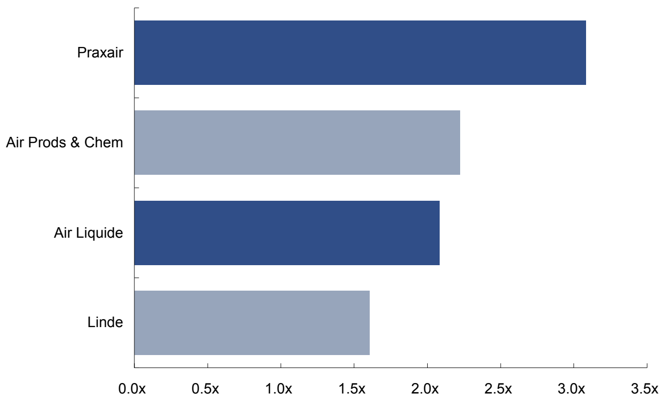
Source: Powered by dataCentral

Figure 35. 2012E EV/EBITDA



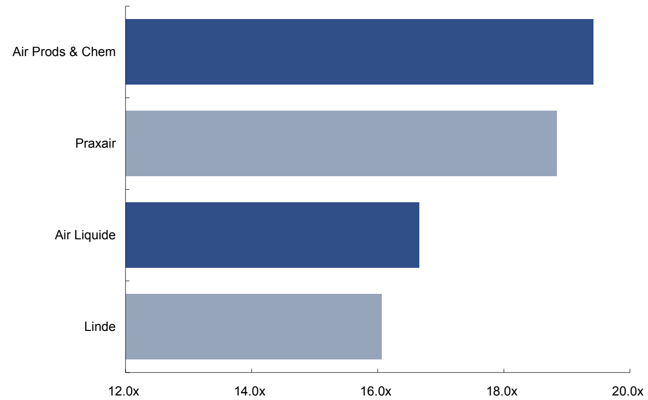
Source: Powered by dataCentral

Figure 36. 2012E EV/Sales



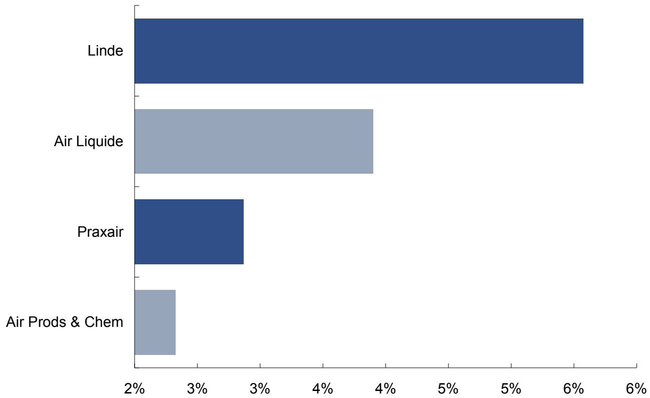
Source: Powered by dataCentral

Figure 37. 2012E EV/NOPLAT



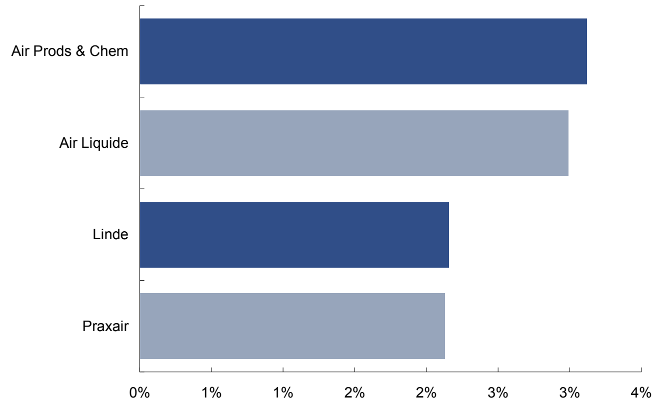
Source: Powered by dataCentral

Figure 38. 2012E FCF Yield



Source: Powered by dataCentral

Figure 39. 2012E Dividend Yield



Source: Powered by dataCentral

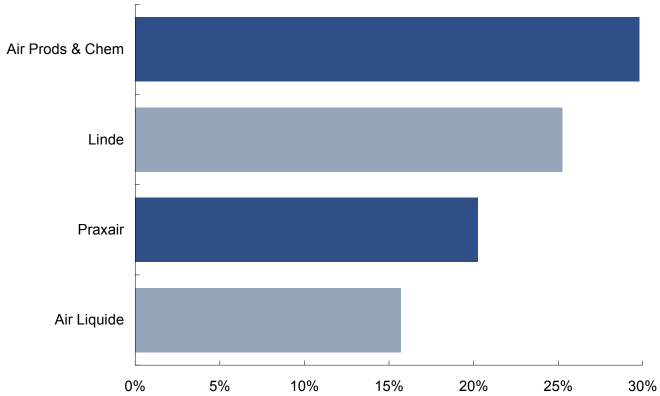
Figure 40. EV Calculation (Local Currency millions)

EV Calculation	Air Liquide	Air Prods & Chem	Linde	Praxair
No of Shares	281	218	170	307.4
Price	90.88	82.20	109.95	103
Market cap	**25,574**	**17,891**	**18,744**	**31,603**
Net Debt	**4,500**	**4,140**	**5,141**	**6,263**
Financial assets	(1,022)	(1,012)	(2,330)	0
Minorities	219	143	552	368
Provisions	1,480	1,679	1,655	0
Preference shares	0	0	0	0
Other adjustments	0	0	0	0
Debt Equivalents	677	810	(123)	368
EV	**30,751**	**22,841**	**23,763**	**38,233**

Source: Company Reports and CIRA Estimates

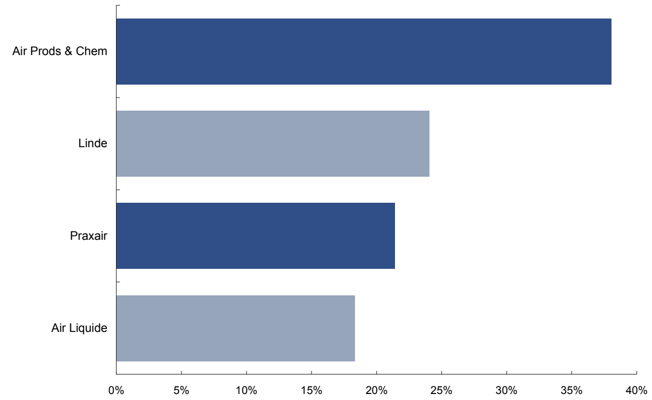
Gearing

Figure 41. Net Debt vs Market Cap, 2012E



Source: CIRA Estimates

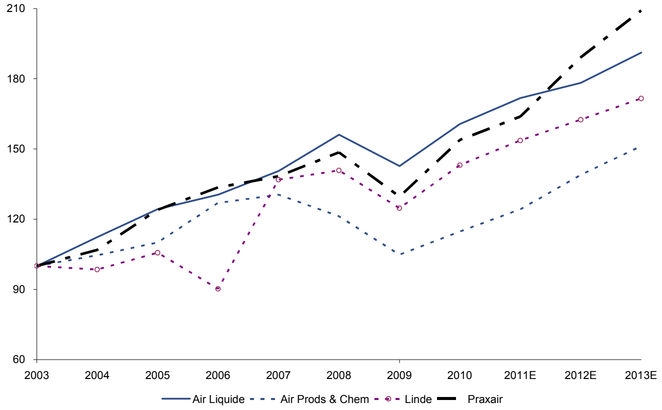
Figure 42. Net Debt + Equivalents vs Market Cap, 2012E



Source: CIRA Estimates

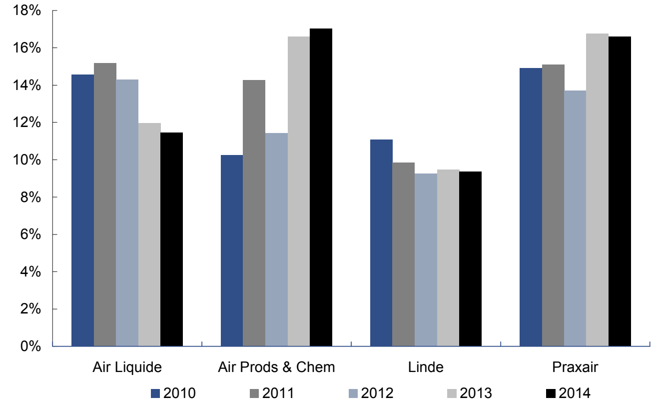
Sales and Capex

Figure 43. Sales Growth, 2003-2013E, 2003 = 100 (changed base year)



Source: Company Reports and CIRA Estimates

Figure 44. Capex to Total Sales, 2010– 2014E



Source: Company Reports and CIRA Estimates

Company Focus

Company Focus

- Company Update
- Rating Change
- Target Price Change
- Estimate Change

Buy	**1**
from Neutral	
Price (09 Dec 11)	€110.60
Target price	€140.00
from €120.00	
Expected share price return	26.6%
Expected dividend yield	1.6%
Expected total return	**28.2%**
Market Cap	€18,909M
	US$25,290M

Price Performance
(RIC: LING.DE, BB: LIN GR)

Linde AG (LING.DE)

Upgraded to Buy

- **Linde upgraded to buy** — We see upside to the share price driven by the growth in earnings over the medium term. While the economic crisis will slow growth in 2012, the expansion of the tonnage and health activities in particular should still lead to EPS increasing about 7% next year. We expect the compound growth to 2014 will be c.9%. If the company achieves its targets, the growth should be c.10% p.a. The growth is underpinned by the scale of demand we outline in the Appendix and the strong geographical footprint Linde has, which enables it to exploit this demand. We raise our target price to €140 to reflect our improved view of growth, which now supports a Buy recommendation (upgraded from Neutral).

- **Leadership in emerging markets** — Linde is the market leader in 4 out of 5 growth markets (China, India, South East Asia and Eastern Europe and is the number two player in South America). It is well placed to capture the growth opportunities in these emerging markets. We expect demand growth in these regions is likely to be in the 10%-12% range for the foreseeable future.

- **Tonnage schemes to drive growth** — Energy and the environment are key growth drivers. Hydrogen for clean fuel in China, coal-to-chemicals projects, again mainly in China, and petrochemicals and enhanced oil recovery in the Middle East provide strong growth opportunities. Its well-established presence in these growth markets appears to have helped it win sufficient contracts to achieve robust growth. We expect these supply contracts will drive mid-term growth.

- **Some slowdown in Engineering expected from 2012** — Engineering is likely to experience a slowdown, with margins cooling off in 2012 due to the maturing of projects secured when markets were weak post the first credit crunch. Linde's competitive advantage in engineering is critical to its expansion in its Gases division, in our view.

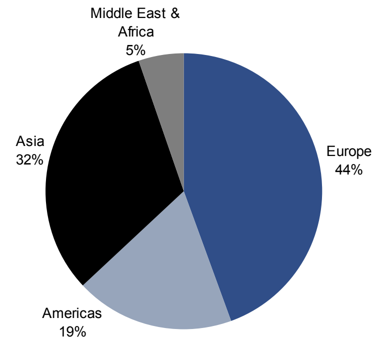
- **Robust financial position** — Linde has a strong balance sheet and it is well placed to fund its growth. The company has delivered on its cost-reduction aims, which is still increasing ROCE, leading to operating free cashflow above its growth needs. We expect it to end 2011 with c.€5.1bn of net debt and a net debt/EBITDA of 1.6x.

- **Buy recommendation** — We have increased our estimates slightly to reflect the strong emerging market growth potential. We have increased our target price to €140 to better reflect the growth and cashflow prospects of the group.

Linde AG (EUR)

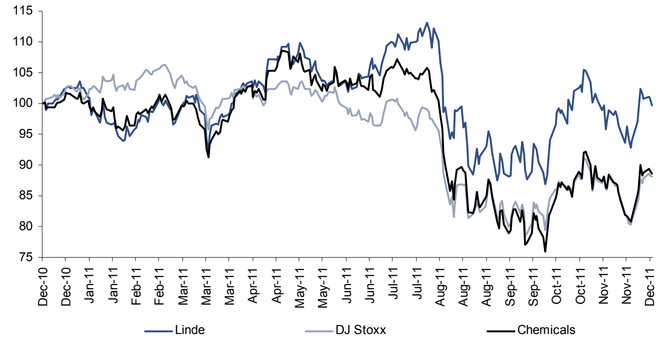
Year to 31 Dec	2009A	2010A	2011E	2012E	2013E
Sales (€M)	11,211.0	12,868.0	13,864.9	14,633.6	15,626.7
Net Income (€M)	854.7	1,153.2	1,280.9	1,381.4	1,509.9
Diluted EPS (€)	5.06	6.81	7.51	8.08	8.81
Diluted EPS (Old) (€)	5.06	6.81	7.51	7.99	8.54
PE (x)	21.9	16.2	14.7	13.7	12.6
EV/EBITDA (x)	10.4	8.7	7.8	7.3	6.8
DPS (€)	1.80	2.00	2.21	2.37	2.59
Net Div Yield (%)	1.6	1.8	2.0	2.1	2.3

Figure 45. Sales by Destination, 2010



Source: Company Reports

Figure 46. Share Price Performance vs DJ Stoxx/Chemicals



Source: Powered by dataCentral

Growth in all regions

Linde pursues solid development in mature regions and achieves strongest momentum in growth markets.

In the 9M11, Linde group sales increased by 8.5% to €10,209m. With an increase of 10.2% to €2,363m operating profit grew stronger than sales. The company registered a continuous strong increase of reported EPS by 21.5% to €5.02 and adjusted EPS by 16.4% to €5.68. For FY2011, Linde looks set to grow sales and operating profit from the levels in the record year of 2010.

Growth momentum is strongest in the Asia/Pacific region with sales increase at 16.2% growth YoY in 9M11.

In the **Gases** division, growth momentum continued; comparable sales increased by 8.1% YoY in 9M11 to €8270m. Growth was strongest in the Tonnage segment with a 9.7% YoY increase in the 9M11 period to €2,015m. Gases operating margin rose to 27.3%. On a regional basis, growth momentum continued in all regions with the Asia/Pacific segment showing highest increase in sales at 16.2% growth YoY in 9M11. The other areas – EMEA and Americas – registered positive growth in sales at 7.0% and 4.6%, respectively. Operating profits across the globe followed similar path with a strongest increase in Asia/Pacific by 14.9% and a slower growth in EMEA (+7.9%) and the Americas (+7.4%).

Operating profit improvement was driven by continuing successful execution of a number of individual projects.

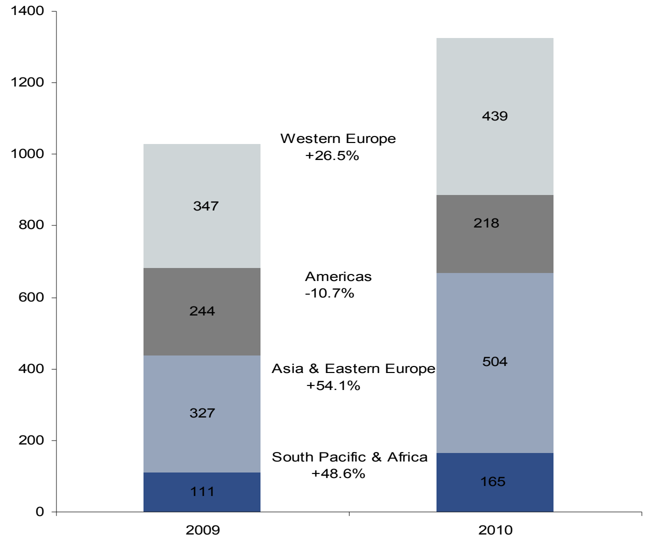
Engineering had a stable performance in the 9M11. The division increased sales by 6.1% YoY to €1,776m and achieved an operating profit growth of 16.3% to €214m, whereas its operating margin improved by 100bp to 12%. The operating profit improvement was driven by continuing successful execution of a number of individual projects. Order intake in 9M11 was €1,676m (+9% YoY), and the backlog remained high at €3,761bn.

Gases well placed to grow

- **70% of revenues come from market share positions in excess of 30%.** Linde is a market leader in 47 of the 75 countries it operates in and is the number two player in another 15. Linde has a market share of more than 40% of the outsourced component of the market in China and Russia and strong positions in South Africa and Central Europe. The major end-customers in 2010 were chemicals with a share of 22%, followed by manufacturing (20%) and metallurgy and glass (15%). As noted earlier, it is also the leader also in Eastern Europe, South East Asia, India and is the no2 player behind Praxair in South America.

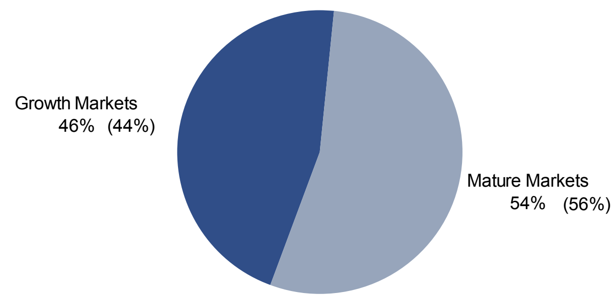
- **Linde is focused on sustaining its leading position in growth markets.** The company's sales in growth markets increased from 26% of total gases sales in 2006 to 33% share of total gases sales in 2010 achieved by disproportionate Capex in these emerging regions.

Figure 47. Split of capex of gases division by markets



Source: Company reports, Citi Investment Research and Analysis

Figure 48. Split of capex by markets – 2010 (2009)



Source: Company reports, Citi Investment Research and Analysis

The results this year are in line with our expectations of increasing industrial gases demand in growth. In investor releases this year, Linde has estimated project **demand growth requiring €24.5bn of capex from China, India, Middle East, South America and South Africa that it plans to pursue.** In comparison, demand in mature markets such as the Americas, Europe and Australia are forecast to rise by €10bn. Linde is market leader in 4 out of the 5 growth markets – Eastern Europe and Middle East, China, South East Asia and India plus the company has a number two position in the South American market. Linde was the first international gases company in China in the 1980s and now employs over 4,000 employees in the country, boasts around 50 wholly-owned companies and JVs and around 150 operational plants. The company serves pillar industries such as chemical, oil and petrochemicals, metallurgy, manufacturing and electronics.

Linde should profit from mega-trend opportunities in the Energy/Environment sector by focusing on better use of fossil resources, renewable energy production and clean energy development.

Linde well placed to exploit the energy/environment mega-trends. We set out in the appendix the growth opportunities that exist in the key gases. These growth drivers will mainly be in emerging regions notably China. Linde looks well placed to exploit these growth drivers given its leading positions in these regions. The company stresses its competitive advantage in engineering know-how and development of equipment. Linde is targeting all the major opportunities including steel modernisation, enhanced oil recovery, renewable energy, hydrogen etc. The photovoltaic and Coal-to-Gas markets are expected to grow rapidly in the long run, although the PV segment is suffering the effects of overcapacity at present.

Figure 49. Carbon capture potential market size projection by Linde

Role	Assumptions	2015	2020	2030
EOR	Single to double-digit number of large N2 EOR/NRU projects Double-digit number of large CO2 EOR projects including Industrial CO2 capture and pipeline (overlapping w/CCS)	€1-€1.5 bn	€4-€5 bn	€18-€35 bn
Carbon Capture & Clean Coal	Triple-digit number of 1 GW Carbon Capture (1.5 Gt/a CO2 at €25-€40/t)	0	0	€30-€50 bn
CO2 networks	Installation of significant pipeline network and corresponding compression (1.5 Gt/a handling fee CO2 at €10-€15/t)	small	€ 1 bn	€15-€25 bn

Source: Linde

Linde has focused its growth strategy partly on ensuring its customers make **better use of fossil resources**. For example, Linde's engineering division has built a plant in Norway for Statoil plant to produce Liquified Natural Gas (LNG). Linde is also now operating a merchant LNG facility in Sweden. There is no natural gas pipeline grid on the Swedish East coast as the government focuses on renewable energy with LNG as a bridge technology.

Linde engineering constructed RECTISOL CO2 wash technology to scrub carbon dioxide, it co-operated with Qatar Shell on its Gas-To-Liquid (GTL) production, and built ASUs for coal gasification in China. Linde Gases division has a tonnage contract with Bayer/SCCC in China to provide coal liquefaction, and in Enhanced Oil&Gas recovery Linde has launched projects in Mexico and Abu Dhabi with Pemex Cantarell and Adnoc Joint Venture. Linde Gases has also signed tonnage contracts for refinery hydrogen with Shell, EMAP, Chevron, CITGO and others.

Linde has undertaken numerous projects in the **renewable energy** sector for developing growth markets. In photovoltaic industry, Linde signed gases contracts for 6GWp of nominal capacity. Linde Gases will develop a choren/sun fuel pilot project in Germany. The engineering division formed a joint venture with Waste Management in 2009 to convert biomass to liquid fuels.

Linde has won a substantial volume of major supply schemes, mainly in emerging markets. These will be major motors of growth over the medium term. The trends for Linde are mirrored generally within this industry group in that the bulk of mid-term growth is from major supply schemes, which is increasing the resilience and visibility of the earnings power of the company.

Figure 50. Major supply schemes on stream or due for commissioning in 2012 and 2013

Customer	Location	Type	End market
ThyssenKrupp	Germany	ASU	Steel
ArcelorMittal	Kazakhstan	ASU	Steel
KNPEMZ	Russia	ASU	Steel
PT	Indonesia	ASU	Steel
Tata Steel	India	ASU	Steel
Yantai Wanhua	China	ASU	Chemicals
PanGas	Switzerland	ASU	Chemicals
MOX-Linde	Malaysia	ASU	Steel and Chemicals
BASF/CCPHC	China	HyCo	Chemicals
Ceylon Oxygen	Sri Lanka	ASU	Healthcare and Chemicals
Topsil	Denmark	ASU	Electronics

Source: Company reports and Citi Investment Research and Analysis

Market environment suggests growth in healthcare sector, which Linde should capture given its scale and global reach.

Healthcare will be a steady growth driver, although European price pressures will impact in 2012. Linde's global medical gas business is the second largest in the world with activities in more than 50 countries with approximately 3,000 employees. Sales in 2011 are likely to reach €1.2bn. Linde expects the additional medical gases market in emerging markets to be €4.2bn by 2020 and estimates that increase in demand will reach €1.2bn in growth markets. There are strong drivers in developed regions, cost containment pressures, ageing populations and the growth of non-communicable diseases. In emerging regions, the growth is driven mainly by the provision of healthcare in the first instance.

Engineering at the height of a boom

Engineering division undertakes numerous projects which will support its consistent performance but a slight decline is expected as projects have been in decline since 2007.

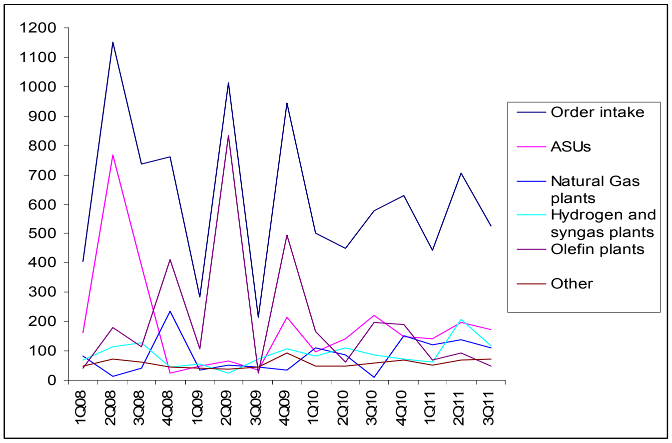
Order intake in 9M11 reached €1,676m and just under half of new orders came from the Asia/Pacific region, whereas a third came from Europe and North America. Over half of the new orders related to the natural gas and air separation plant product areas, while the remainder was distributed across the other plant types.

An example of the growth: the engineering division signed a cooperation agreement with the Thai Oil group PTT to develop a floating natural gas liquefaction plant in Australia. If the gas reserves meet expectations, the project will move into the front-end engineering and design phases by the end of 2011. Commercial production is expected to commence at the end of 2016 if the final investment decision is positive.

In North America, Linde is focused on positioning itself in the promising market for the efficient exploitation of shale gas reserves. The operating margin of the engineering division has been improving strongly, driven by successful execution of individual projects and currently stands above the company's floor level target of 10%.

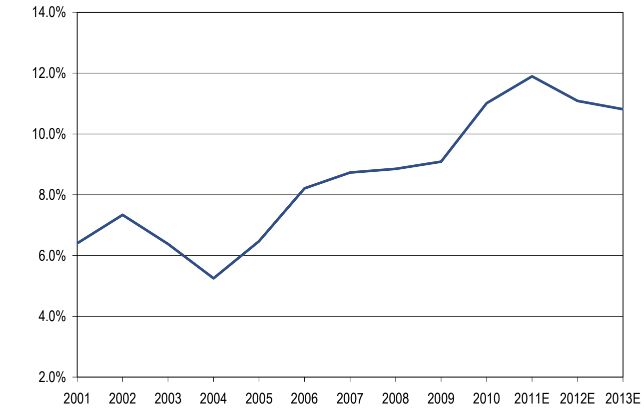
Sales this year are partly from contracts won in 2007/8 when prices were high. The delivery of contracts has tended to come in below budget due to competitive pressures in the supply chain post the crisis. Looking into 2012 and beyond, the sales will likely come from contracts won in far tougher market conditions and procurement costs are tending to increase. The net effect is that we expect margins to come under some pressure over the medium term within the Engineering division.

Figure 51. Linde's Order Intake by Plant Type, 2008-2011



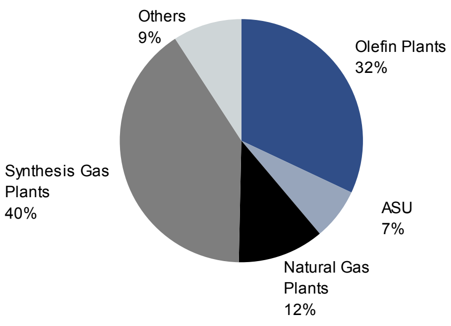
Source: Company reports, Citi Investment Research and Analysis

Figure 52. Linde Engineering EBITDA Margins, 2001-2013E



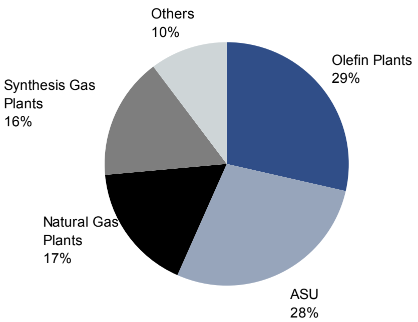
Source: Company reports, Citi Investment Research and Analysis

Figure 53. Breakdown of Linde Engineering Sales



Source: Company Reports

Figure 54. Breakdown of Linde Engineering order intake



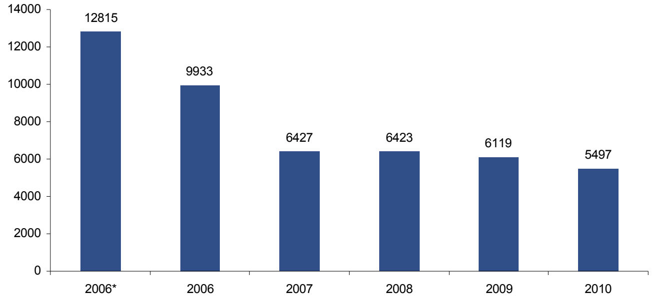
Source: Company Reports

Robust financial position

Linde's cost saving programme in the gases division, HPO, has contributed to significant margin improvements. Since its start in 2009, HPO has resulted in savings of €460m by the year end of 2010. For 2011 Linde has indicated that savings will be in the range of €150-200m and accumulated gross cost savings are expected to reach €650-800m by the end of 2012. Increased efficiency is achieved by sharing best practices and standardising processes throughout the group.

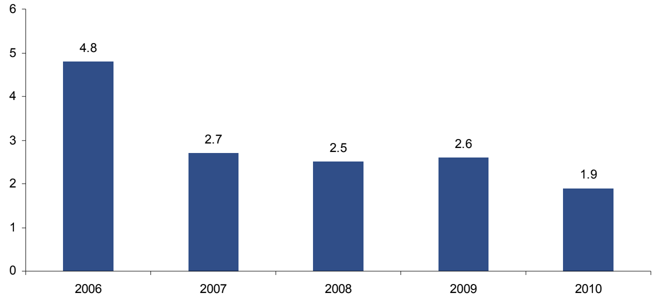
This has helped cash inflows. The robust growth of the business has also contributed. As a result net debt has fallen fairly consistently. We expect it to end 2011 at €5.1bn, generating a net debt to EBITDA multiple of 1.6x. The company looks well placed to support its growth aspirations.

Figure 55. Net Debt - € Mn



Source: Company reports, Citi Investment Research and Analysis

Figure 56. Net Debt/ EBITDA



Source: Company reports, Citi Investment Research and Analysis

9% compound EPS growth with ROCE on rising trend

Strong trading for the first nine months of the year and the defensive nature of its business in general means that we expect Linde to deliver EPS growth of c.10% this year. Linde reconfirmed its goal of higher sales and EBITDA with its 3Q11 results. Productivity gains are on track with the HPO programme, which should deliver total reductions in gross costs in the period 2009-2012 of €650m-€800m.

Linde has set a **medium-term target** for the 2014 financial year of Group operating profit of at least €4bn and a minimum target of 14% for ROCE. The company expects positive business trends to be supported by the megatrends in energy/ environment and health sectors and by growth trends in emerging economies.

Given the European debt crisis, we expect EPS growth to slow somewhat in 2012 and we are currently expecting EBITDA to reach €3.75bn by 2014. This generates 9% compound EPS growth over the period and factors in some erosion in margin in the engineering activities. This is a modest upgrade to expectations and reflects our changed and more positive view of Linde's growth potential having completed this analysis.

Figure 57. Linde P&L (Euros in Millions)

Profit and Loss	2007	2008	2009	2010	2011e	2012e	2013e
Sales							
Engineering and Contracting	2,750	3,016	2,311	2,461	2,535	2,611	2,715
Material Handling	0	0	0	0	0	0	0
Refrigeration	0	0	0	0	0	0	0
Industrial Gases	9,209	9,515	8,932	10,228	11,097	11,785	12,669
Others	347	132	(32)	179	233	237	242
Intercompany	0	0	0	0	0	0	0
Net sales	**12,306**	**12,663**	**11,211**	**12,868**	**13,865**	**14,634**	**15,627**
EBITA							
Engineering and Contracting	217	239	181	243	272	259	261
Material Handling	0	0	0	0	0	0	0
Refrigeration	0	0	0	0	0	0	0
Industrial Gases	1,530	1,613	1,534	1,821	1,985	2,134	2,304
Others	(156)	(149)	(154)	(131)	(138)	(142)	(145)
EBITA	1,518	1,643	1,495	1,865	2,048	2,176	2,342
Analyst adjusted EBIT	**1,591**	**1,703**	**1,560**	**1,797**	**2,120**	**2,251**	**2,421**
Analyst adjusted EBITDA	**2,351**	**2,495**	**2,403**	**2,857**	**3,086**	**3,237**	**3,440**
Associates	73	60	65	68	71	75	79
Net interest income/expense	(377)	(385)	(345)	(280)	(280)	(265)	(250)
Exceptional items	607	59	(83)	0	0	0	0
Pretax profit	1,375	1,006	822	1,399	1,595	1,807	1,993
Taxation	(379)	(230)	(188)	(335)	(373)	(439)	(490)
Normalised tax rate (proforma)	35%	35%	35%	35%	35%	35%	35%
Net extraordinary items	0	0	0	0	0	0	0
Minority interest	(44)	(59)	(54)	(59)	(62)	(68)	(75)
Preferred dividends	0	0	0	0	0	0	0
Reported net income	952	717	580	1,005	1,160	1,299	1,428
Analyst adjusted earnings	**815**	**904**	**855**	**1,153**	**1,281**	**1,381**	**1,510**
Average weighted ordinary shares - adjusted	162.2	167.0	169.0	169.3	170.5	171.0	171.5
EPS - diluted	**5.02**	**5.41**	**5.06**	**6.81**	**7.51**	**8.08**	**8.81**
Reported EPS - diluted	5.87	4.29	3.43	5.94	6.80	7.60	8.33
EPS growth		7.8%	-6.6%	34.7%	10.3%	7.5%	9.0%
DPS	1.70	1.80	1.80	2.00	2.21	2.37	2.59

Source: Company reports, Citi Investment Research and Analysis

Figure 58. Linde Balance Sheet (Euros in Millions)

Balance Sheet	**2007**	**2008**	**2009**	**2010**	**2011e**	**2012e**	**2013e**
Cash and marketable securities	903	1,022	848	1,176	1,176	1,176	1,176
Accounts receivable	1,704	1,716	1,682	1,855	1,999	2,110	2,253
Inventory	1,062	986	966	956	1,030	1,087	1,161
Total other current assets	716	603	502	641	689	730	780
Current assets	4,385	4,327	3,998	4,628	4,894	5,103	5,370
Net tangible fixed assets	7,213	7,162	7,566	8,723	9,168	9,785	10,447
Investments	516	535	559	678	698	719	741
Other financial assets	1,718	1,730	1,643	1,554	1,632	1,713	1,799
Total financial assets	2,234	2,265	2,202	2,232	2,330	2,433	2,540
Net goodwill	7,332	6,893	7,297	7,799	6,798	6,619	6,441
Total assets	**24,955**	**23,824**	**24,381**	**26,888**	**26,337**	**27,077**	**27,925**
Accounts payable	5,069	4,731	4,631	5,173	5,502	5,820	6,192
Short-term debt	1,303	1,290	381	459	459	459	459
Total other current liabilities	0	0	0	0	0	0	0
Current liabilities	6,372	6,021	5,012	5,632	5,961	6,279	6,651
Long-term debt	**6,027**	**6,155**	**6,586**	**6,214**	**5,822**	**5,643**	**5,417**
Deferred tax liability	2,164	1,889	1,780	1,990	2,144	2,263	2,417
Other non-current liabilities	0	0	0	0	0	0	0
Total other non-current liabilities	2,164	1,889	1,780	1,990	2,144	2,263	2,417
Total provisions	1,182	1,510	1,816	1,690	1,655	1,620	1,584
Total liabilities	**15,745**	**15,575**	**15,194**	**15,526**	**15,583**	**15,805**	**16,068**
Minority interest - accumulated	449	377	451	514	554	585	624
Preferred equity	0	0	0	0	0	0	0
Common equity	8,761	7,872	8,736	10,848	10,200	10,687	11,232
Shareholders' equity	8,761	7,872	8,736	10,848	10,200	10,687	11,232
Shareholders' funds	**9,210**	**8,249**	**9,187**	**11,362**	**10,754**	**11,272**	**11,856**
Liabilities and shareholders' funds	**24,955**	**23,824**	**24,381**	**26,888**	**26,337**	**27,077**	**27,925**
Net tangible fixed assets	7,213	7,162	7,566	8,723	9,168	9,785	10,447
Total other non current assets	3,791	3,177	3,318	3,506	3,147	3,137	3,127
Net working capital	(1,587)	(1,426)	(1,481)	(1,721)	(1,784)	(1,893)	(1,998)
Capital employed	**9,417**	**8,913**	**9,403**	**10,508**	**10,531**	**11,029**	**11,576**
ROCE (post tax)	11%	12%	11%	11%	13%	13%	14%

Source: Company reports, Citi Investment Research and Analysis

Figure 59. Linde – Cash Flow Statement (Euros in Millions)

Cash flow	**2007**	**2008**	**2009**	**2010**	**2011e**	**2012e**	**2013e**
Reported net income	**952**	**717**	**580**	**1,005**	**1,160**	**1,299**	**1,428**
Preferred dividends	0	0	0	0	0	0	0
Minority interest	44	59	54	59	62	68	75
Depreciation and amortization	1,279	1,223	1,218	1,246	1,283	1,241	1,276
Cash tax adjustment	0	0	150	10	10	11	11
Other operating cash flow	(367)	164	(321)	(360)	(377)	(347)	(367)
Total other operating cash flow	(367)	164	(321)	(360)	(377)	(347)	(367)
Net change in working capital	(183)	(428)	160	26	(74)	(121)	(118)
Cash from operations	**1,725**	**1,735**	**1,841**	**1,986**	**2,064**	**2,151**	**2,305**
Capital expenditure	(1,049)	(1,404)	(1,104)	(1,192)	(1,379)	(1,574)	(1,652)
Net acquisitions/disposals	3,135	132	(9)	118	(103)	(105)	(107)
Total other investing cash flows	0	0	0	0	0	0	0
Cash from investing activities	**2,086**	**(1,272)**	**(1,113)**	**(1,074)**	**(1,483)**	**(1,679)**	**(1,759)**
Change in borrowings	(3,266)	115	(478)	(294)	(392)	(179)	(226)
Equity raised/share buybacks	0	0	20	81	85	89	94
Dividends paid	(281)	(329)	(343)	(349)	(346)	(382)	(413)
Total other financing cash flows	0	0	123	0	0	0	0
Cash from financing activities	**(3,547)**	**(214)**	**(678)**	**(562)**	**(653)**	**(472)**	**(546)**
Change in cash	264	249	50	350	(71)	0	(0)
Opening net debt	9,975	6,427	6,423	6,119	5,497	5,105	4,926
Closing net debt	**6,427**	**6,423**	**6,119**	**5,497**	**5,105**	**4,926**	**4,700**
Change in net debt	(3,548)	(4)	(304)	(622)	(392)	(179)	(226)

Source: Company reports, Citi Investment Research and Analysis

Company Focus

L'Air Liquide SA (AIRP.PA)

Target Price Increased to €100; Steady Growth Forecast

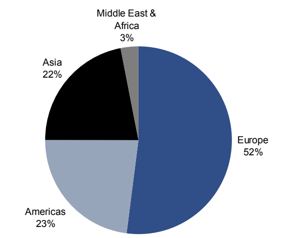
- Company Update
- Target Price Change

Neutral	**2**
Price (09 Dec 11)	€92.25
Target price	€100.00
from €95.00	
Expected share price return	8.4%
Expected dividend yield	2.3%
Expected total return	**10.7%**
Market Cap	€26,176M
	US$35,009M

Price Performance
(RIC: AIRP.PA, BB: AI FP)

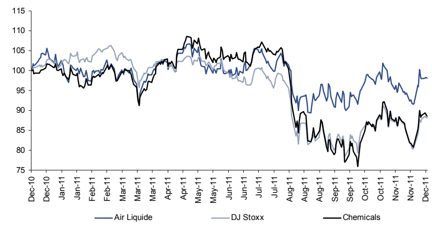
- **Compound EPS growth to 2015% of 6.5% forecast** — We believe Air Liquide is well placed to deliver c6.5% CAGR 2010-15E. This projection is based on a scenario that reflects the growth of the tonnage business in emerging regions, but also the weaker mid-term outlook for Europe given the likely low level of GDP growth the region is likely to deliver in the next five years.
- **EPS growth driven by up to €12bn of investment** — The company is targeting €10bn of capex in the next five years to 2015 and we have factored this into our estimates. The company has also indicated that it might invest upwards of €2bn in acquisitions, most likely buying capacity from new customers as they choose to outsource and probably a few smaller home care activities as well. We have not factored in possible acquisitions into our forecasts so there is the potential for some slight upside potential in the mid-term.
- **Strong balance sheet** — The company has reduced its debt to pre-Messer acquisition levels. We believe Air Liquide's balance sheet is strong (net debt to EBITDA of 1.25x) and enables it to drive its capital intensive plans, although we see operating cashflow as sufficient to fund its growth aspirations.
- **Target price increased to €100** — The somewhat higher valuation metrics than for Linde and the relatively higher exposure to continental European markets, that should be a drag on Air Liquide's growth, especially in 2012, mean the scope to increase the price target was more limited than for Linde. We remain neutral on the stock on a 12 month-view. The fundamental confidence we have in the sustainability and quality of growth has increased, which leads us to raise our target price to €100 (from €95). We have lowered our WACC from 7.5% to 7.1% to be consistent with peers and to reflect the high visibility of the profit outlook.

Figure 60. Sales by Destination 2010



Source: Company reports

Figure 61. Shares vs DJ Stoxx/Chemicals



Source: Datastream

L'Air Liquide SA (EUR)

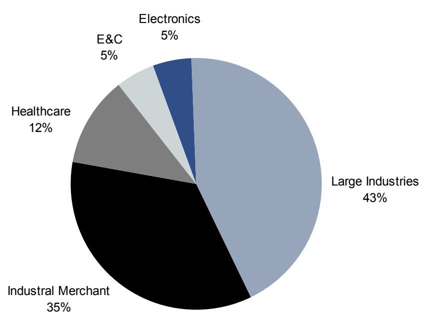
Year to 31 Dec	2009A	2010A	2011E	2012E	2013E
Sales (€M)	11,976.0	13,488.0	14,415.1	14,955.8	16,040.5
Net Income (€M)	1,222.1	1,401.9	1,532.8	1,601.7	1,743.2
Diluted EPS (€)	4.37	4.98	5.45	5.69	6.19
Diluted EPS (Old) (€)	4.37	4.98	5.45	5.69	6.19
PE (x)	21.1	18.5	16.9	16.2	14.9
EV/EBITDA (x)	10.8	9.4	8.8	8.4	7.9
DPS (€)	2.11	2.35	2.54	2.72	2.93
Net Div Yield (%)	2.3	2.5	2.8	2.9	3.2

Global Leader in Gases Market

Major Growth drivers in medium term

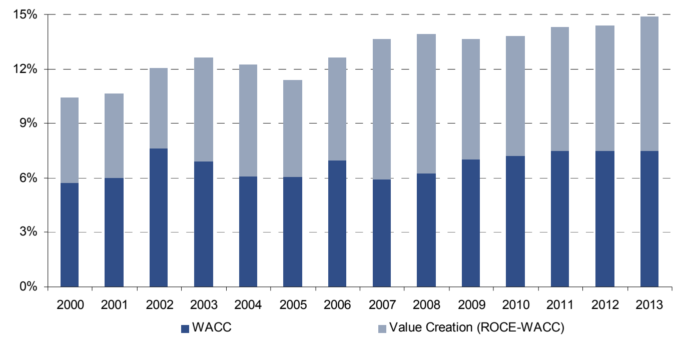
Large scale industries with a quality tonnage business remain key growth drivers for Air Liquide in medium term. In 2011 we forecast tonnage activities will generate 32% of sales and 44% of EBIT. In the coming five years, we expect the tonnage business will generate 65% of the EBIT growth with demand in emerging markets (notably China, South East Asia, Eastern Europe and the Middle East) the key region, and with steel, energy, chemicals and refining industries the key demand drivers. Perhaps up to 80% of its expansion capex (and two thirds of its total capex) will be in emerging markets.

Figure 62. Air Liquide's capex plans, 2011– 2015e –c€12 bn



Source: Company reports, Citi Investment Research and Analysis

Figure 63. ROCE is expected to increase over medium term to c15%



Source: Company reports, Citi Investment Research and Analysis

We believe following are the key drivers for Air Liquide:

- **Steel**: Air Liquide has improved its presence in this important market with few major contracts won in past 12 months. We believe this sector will be one of the major drivers of growth in next five years. Most of these contracts are long-term tonnage contracts, thus not dependent upon future economic fluctuations.

- **Hydrogen**: This segment accounts for c32% of total large scale industrial sale of Air liquide and its sales have been growing at rate of c16% for the past five years.

- **Electronics**: Asia is the main location for electronics production and will remain so, with manufacturing hubs moving to Taiwan, Korean and China. Most of the electronics business offering depends upon cogenerated gases from ASUs, thus the increasing footprint of Air Liquide in Asia also supports their electronic business. The electronics market is expected to grow c10% CAGR and we expect Air Liquide's share to grow in line with the market.

- **Homecare**: Health is c16% of 2010 sales. It is one of the most defensive plays and was the only segment to contribute towards sales growth in 2009. The majority of its sales are from Europe (c78%) followed by Americas (Canada and Brazil) and Asia. The plan is to accelerate this pace of growth partly through acquisition, but also by applying the technologies and skills from individual activities to the entire group. Homecare, which is c43% of total healthcare business in Europe, is likely to remain the key growth driver. That said, price pressures are growing driven by the need by European governments to cut costs, so prospects for 2012 look relatively challenging.

Capex levels support growth in sales

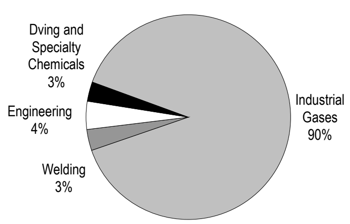
In total from 2011-2015, the company has budgeted to invest €10bn in capex and up to €2bn in acquisitions to expand the group. Air Liquide remains the global leader in this segment, with 20% market share. This pace of investment is roughly consistent with sustaining this position, although acquisitions could increase this somewhat.

Figure 64. Major contract wins in past 12 months by type (capacity means oxygen unless defined)

Customer	Location	Type	End Market	Capacity	Division	Capex-€Mn	Startup date
SNCG	China	MTP Plant	Coal to Chemicals	500,000 tpa -MTP	E&C	na	na
Sinopec	China	ASU	Refinery	3000 tpd	IG	85	2013
Saudi Aramco	Saudi Arabia	ASU	EOR	500 tpd	IG	25	2012
PETKIM	Turkey	ASU	Chemicals	400tpd	IG	60	2013
Posco	South Korea	ASU	Steel	7500 tpd	E&C	na	na
EMZ	Ukraine	ASU	Steel	1700 tpd	IG	100	2014
Severstal	Russia	ASU	Steel	300 tpd	IG	40	2012
Aurubis	Bulgaria	ASU	Copper	350 tpd	IG	10	2013
Industrial	Philippines	ASU	Various	200 tpd	IG	22	2012
IRICO Electronics	China	ASU	Glass plant	770 tpd	IG	50	2012
Industrial	Chile	ASU	Various	150 tpd	IG	25	2013
Xilin Steel	China	ASU	Steel	1200 tpd	IG	40	2012
RINL	India	ASU	Steel	1800 tpd	IG	70	2012
Datong	China	ASU	Coal to Chemicals	2000 tpd	IG	60	2012
AHMSA	Mexico	ASU	Steel	1700 tpd	IG	70	2013
Industrial	India	ASU	Various	200 tpd	IG	na	2012
Industrial	Turkey	ASU	Various	200 tpd	IG	35	na

Source: Company reports and Citi Investment Research and Analysis

Figure 65. Sales by division, 2012E



Source: Company Reports and CIRA Estimates

Expanding Engineering

With engineering procurement costs skyrocketing, the Lurgi acquisition appears well timed. Average project sizes are increasing and the technological challenges of the future, notably carbon capture, and the ever larger scale required for oxygen and hydrogen production will make engineering capability an ever more important differentiating factor. Lurgi brought hydrogen production skills as well as turnkey biofuel production capability. Lurgi is a profit centre in its own right, but the real value of Lurgi will emerge over the medium term as the complexity and cost of major plant contracts grows. Indeed, strategically Lurgi is being structured to maximise the ability of the group to win major supply schemes that can also sell engineering solutions. In this sense it is managed very differently to Linde, where the focus is on engineering solutions for the market as a whole with its own Gases division seen as almost just another customer, albeit a very important one.

Restructuring remains a key driver – €200m annual efficiency target

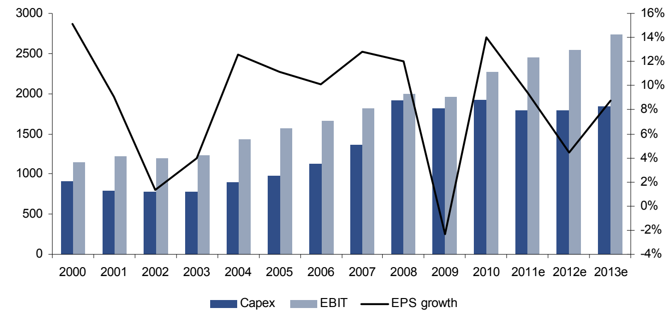
Air Liquide's efficiency drive is run under the ALMA label. Through cost reductions, greater standardisation of processes and the better spread of best practices, the aim is to be able to deliver c.€200m in savings p.a. through to 2015. ALMA is also about the growth strategy and the development of business in emerging regions. The aim is to try to ensure that ROCE remains within a 12%-13% band (company calculated ROCE includes goodwill and intangible assets in capital employed).

Compound EPS growth of 8% through 2015 likely

The compound growth in the ten years to 2011 is 8%. We see this as likely to be sustainable. This has been achieved with an average capex to sales ratio of 11.4%, plus acquisitions investment of a further 3.3% of sales p.a. In other words the total investment has been close to 15% of sales.

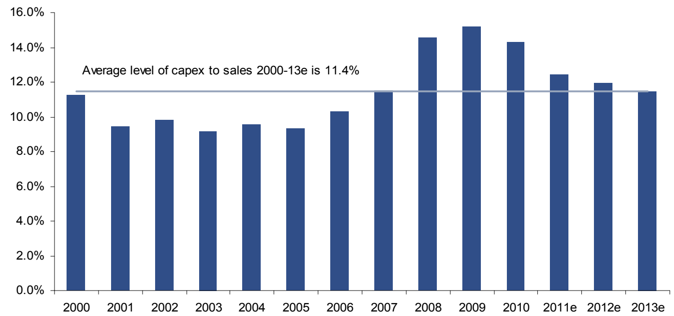
Roughly speaking the company's ambitions are for this sort of pace of investment to continue. In our opinion, the fundamental underpinning demand is there and we expand on this in detail in the appendix. Consequently, we believe the potential for the trend pace of EPS of c.8% to continue into the foreseeable future is good.

Figure 66. Capex, EBIT and EPS growth, 2000 to 2013e (€ in millions)



Source: Company reports, Citi Investment Research and Analysis

Figure 67. Capex to sales ratio, 2000 – 2013E

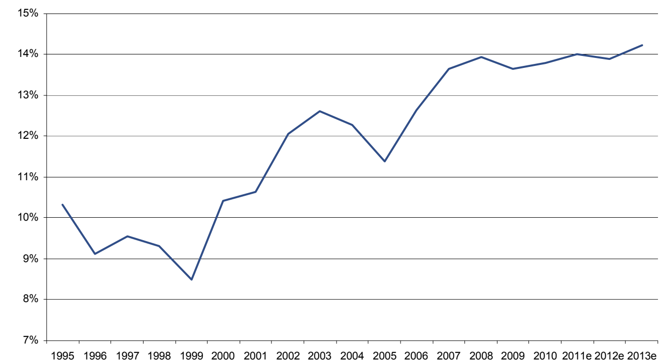


Source: Company reports, Citi Investment Research and Analysis

The ROCE has also been somewhat volatile, but around a narrow range of 10% plus or minus 1%. The main factors depressing growth have been acquisitions (the falls in 2002 and 2005), the scale of overcapacity (from 1996 to 1999). Note the impact of the global financial crisis in 2009 was relatively minor.

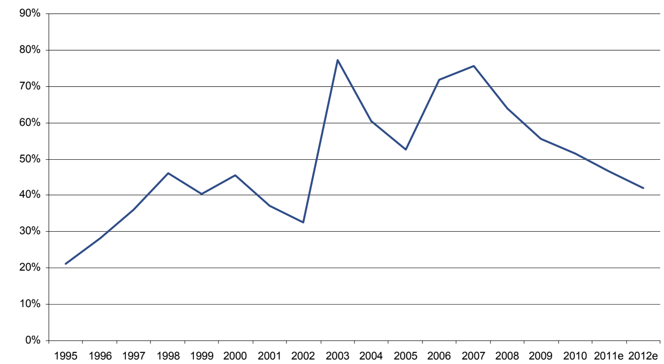
We believe that the shift in the business mix more towards tonnage will tend to further reduce the volatility of ROCE and tend to slightly increase it. This investment programme, we calculate, can be financed out of cash generation and would still leave scope for progressive debt reduction without acquisitions and or share buybacks.

Figure 68. Post tax ROCE, 2000 – 2013E



Source: Company reports, Citi Investment Research and Analysis

Figure 69. Net Debt / Equity, 2000 – 2013E



Source: Company reports, Citi Investment Research and Analysis

Risks to Estimates Modest

- Further slowing in European growth (or rather a deeper recession in 2012) and the reduction in GDP growth globally would have a modest adverse impact on the business and would depress growth.
- Project cancellations and delays did occur in 2009 although the number of cancellations was modest. There is some risk to this in 2012 although so far, the projects seem on plan.

Overall, we believe the prospects for 4% EPS growth in 2012 are good; we are expecting the European credit crisis to adversely impact the business. In the long term we believe company can achieve c 8% CAGR 2011-15E ex currency effects.

Figure 70. Air Liquide – P&L (Euros in millions)

Profit and Loss	**2007**	**2008**	**2009**	**2010**	**2011E**	**2012E**	**2013E**
Sales							
Large Industries	3,024	3,675	3,219	4,019	4,622	4,992	5,491
Electronics	944	1,044	872	1,177	1,330	1,290	1,406
Industrial Customers	4,439	4,609	4,277	4,753	4,848	4,897	5,141
Healthcare	1,592	1,700	1,824	1,937	2,073	2,176	2,329
Other Activities	1,803	2,075	1,784	1,602	1,546	1,605	1,679
Net sales	**11,802**	**13,103**	**11,976**	**13,488**	**14,415**	**14,955**	**16,040**
EBIT							
Large Industries	693	797	829	965	1,100	1,199	1,318
Electronics	112	105	100	153	171	163	177
Industrial Customers	735	757	750	808	832	816	848
Healthcare	270	289	315	368	386	406	434
Unallocated expenses	(166)	(167)	(170)	(178)	(195)	(199)	(207)
EBIT	1,794	1,949	1,949	2,252	2,448	2,543	2,737
Analyst adjusted EBIT	**1,818**	**1,998**	**1,958**	**2,269**	**2,448**	**2,543**	**2,737**
Analyst adjusted EBITDA	**2,749**	**2,961**	**2,988**	**3,393**	**3,619**	**3,774**	**4,025**
Associates	27	25	20	28	29	30	31
Net interest income/expense	(234)	(270)	(275)	(311)	(310)	(310)	(310)
Exceptional items	(5)	(30)	10	2	0	0	0
Pretax profit	1,582	1,673	1,704	1,971	2,167	2,263	2,459
Taxation	(412)	(402)	(419)	(513)	(574)	(600)	(652)
Normalized tax rate (proforma)	26%	24%	25%	27%	27%	27%	27%
Minority interest	(47)	(52)	(55)	(55)	(60)	(62)	(64)
Reported net income	1,123	1,220	1,230	1,403	1,533	1,602	1,743
Analyst adjusted earnings	**1,127**	**1,243**	**1,222**	**1,402**	**1,533**	**1,602**	**1,743**
Average weighted ordinary shares - adjusted	282.3	277.9	279.9	281.6	281.4	281.6	281.8
EPS - diluted	**3.99**	**4.47**	**4.37**	**4.98**	**5.45**	**5.69**	**6.19**
Reported EPS - diluted	3.98	4.39	4.39	4.98	5.45	5.69	6.19
EPS growth		12.1%	-2.4%	14.0%	9.4%	4.4%	8.8%
DPS	1.91	2.11	2.11	2.35	2.54	2.72	2.93

Source: Company reports, Citi Investment Research and Analysis

Figure 71. Air Liquide – Balance Sheet (Euros in millions)

Balance Sheet	2007	2008	2009	2010	2011E	2012E	2013E
Cash and marketable securities	774	1,494	1,445	1,575	1,575	1,575	1,575
Accounts receivable	2,829	2,946	2,480	2,690	2,979	3,142	3,382
Inventory	796	818	710	742	779	818	859
Total other current assets	434	442	451	460	469	479	488
Current assets	**4,832**	**5,700**	**5,086**	**5,467**	**5,802**	**6,013**	**6,304**
Net tangible fixed assets	8,731	9,869	10,230	11,340	11,657	11,965	12,337
Investments	312	290	501	516	547	580	615
Total financial assets	719	712	940	973	1,022	1,074	1,129
Net goodwill	3,643	3,956	4,003	4,391	4,391	4,391	4,391
Total assets	**18,292**	**20,605**	**20,626**	**22,538**	**23,239**	**23,810**	**24,528**
Accounts payable	1,921	1,884	1,477	1,297	1,362	1,430	1,502
Short-term debt	430	765	867	964	229	229	229
Total other current liabilities	1,384	1,670	1,942	2,217	2,284	2,352	2,423
Current liabilities	3,735	4,319	4,287	4,478	3,875	4,011	4,153
Long-term debt	4,993	6,205	5,529	5,681	5,847	5,413	5,036
Deferred tax liability	1,199	1,268	1,291	1,493	1,642	1,715	1,863
Other non-current liabilities	163	193	281	336	353	371	389
Total other non-current liabilities	1,362	1,461	1,572	1,830	1,995	2,086	2,252
Total provisions	1,726	1,369	1,486	1,437	1,480	1,524	1,570
Total liabilities	**11,815**	**13,354**	**12,874**	**13,425**	**13,196**	**13,035**	**13,012**
Minority interest - accumulated	148	149	168	209	219	230	242
Shareholders' equity	**6,328**	**7,102**	**7,584**	**8,904**	**9,824**	**10,545**	**11,274**
Shareholders' funds	6,476	7,250	7,752	9,113	10,043	10,776	11,516
Liabilities and shareholders' funds	**18,292**	**20,605**	**20,626**	**22,538**	**23,239**	**23,810**	**24,528**
Net tangible fixed assets	8,731	9,869	10,230	11,340	11,657	11,965	12,337
Total other non current assets	367	367	367	367	367	367	367
Net working capital	754	653	222	378	581	656	804
Capital employed	**9,852**	**10,889**	**10,819**	**12,084**	**12,605**	**12,988**	**13,509**
ROCE (post tax)	14%	14%	14%	14%	14%	14%	15%

Source: Company reports, Citi Investment Research and Analysis

Figure 72. Air Liquide – Cash Flow Statement (Euros in millions)

Cash flow	2007	2008	2009	2010	2011E	2012E	2013E
Reported net income	**1,123**	**1,220**	**1,230**	**1,403**	**1,533**	**1,602**	**1,743**
Minority interest	47	52	55	55	60	62	64
Depreciation and amortization	936	993	1,020	1,122	1,159	1,196	1,239
Cash tax adjustment	(52)	(58)	(31)	81	(15)	(16)	(17)
Other operating cash flow	(4)	(23)	8	1	(4)	(4)	(4)
Total other operating cash flow	(4)	(23)	8	1	(4)	(4)	(4)
Net change in working capital	94	128	166	(155)	(204)	(74)	(149)
Cash from operations	**2,144**	**2,311**	**2,448**	**2,507**	**2,529**	**2,766**	**2,876**
Capital expenditure	(1,359)	(1,908)	(1,818)	(1,927)	(1,788)	(1,788)	(1,837)
Net acquisitions/disposals	(1,108)	(184)	(29)	(196)	46	48	51
Total other investing cash flows	0	(42)	12	(86)	0	0	0
Cash from investing activities	**(2,468)**	**(2,134)**	**(1,835)**	**(2,209)**	**(1,742)**	**(1,740)**	**(1,786)**
Change in borrowings	1,079	1,548	(575)	348	(569)	(433)	(377)
Equity raised/share buybacks	(443)	(124)	174	113	14	14	14
Dividends paid	(530)	(590)	(631)	(647)	(697)	(745)	(804)
Total other financing cash flows	80	(311)	48	(183)	(144)	(96)	(98)
Cash from financing activities	**186**	**523**	**(984)**	**(369)**	**(1,397)**	**(1,261)**	**(1,265)**
Change in cash	(138)	700	(371)	(71)	(611)	(236)	(176)
Opening net debt	3,446	4,649	5,477	4,951	5,070	4,500	4,067
Closing net debt	**4,649**	**5,477**	**4,951**	**5,070**	**4,500**	**4,067**	**3,690**
Change in net debt	1,203	828	(526)	118	(569)	(433)	(377)

Source: Company reports, Citi Investment Research and Analysis

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Appendix

Gases: A Structural Growth Market

We estimate that the worldwide market for industrial gases is currently worth approximately US$63bn for 2010, up from US$33bn in 2001. The market has grown at a compound rate of 7.5% over the past nine years. Adjusting for currencies and natural gas price pass-through, the sales value of the market has grown at 2x GDP over the period. Of this annual adjusted growth of 6.5% p.a. (or 1.5x GDP), selling price increases have been in the region of 1.5% over the period, we estimate. In developed markets, price inflation has probably exceeded volumes. In emerging markets, volume growth dominates.

With pricing power likely to be robust in most regions, we would expect the Industrial gas sector to be able to continue to pass on the effects of inflation and to be able to deliver sales growth at least in line with the 2.0x ratio seen over the past few years. Underpinning this is the expansion of oxygen and hydrogen demand that we outline in this section. This growth is focused in the tonnage segment of the market and so should deliver a highly predictable return on capital.

In this section, we breakdown the market into its component gases and define how we see its growth over the medium term.

Industrial gases are generally categorised into air gases, synthetic gases and speciality gases. Looking at these in turn:

Air gases

Air gases generate about 73% of global volumes and 60% of revenues of the Gases space. Oxygen and Nitrogen make up the bulk of this volume. Argon (Ar) is responsible for approximately 1% by volume but accounts for 11% of worldwide sales. The main raw material for industrial gas companies is air, which is 99.04% composed of nitrogen and oxygen (see Figure 73). Nitrogen, oxygen and argon are usually produced in large cryogenic plants. Oxygen is the high growth gas.

While not strictly just oxygen, we have included medical gases in this section for simplicity reasons as the main medical gas is oxygen. The growth driver in healthcare is homecare, which is mainly a service driven off respiratory care, which gets back to oxygen. Other medical gases include nitric oxide/air and nitrous oxide/air mixtures, which are also manufactured and distributed by the industrial gas companies. Nitrous oxide is called ‘laughing gas’ and is used as a painkiller, for example, during childbirth. All the gas companies have a presence in this segment and their hospital gases offering is still the bedrock of the healthcare businesses.

Figure 73. Air Composition

Component	Proportion of air
Nitrogen	78.09%
Oxygen	20.95%
Argon	0.93%
Carbon Dioxide	0.03%
Neon	0.0016%
Helium	0.00052%
Krypton	0.00011%
Hydrogen	0.00001%
Xenon	0.0000008%

Source: Messer

Synthetic gases

Carbon dioxide (chemical symbol CO2), hydrogen (H2) and acetylene (C2H2) are the main synthetic gases, and accounted for 27% of worldwide volume and 23% of worldwide revenue in 2010, we estimate. They are manufactured via chemical synthesis.

- **Hydrogen** continues to have strong growth potential over the next few years largely due to continuing demand in the energy sector. Its main use is to desulphurise crude to meet clean air legislation requirements and to upgrade heavy crudes.

- There is a possibility that **carbon dioxide** will become a source of substantial growth for the industrial gas companies, driven by the need to reduce emissions of this gas into the atmosphere. The gas companies might be able to develop services to help its removal or capture from power plants. The key issue is the gas companies knowledge and core skills in gas management. The removal of gas via sequestration will probably be beyond the scope of the activities of the gas majors. These emerging technologies are not yet competitive or viable, but on a ten-year view may become a material component of incremental growth.

Speciality gases

- Rare or noble gases — **helium** (He), krypton (Kr), neon (Ne) and xenon (Xe) — are present in air in much smaller quantities. Demand for helium should be driven by the development of the electronics industry in Asia. Noble gases have many industrial, medical and scientific applications and we estimate demand growth rate of 3.5% p.a. until 2013, whereby healthcare will grow the fastest.

- Other speciality gases include those used in electronics, particularly **semiconductor** fabrication and now also in solar wafer manufacture. Globally, semiconductor industry is forecast to grow at 3-4% p.a., with the growth rate highest in the Asian markets at 10% to 20% p.a.

- A major growth driver for speciality gases lies in the LED market, which we expect to grow at 50% in 2011 and 25% at 2012.

Growth of about 2x GDP Forecast to 2015

We believe that the trend revenue growth for the industrial gas industry of 2x GDP is set to continue. By segments, there will be differences, but we expect relatively broad-based growth, which provides the basis for confidence. The expectations by gas are summarised in Figure 74. Much of the difference between value and volumes relates to the costs of production in order to deliver a positive return on the assets employed. Most of the gas companies operate on the basis of the need to a post tax rate of return somewhere between 12% and 15% and they seem to have the pricing power to be able to deliver on their objectives.

We expect the market to grow by about c.8.4% p.a. over the next five years. The key assumptions that underpin this estimate are:

- Exchange rates remain constant (so we will be wrong, but this is our current assumption);

- Natural gas prices remain unchanged from current levels;

- The ratio of volumes to GDP remain 2.0x (relative to market of operations, we assume c70% growth from emerging markets and c30% from mature economies);
- Annual price inflation averages 1%;
- We use Citi economists' GDP growth projections for the next two years and just assume this pace of growth holds good for the 5-year period.

Figure 74. Industrial Gases – Market Size and Growth, 2010- 2015E (USD millions)

Sector	Volume Market Share	Value Market Share	2010 USD m	2015e USD m	CAGR 2010 -2015E	Component of growth 2010-2015E
Air Gases						
Nitrogen	27%	20%	14,200	18,123	5%	11%
Oxygen	40%	30%	21,300	32,773	9%	33%
Argon	1%	11%	7,810	9,502	4%	5%
Synthetic Gases						
Carbon Dioxide	7%	6%	4,260	5,975	7%	5%
Acetylene	0%	7%	4,970	5,487	2%	1%
Hydrogen	25%	17%	12,070	24,361	15%	35%
Specialty Gases						
Noble & other speciality gases	—	3%	2,130	2,918	6.5%	2%
Electronic gases	—	6%	4,260	6,861	10%	7%
TOTAL	**100%**	**100%**	**71,000**	**106,000**	**8.35%**	**100%**

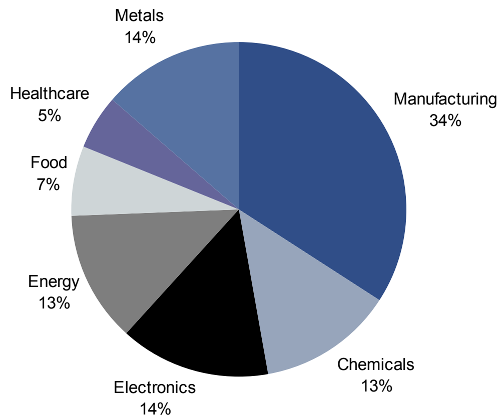
Source: Company Reports, Citi Investment Research and Analysis

The main growth drivers will be:

- **Hydrogen** — we believe its contribution to growth will remain well above its share of market value. The main driver remains the requirements to reduce sulphur content and raise the hydrogen content in motor gasoline (petrol). Both require hydrogen and this must be imported into the refinery. We believe current merchant market for hydrogen will **double in next five** years. Besides growth in hydrogen demand for refinery, we believe increasing trend of outsourcing these units will provide impetus to merchant hydrogen market. We project growth for this market is driven by: 1) **Cheap natural gas in US**: providing arbitrage to use it for converting higher value petroleum products from residual fuel; **2) Heavy and Sour crude**: new incremental bbl will be heavy and sour warranting investment in new hydrogen facilities; 3) **Implementation of stringent emissions standards**, launch of Euro 5 in Sep 2009, Euro 6 due in 2015, and emerging markets adopting these norms with lag impact
- **Oxygen** looks set to continue to grow, and we believe this industrial gas will be major beneficiary of clean fuel drive. Healthcare and steel capacity in Asian countries should support the growth of Linde and Air Liquide in particular. Coal gasification continues to be interesting prospect, particularly in China and US. We believe the growth will be driven by tonnage schemes supplied under long-term contracts. We believe new technology to produce economic large scale of oxygen quantities can unlock c€50bn+ market in the long term, indicating industrial gas companies have good potential to have GDP + growth in the long term. In near term, we project growth for this market is driven by: 1) Steel industry: increasing by roughly **8% on Asian** prospects; 2) Coal gasification: **c10% CAGR** driven by coal to chemical and clean coal for power; and 3) medical gases, providing stable business and increasing roughly c6% CAGR 2010-15E.

- **Argon —** Driven by steel demand and capacity upgrading in Asia. Automotive production growth is also a driver. We expect it to grow by an average **of 10%** annually over the forecast period.
- The **electronics** industry should continue to drive demand steadily for the foreseeable future. The scale of demand growth has **averaged 9% p.a.** long term (but with very high volatility especially over the 2000 to 2003 period) and we are basing our assumptions on this sort of rate continuing.

Figure 75. Contribution to Growth of Gases Market 2010 – 2015E



Source: Air Products, Citi Investment Research and Analysis

By application, the sources of growth are likely to be broadly based due in no small part to the impact of the industrialisation of Asia. Manufacturing which includes refining should remain the biggest of the growth drivers, but metals and energy should also be an increasing contributor to the growth.

The Air Gases

The gases separated from air are: oxygen, nitrogen and argon and these are the foundation gases of the industry. Oxygen looks set to remain a driving force for growth on current megatrend of fuel efficiency and clean combustion. Nitrogen and Argon continues to be used in conjunction with oxygen and should benefit from megatrends in oxygen demand.

Oxygen

Background: Oxygen is colourless, odourless gas and the second most abundant gas present in air after nitrogen. It is soluble in water and can react with almost all elements to form oxides unlike nitrogen. This property of oxygen makes it essential for combustion process in which hydrocarbons react with oxygen to form carbon dioxide in an exothermic reaction i.e. a chemical reaction in which bonding of two chemicals release heat in process.

Merchant oxygen was mainly used for production and fabrication of various metals, in chemical process, manufacturing industries and for healthcare applications. We believe much of the growth will come from oxy-combustion processes and in energy-related applications.

In the **developed markets** like the US, Western Europe and Japan, the merchant oxygen market is mature, but growth should reach **c3% CAGR 2010-15E** driven by healthcare and clean energy megatrend and some pricing. We expect demand for oxygen **in developing markets** to grow by **c8%-12% CAGR 2010-15E**, driven by steel, chemicals and healthcare sectors as developing countries continue to invest in infrastructure and modernization of domestic manufacturing capacities. By 2020, it is estimated that at least 300 new oxygen plants will be required with average capacity of 3000tpd to cater additional tonnage demand for oxygen. c40% of this growth will come from steel production, c45% growth from gasification and c15% growth from clean coal technologies.

In the long term, the need for clean coal technology could add **another c€10-€15bn (2020+)** to the oxygen market. As discussed in our carbon section, we expect this megatrend to be one of the most important drivers for industrial gases and should be realised sooner than expected. Already 74 large integrated demonstration projects are targeted worldwide for CCS and as oxy fuel technology advances towards commercialisation; oxygen is poised to play a major role in long-term growth of industrial gas business.

Production Process

Large scale production (over 300tpd) is usually done through cryogenic ASUs which produces 99.99% pure oxygen.

Large scale oxygen production (over 300 tpd) is done through cryogenic separation where oxygen is produced along with other air gases. With the advancement of technology, non-cryogenic production plants can produce up to 300 tpd high purity product, thus enabling bulk merchant buyers to have their own onsite plant, which is cheaper compared to bulk liquid oxygen due to high transportation cost associated with it. We estimate that these plants have now replaced c30%-35% of the traditional merchant liquid demand. We discuss various processes and transportation model in detail in production and distribution sections.

Key Applications

Due to its highly reactive property, oxygen is used for enhancing combustion, oxidisation and for medical purposes. Key applications are discussed below:

Steel and Chemical industry uses significant amount of oxygen for enhanced combustion and oxidization

Steel Manufacturing: Worldwide c40%-45% of merchant oxygen is consumed by steel manufacturers. Oxygen-enriched air increase combustion temperatures in blast furnaces and enhances recycling of scrap metal in electric arc furnaces.

Chemical Processing: c20%-25% of merchant oxygen is used by the chemical sector where it is used to alter the structure of feed stocks through oxidation, producing nitric acid, ethylene oxide, propylene oxide, VCM and other building block chemicals.

Metal Fabrication: To support oxy-fuel cutting operations. Sometimes added in small quantities for shielding gases though its usage in developed market is on the decline due to the development of alternative fuels like LPG, propane.

Health services is relatively small but only area of growth for liquid oxygen market

Health Services: To resuscitate or, in combination with other gases, to anesthetise; but also essential to life-support systems used in emergencies or long-term treatment of patients with respiratory disorders. Volume share of health services is around 4%-5% but it's a niche market and only area of growth for liquid oxygen business**.**

Petroleum Recovery and Refining: To reduce viscosity and improve flow in oil and gas wells; to increase capacity of fluid catalytic cracking plants as well as to facilitate use of heavier feed stocks; and to reduce sulfur emissions in refineries.

Pulp and Paper: To help manufacturers meet stringent environmental regulations in a variety of mill processes including delignification, bleaching, oxidative extraction, chemical recovery, white/black liquor oxidation and lime kiln enrichment.

Clean fuel and gasification is another important application

Glass Manufacturing: To enhance combustion in glass furnaces and reducing nitrogen oxide (NOx) emissions to levels below new stringent requirements of the U.S. Clean Air Ac.

Carbon capture: CCS is likely to be one of the biggest environment megatrends of the millennium and oxygen plays an important part in providing carbon clean fuel for energy-intensive industries like power generation.

GTL/CTL plants: Large scale GTL/CTL plants are built around cheaper gas and coal resources to produce expensive liquid fuels like diesel, naphtha and diesel. These plants use oxygen on a large scale, which is provided through dedicated onsite plants usually operated by industrial gas companies.

Growth drivers for Oxygen

Oxygen market is mainly driven by tonnage business which is usually on take or pay basis

As discussed above, oxygen is used in various industries for enhanced combustion, chemical oxidisation, cleaner emissions and medicinal purposes. Most of these uses are megatrends of this decade, driving demand for oxygen above GDP growth. Moreover, bulk of this growth will be **tonnage business** where large scale plants will be built to supply industrial plants for cleaner fuel applications, gasification and large integrated steel plants. Small non-cryogenic plants can also grow at moderate rate for small scale users like pulp and paper, chemicals etc. Industrial gas companies prefer to lease plants where they get standard lease and maintenance costs with take or pay contracts. This shields them from variable power and energy costs and helps them to generate steady cash flow.

We expect developed markets demand for liquid oxygen to grow at c4-6% while developing market overall demand for oxygen is expected to grow by c8%-12%

Liquid oxygen is typically used for primarily used for small scale industries, for welding purposes and for healthcare and homecare market. With increasing viability of non-cryogenic technology, we believe small scale usage by bulk merchant buyers will shift to captive onsite plant operated by Industrial gases. Use of oxy-acetylene for metal brazing, welding and cutting is on decline due to development of easy to use environmental friendly fuel like LPG and propane. Laser techniques are growing in this segment as well. The main growth driver for liquid oxygen is the healthcare market where the megatrend of ageing populations and growing homecare markets should drive demand for liquid oxygen by c4%-6% in developed markets. We expect c8%-12% growth for emerging markets driven by both tonnage and liquid growth. We discuss key growth drivers for oxygen in detail below.

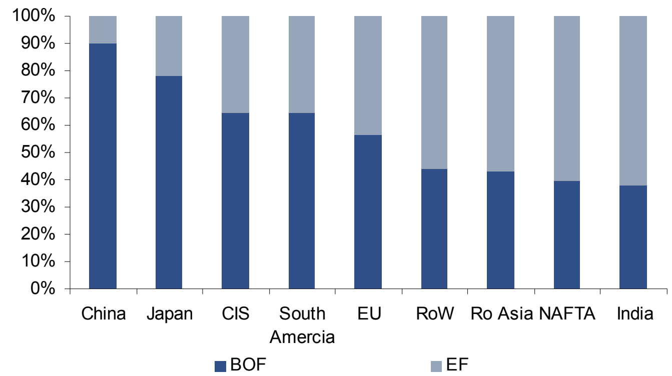
1) Steel – India infrastructure and Chinese capacity upgrade

Process Background: Iron and steel production need very high temperatures for their production process. Oxygen-enriched air achieves these high temperatures more efficiently in absence of inert gases like nitrogen. For producing pig iron, c1200^{0}C of hot air is introduced in blast furnaces to melt iron and form carbon monoxide which reacts with iron ore to remove impurities. This iron is then used to manufacture steel by oxidising impurities in basic oxygen furnaces or electric arc furnaces.

The steel sector accounts for c40-45% of tonnage business of oxygen in developed countries, whereas in developing economics like India, its share goes as high as c70%. On average, c35-160 ST of oxygen is consumed per 1000 ST of steel produced depending upon the production process (basic oxygen furnace or electric arc furnace). For the BOF process, first pig iron is produced from iron ore by processing it in blast furnace. This consumes around 85 ST of oxygen/1000 STS. This pig iron is then further refined in BOF which further consumes around c75 ST of oxygen/1000 ST of steel. An electric arc furnace on the other hand processes scrap steel, eliminating requirement of pig iron and consumes only c45 ST of oxygen for processing of 1000 ST of steel. Oxygen is also used for various other purposes in both processes, albeit in small quantities for cutting away imperfections and scales on steel billets.

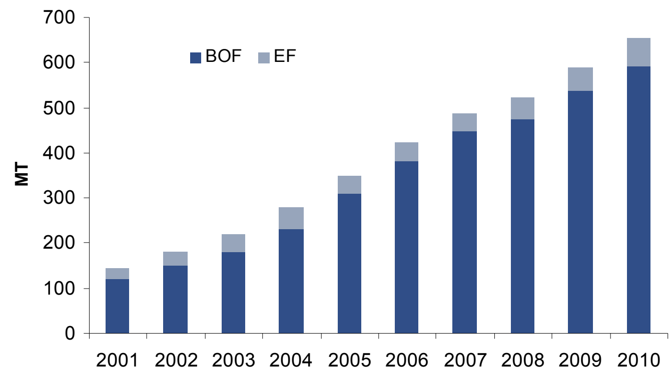
Steel production around the world is broadly based on BOF process (c70% of 2010 production) though electric arc furnaces (used mainly for scrap steel) are growing in popularity, especially in the US market, where it has consistently gained market share and now accounts for c60% steel production. Figure 76 showcase 2010 steel production sorted by use of BOF process in which China, Japan are pioneers followed by the CIS and Europe. Countries using EF as their main technology are US and India. We believe the choice of technology is based on availability of local resources and domestic circumstances instead of any technological advantage. In Figure 77, we highlight the Chinese steel industry, which currently accounts for c46% of world production, and has consistently increased BOF based capacity with c18.4% CAGR growth in capacity since 2001.

Figure 76. Regional breakup of steel production by process



Source: Steel Statistical Yearbook, CIRA

Figure 77. Chinese production since 2001 has increased by c18.4% CAGR but has been broadly based on BOF process



Source: Steel Statistical Yearbook, CIRA

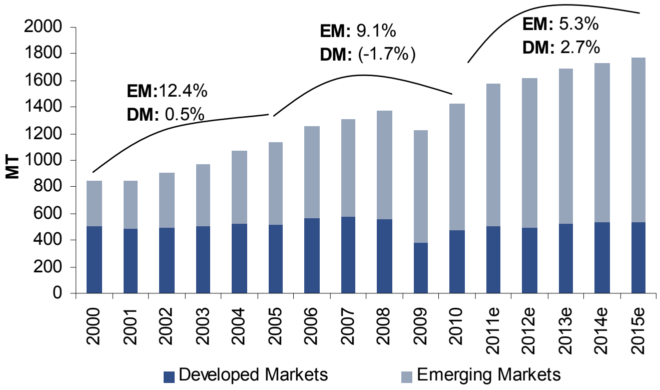
BOF process is going to be main technology in near term future with focus on large scale economics

We believe new capacity expansions in developing nations are going to be large-scale integrated plants, based on the BOF process. Industrial gases will either have their role in project engineering with large ASU projects undertaken as turnkey projects or will operate them under "over the fence" contracts with dedicated ASU and long-term take of pay contracts. The share of bulk merchant liquid oxygen, (c7% of total oxygen demand for steel sector) which is driven by demand from small scale units may actually decline, as non cryogenic technologies are increasingly becoming viable for small-scale industries to have onsite dedicated plants. We do not forecast incremental oxygen demand due to the use of new processes listed by ULCOS which we believe will have impact on oxygen demand post 2015, beyond our explicit forecast period.

We expect oxygen demand from developed nations for its steel sector will be in line with overall sector growth, driven by recovery in construction and automobile sector post recession

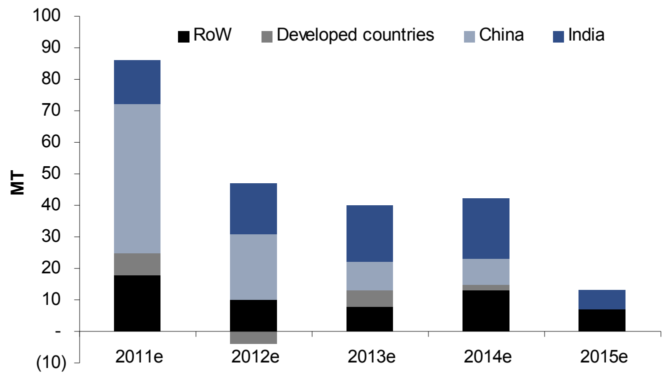
Overall global production of steel is projected by our Metals and Mining team to grow at c4.4% CAGR 2010-15e. Steel demand is closely linked to GDP development and our commodity team forecasts little expansion in 2013 and 2014 in developed markets. Private sector balance sheets look too stretched to sanction new projects and European recovery looks pale. Also, developed markets (we have included EU, NAFTA, CIS and Japan) production has remained stagnant since 2000 with meagre growth of 0.5% CAGR 2000-2005 followed by decline -1.7% CAGR 2005-2010, amid the global financial crisis. In absolute terms, our Metals & Mining colleagues expect production of these nations in 2011 to be at level of 2000, implying no growth in last 11 years. For 2010-15e, production growth of c2.7% CAGR is expected, broadly based on recovery in the US and European markets. We believe tonnage demand for oxygen for steel sector in developed markets will follow this growth rate and thus expect growth in range **of c2%-3% for next five years**.

Figure 78. Developed and Emerging market production



Source: CRU , IISI , MB, CIRA estimates

Figure 79. Global capacity additions 2011e-15e



Source: CRU , IISI , MB, CIRA estimates

China and India will account for c70% of new capacity expansion over next five years, excluding the replacement of old capacity

We expect steel production of developing nations to grow at c5.3% CAGR 2010-15E. 70% of this growth will be capacity additions in China and India (see Figure 78. Developed and Emerging market production). Chinese steel production is expected to grow at c3.1% CAGR 2010-15e, as the focus of the country has shifted to effective and efficient use of energy resources. (For details on the China efficiency drive, please refer to our note *Yara International (YAR.OL) - Chinese Energy Policy likely to Support Strong Profit Outlook*, 26 August 2011, highlighting China cutting energy intensive capacities and energy intensive exports as per its 12th FYP).

The Chinese government plans to consolidate its fragmented market by achieving 70% of its domestic production through China's top 10 mills by 2020, up from ~50% in 2011. This will involve closure of c26mn tonnes of old, inefficient capacity and the building of mega scale integrated plants. Baosteel alone is looking to build an ultra-large 10mn MT integrated plant in Zhanjiang provision. Since capacity expansion plans do not include these net off expansions, we believe this will provide another good expansion opportunity for Industrial gases to capture market share in developing markets. Another important factor to note is that increase in demand for oxygen also creates demand for its co produced gas, argon and nitrogen which can be used in steel and other manufacturing processes.

Linde and Air liquide are front runners to capture fast growing Indian market. Air Liquide is planning to invest c$2bn in India over next 10 years

Another major growth region in emerging markets will likely be India, which is expected to grow the fastest in the world with c17% CAGR growth in industrial gas capacity from 2010-15e. India has a very large requirement for its local infrastructure and is looking at major expansion plans in the steel sector. According to MCI, India will attract c$69bn of investment in steel sector at its 3 major steel production hubs alone with c35 new projects in pipeline. Major industrial gas companies are already playing a major role in emerging markets and have been successful in winning new steel contracts in emerging markets like India and China. We have listed few major projects awarded to these companies in emerging markets to showcase the scope and extent of their growth.

Figure 80. Major ASU projects for steel industry undertaken by Air Liquide and Linde in emerging markets

Company	Region	Steel grouo	ASU capacity - TPD	Capex - €Mn	Startup	Description
Air Liquide	China	Bohai Steel Group	2200	55	Q2 2011	Long-term contract with Bohai group to supply oxygen to its plant in Hebei province
Air Liquide	China	Jianbang Group	800	20	Q2 2011	Long-term contract with Jianbang Group to supply oxygen to its plant in Shanxi Province
Air Liquide	China	Dongnei group	800	25	Q3 2011	Extension of contract signed with Dongnei group in 2007
Air Liquide	Russia	Severstal	2000	50	Q4 2011	Air Liquide in JV with Severstal to upgrade capacity based at Cherevopets. It will bring the total production capacity of ASU on this site to 5,000 tpd
Air Liquide	China	Xilin Steel Group	1200	40	Q1 2012	Strategic investment into leading northeastern industrial region of China
Air Liquide	India	RINL	1800	70	Q4 2012	Long-term contract with RINL for its steel plant expansion from 3 to 6.3mn. Air Liquide also will produce other liquid gases from this plant to meet the needs of the industrial and medical customers in the region.
Air Liquide	Ukraine	Metinvest	1700	100	Q2 2014	Long-term contract with Metinvest for its I&SW facility in the Donetsk region. Air Liquide will also supply liquid gases to other industries in Ukraine
Linde	Kazakhstan	ArcelorMittal	2000	95	Q2 2012	Long-term contract with ArcelorMittal Temirtau to supply the Temirtau steelworks with oxygen and nitrogen gas
Linde	India	Tata Steel	2550	90	Q4 2012	One of the largest ASU for Tata steel plant in Jamshedpur. Under contract, BOC will also acquire TATA Group's other three ASUs (c1475tpd) on this site
Linde	India	SAIL	1706	72	Q4 2012	BOC India (Linde Group subsidiary) will supply 2600 tpd by installing 2 ASU at the site. BOC will also produce nearly 400 tonnes of addition liquid products for local industrial demand
Linde	Indonesia	Posco	3000	88	Q4 2013	To supply 2000 tpd of oxygen for 3mn MT steel plant in the Celegon area, west of Jakarta. Linde will also supply liquid products for industrial demand

Source: Company Press releases, Market data and Citi Investment Research and Analysis

In summary, we believe major industrial gas players are well poised to capture growth from developing regions, thus delivering growth **rate of c8%-12% CAGR 2010-15E** for their tonnage business of oxygen or c2x of steel production growth expected in these emerging markets.

New Technologies and Carbon Capture

Though emissions and the energy intensity of steel industry has improved over time, there is still scope for improvement. ULCOS (Ultra-Low CO2 Steelmaking), a consortium of 48 European companies and organisations from 15 European countries, has launched a cooperative research and development initiative to enable a drastic reduction in CO2 emissions (c50% from current processes). This programme completed its first phase which was initiated in Sep 2004 for assessing various technologies for demonstration feasibility. Now it has rolled out Phase II of the programme where four families of process routes have been selected for further investigation. These new technologies for steel production offer good growth potential for the gas companies as most of new processes are based on extensive use of oxygen. We have not included this potential in our forecasts, as the results of ULCOS II are expected only to roll out in next15-20 years, but this technology change designed to lower energy use the sustainability of the steel industry as a growth driver for the gases sector in the long term.

- **Blast Furnace with TGR (Top Gas Recycling) and CCS** – This is a radical re-examination of the process which currently dominates iron making. Replacement of hot air **by pure oxygen** and the recycling of the top gas into the furnace is the most promising line of research. A key step in that process will be the capture and storage of CO2 from the furnace top gas. The New Blast Furnace will remain a coke-based process which will produce liquid iron suitable for conversion to steel in the current way. This process is in the demonstration phase and is expected to be the first process to be rolled out commercially.

- **Hisarna** – This process uses a Cyclone Converter Furnace (CCF) instead of traditional blast furnaces. In this process, crushed iron ore and oxygen are used to reduce iron ore to iron. Then this molten crude iron is passed through a second set of **heated oxygen injectors** and coal powder cannons which refines iron to pig iron which can then directly be used in BOFs for steel manufacturing. Furthermore, it is a flexible process that allows partial substitution of coal by biomass, natural gas or **hydrogen**. Its pilot project is expected to be commissioned at Tata Steel's 60000 tpa plant in the Netherlands.

Out of 4 listed processes, 3 of them use oxygen instead of air and once rolled out will increase the market for tonnage-based oxygen contracts

- **ULCORED** – Under this process, Direct-reduced iron (DRI) is produced from the direct reduction of iron ore (in the form of lumps or pellets) by a reducing gas produced from natural gas with a partial oxidation which **uses 100% oxygen instead of air** for used in reformer. This process constitutes the possibility to be used with **syngas** from coal (**which uses oxygen for coal gasification).** The first pilot project is expected to be constructed in 2012.

- **Two electrolysis variants** – Two variants of the electrolysis process: alkaline electrowinning and pyroelectrolysis will be tested in phase 2. The pilot projects for these technologies are not expected soon as they rely on carbon lean electricity, such as nuclear or hydro power.

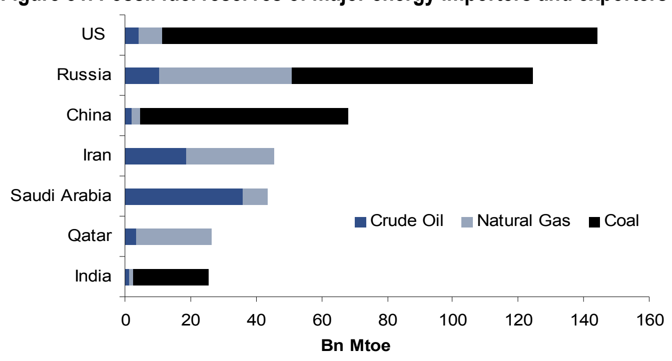
2) Gasification – Clean and cheap energy source

The US, China and India remain energy importers despite holding huge fossil fuel reserves

Current gasification technology is viable at prevalent energy prices

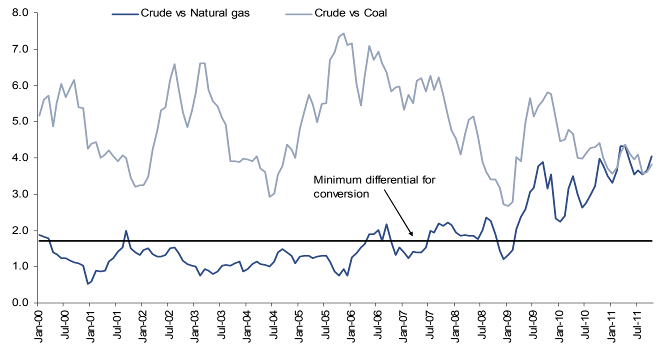
Fossil fuels are the major source of energy worldwide and will remain so in foreseeable future. There are three major forms of fossil fuels – coal, natural gas and crude oil, but the value of these resources vary widely with crude oil being the most expensive of the three due to the ease of its use in transportation. Currently crude is trading at c$100/bl, and on a comparative basis natural gas and coal prices in the US are just c$26/bbl and c$19/bbl. Gasification technology can convert these natural gas and coal reserves into either fuels or chemical intermediates, exploiting the low cost of these materials versus the high price of crude oil. Part of the calorific value of these fuels is consumed in the process (that it is takes significant amounts of energy to convert these materials into useful/transportable products), but current price differentials makes them a viable alternative to crude oil.

Figure 81. Fossil fuel reserves of major energy importers and exporters



Source: BP, Citi Investment Research and Analysis

Figure 82. Relative value of crude vs coal and natural gas



Source: Sasol, Bloomberg, Citi Investment Research and Analysis

Syngas output has increased c26% from 2007 levels with 144 operating plants and 412 gasifiers worldwide. The US DoE has listed 48 projects in the start-up, construction, design and development phase. The US and China are front runners with 18 and 17 projects listed for both countries respectively under various stages of planning. These projects present material growth opportunity for industrial gases which we estimate will deliver **c10% CAGR growth** in 2011-15e for syngas output.

Figure 83. Gasification plants planned worldwide — 2011-16e

Plant Owner	Country	Year	Status	Syngas Capacity (MWth)	Feedstock	Product Classification
Datang MTP	China	2011	Startup	3,379	Coal	Chemicals
Duke Energy	United States	2011	Construction	1,154	Coal	Power
Shanghai Huayi Group Company	China	2011	Construction	682	Coal	Chemicals
Shandong Shengda Co., Ltd	China	2011	Construction	859	Coal	Chemicals
Huaneng Group	China	2011	Construction	750	Coal	Power
Hebi Coal & Electticity Co., Ltd	China	2012	Construction	546	Coal	Chemicals
Nuon Power	Netherlands	2012	Construction	1,925	Coal	Power
Vinachem	Vietnam	2012	Construction	109	Coal	Chemicals
Datong	China	2013	Construction	546	Coal	Chemicals
YYTH Shuifu	China	2013	Construction	232	Coal	Chemicals
Mississippi Power	United States	2014	Construction	683	Coal	Power
Yankuang Group	China	2011	Development	459	Coal	Chemicals
CNOOC Group	China	2011	Development	420	Coal	Chemicals
CNOOC Group	China	2011	Development	295	Coal	Chemicals
Faustina Hydrogen Products LLC	United States	2012	Development	1,154	Coal	Chemicals
Rentech Development	United States	2012	Development	1,431	Coal	Liquid fuels
confidential	United States	2012	Development	1,802	Coal	Liquid fuels
Shanxi Lanhua Coal Chemical Co., Ltd.	China	2012	Development	874	Coal	Chemicals
China Huadian Power Group	China	2012	Development	377	Coal	Power
Shandong Jiutai Co. Ltd.	China	2012	Development	1,914	Coal	Chemicals
Yankuang Group	China	2012	Development	963	Coal	Chemicals
Shanghai Huayi Group Company	China	2012	Development	448	Coal	Chemicals
Lima Energy Company	United States	2013	Development	2,553	Petcoke	Power
Secure Energy Decatur, LLC	United States	2013	Development	915	Coal	Gaseous fuels
TransGas	United States	2013	Development	1,802	Coal	Liquid fuels
Australian Energy Company	Australia	2013	Development	765	Coal	Chemicals
confidential	Spain	2013	Development	4	Biomass/Waste	Chemicals
confidential	France	2013	Development	25	Biomass/Waste	Liquid fuels
Valero Energy Corp.	United States	2014	Development	2,451	Petcoke	Gaseous fuels
ICM	Mongolia	2015	Development	1,802	Coal	Liquid fuels
Future Power PA	United States	2015	Development	1,851	Coal	Power
Tenaska	United States	2015	Development	928	Coal	Power
Queensland Government	Australia	2015	Development	1,590	Coal	Power
Dongguan Tianming Electric Power Co., Ltd	China	2016	Development	141	Coal	Power
Powerfuel	United Kingdom	2011	Design	1,283	Coal	Power
Synthesis Energy Systems	China	2011	Design	512	Coal	Chemicals
Excelsior Energy	United States	2013	Design	1,475	Coal	Power
Perdaman Chemicals and Fertilisers Pty Ltd	Australia	2013	Design	1,283	Coal	Chemicals
Leucadia Energy LLC	United States	2014	Design	2,230	Petcoke	Chemicals
POSCO	South Korea	2014	Design	942	Coal	Gaseous fuels
Summit Power	United States	2014	Design	969	Coal	Polygen
Korea West Power	South Korea	2014	Design	573	Coal	Power
Capital Power Corporation	Canada	2015	Design		Coal	Power
Mississippi Gasification LLC	United States	2015	Design	1,720	Petcoke	Gaseous fuels
KOWEPO	South Korea	2016	Design	355	Coal	Power
Peabody Energy/ConocoPhillips	United States	2016	Design	1,073	Coal	Gaseous fuels
ConocoPhillips	United States	2016	Design	1,916	Petcoke	Power
Hydrogen Energy International	United States	2016	Design	1,150	Petcoke/ coal	Power

Source: DoE, Citi Investment Research and Analysis

Gasification – Growth potential c10% CAGR 2010-15E

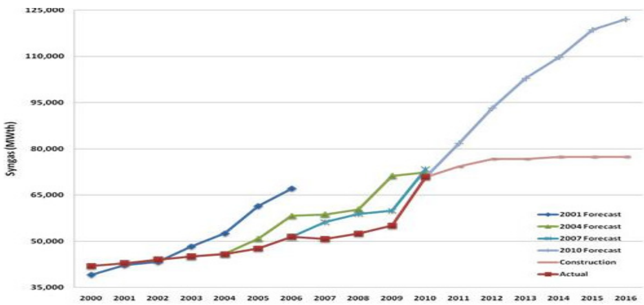
Process Background: Gasification of coal means its partial combustion with use of relatively less oxygen than would be required for its combustion. This 'partial combustion' results in the production of synthetic gas containing CO and H2, known as 'Syngas'. This Syngas has half the energy density of natural gas but can further be refined and used for production of various chemical products or can be used as gaseous fuels, liquid fuels or for clean generation of power

Gasification is a fast emerging megatrend where low-cost gas and/or cheap coal is converted into usable fuel/chemicals. This particular application is looked upon as a substantial market opportunity for industrial gases. As shown in Figure 84, the US DoE's latest projection lagged the actual growth in the industry driven by strong oil prices and a clean coal drive by China, focusing on efficient and effective use of its coal resources. In 2008-11, 21 gasification projects came on-stream – 17 of them were focused on converting coal to chemicals, all based in China.

Shell also came up with its mega Gas-to-Liquid (GTL) plant in Qatar, but we do not expect this technology to grow much as LNG is seen as a more profitable and viable alternative for monetising stranded natural gas resources.

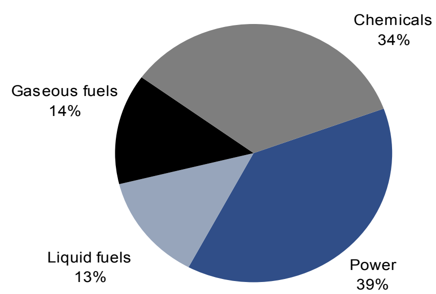
As per the DoE gasification database, Chemicals and Power will be the main driver of gasification for future projects, with coal as main feedstock. The development of these projects also depends upon future crude oil prices, government support/ incentives and technology advancement. Another important factor is energy independence, as all the major energy-consuming countries (US, China, Russia) have large coal resources. We believe this will incentivise governments to focus on technology R&D, leading to further developments in this field.

Figure 84. World gasification planned growth forecast comparison



Source: DoE

Figure 85. Planned capacity by product and end use



Source: DoE, Citi Investment Research and Analysis

Figure 86. Gasification plants started during 2008-2011

Plant Owner	Country	Year	Syngas Capacity (MWth)	Feedstock	Product Classification
Sokolovska Uhelna, A.S.	Czech Republic	2008	355	Petroleum	Power
Shenhua	China	2008	860	Coal	Liquid fuels
Henan Yima Kaixiang Group	China	2008	235	Coal	Chemicals
Zhong Yuan Dahua Group Ltd.	China	2008	466	Coal	Chemicals
Skive Fjernevarme	Denmark	2008	32	Biomass/Waste	Power
Fujian	China	2009	867	Petroleum	Chemicals
ENN Group	China	2009	623	Coal	Chemicals
Jiangsu Linggu Chemicals Co.,Ltd.	China	2009	387	Coal	Chemicals
Jiangsu Sopo Group	China	2009	708	Coal	Chemicals
Qatar Petroleum	Qatar	2010	10,923	Gas	Liquid fuels
Tianjin Bohai Chemical Group	China	2010	1,126	Coal	Chemicals
Guizhou Tianfu	China	2010	563	Coal	Chemicals
Shenhua Ningxia Coal Group	China	2010	765	Coal	Chemicals
Shenhua Ningxia Coal Group	China	2010	721	Coal	Chemicals
Ningbo Wanhua Co.Ltd.	China	2010	492	Coal	Chemicals
Tianjin Bohai Chemical Group	China	2010	1,126	Coal	Chemicals
Guizhou Tianfu	China	2010	563	Coal	Chemicals
Shenhua Ningxia Coal Group	China	2010	765	Coal	Chemicals
Shenhua Ningxia Coal Group	China	2010	721	Coal	Chemicals
Ningbo Wanhua Co.Ltd.	China	2010	492	Coal	Chemicals
Datang MTP	China	2011	3,379	Coal	Chemicals

Source: DoE, Citi Investment Research and Analysis

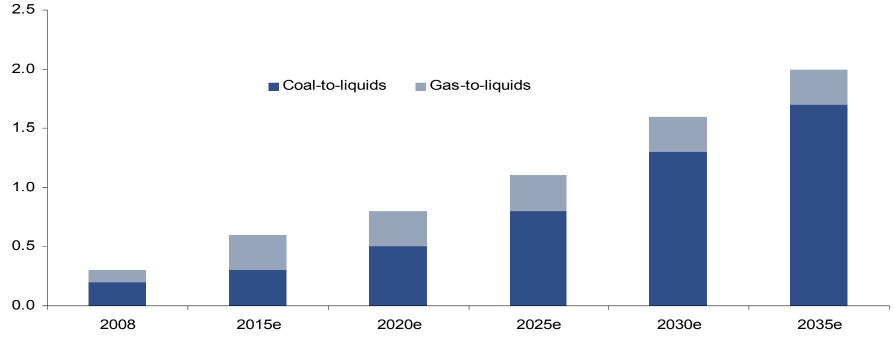
a) Coal to Liquid/Gas-Market to grow at c10% CAGR

Process Background: Coal can be converted into liquid fuels by either using direct Liquefaction where coal is dissolved in a solvent at a high temperature and pressure or through indirect liquefaction where coal is gasified to form 'Syngas' using a gasification process. While direct liquefaction requires a refinery to produce end products, Syngas can be condensed directly over a catalyst using the 'Fischer Tropsch' process to produce high quality, ultra clean petroleum and diesel products.

CTL is not new technology and has been commercially used in South Africa since 1955. Currently c30% of South Africa's gasoline and diesel needs are produced from indigenous coal, and the total capacity of its CTL operations is more than 160kboe/d. Since CTL technology is particularly suited to countries relying on oil imports, the US is looking to invest heavily in this technology, with seven new plants under development due to come onstream in the next five years. The scale of oxygen required for these projects is vast. We estimate that on average a CTL facility requires about c6-c8 tonnes of oxygen per MWth of syngas capacity. This means new projects in the US alone would require c22-c30 ASU plants with an average capacity of 3000 tpd, **warranting c€1.7-€2.3bn** investment from industrial gas companies.

GTL technology, which looked promising in 2007, has seen no new interest after the start-up of Shell's mega plant in Qatar. This is due to the development of the LNG market, which is cheaper and a more profitable avenue to monetise gas resources. No new GTL plants are in pipeline at the moment and the DOE does not expect any growth in this area for next 20 years in its latest estimates.

Figure 87. CTL market to grow at c10% CAGR for next 20 years



Source: DOE-IEA 2011, Citi Investment Research and Analysis

b) Coal to Chemicals – a booming trend in China

Taking one step further, China has focused on using 'Syngas' produced from coal gasification for the purpose of producing high value chemical products. On a cash cost basis, China's coal to olefin (CTO) is **c$230-c$250/tonne cheaper than naphtha based crackers,** which has led to a boom in new investments in this sector. Traditionally, the CTCM industry meant converting coal to ammonia, acetylene and methanol, but with rising crude oil prices, the focus is now on producing products which can replace petroleum derivatives, such as olefin, dimethyl ether, methanol and MEG.

China can invest c€75bn in CTO plants over next five years

The US DoE expects 14 new CTCM plants in China, CMAI lists 19 new projects to start up by 2016, whereas various press releases suggest there were 29 coal-to-olefins projects under construction or being planned in China, with total olefin capacity output projected at more than 20 million tonnes per year by the DoE. Total **investment in** the sector is expected to exceed **RMB 630 billion (c€75bn**). Figure 88 lists seven key projects based on CTCM technology listed by CMAI which it expects will be commercially operational by 2016.

Figure 88. Key coal to chemical capacity additions in China

Company	Location	Startup Timing	Facility
Shenhua	Ningxia	2015	1,500 KTA MTO
CNOOC/Shell JV	Guangdong	2016	1,000 KTA ethylene complex
PetroChina	East China	2016	1,000 KTA ethylene/600 KTA PX complex
PetroChina	Yangzhou	2016	1,000 KTA PX complex
Hainan JV	Hainan	2016	1,000 KTA ethylene/600 KTA PX complex
Qingdao PC	Qingdao	2016	1,000 KTA ethylene
Dalian PC	Dalian	2016	1,000 KTA ethylene
Total			**Ethylene: 5,750 KTA; PX: 2,200 KTA**

Source: CMAI

Demand for oxygen also helps industrial gas companies to increase their bulk liquid trade for other air gases

We estimate that c25-33 new ASU plants with an average capacity of 3000tpd will be required for the DOE projected CCTM facilities. This would warrant **a c€1.8-€2.5bn** market for industrial gases for ASU instalments alone. These estimates do not include other clean environmental initiatives like gas cleanup, sulphur removal and carbon capture. Moreover, most of the new projects are located in the industrialised provinces of Shanxi, Shaanxi, western Inner Mongolia, Xinjiang, which provides industrial gas companies a good opportunity to increase their footprint in the merchant liquid market. In Figure 89, we list a few major projects awarded to these companies in China for CTCM plants to showcase the scope and extent of their growth.

Figure 89. Major contracts awarded to industrial gas companies for coal to chemical plants

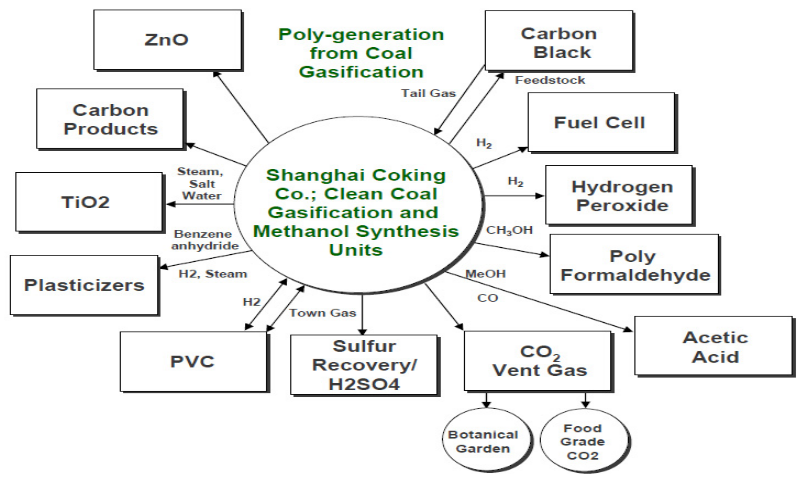
Company	Location	Capacity-TPD	Description
Air Liquide	Shaanxi	2800	E&C project for two new ASU for the new complex of Shaanxi Yanchang Petroleum Group. The project will produce polyethylene and polypropylene
Air Liquide	Shandong	4200	E&C project for two new ASU for Shandong Hualu Hengsheng group for of its new acetic acid plant.
Praxair	Anhui	3300	Long-term contract to supply oxygen for c600 ktpy methanol plant of Huayi group. Praxair is also strategic partner for phase-2 and phase-3 expansion which will require c4-5 new ASU plants with T-3000 capacity
Praxair	Jiangsu	3300	Long-term contract with SOPO group to supply oxygen for its acetic acid plant. In addition, this plant will be used to supply liquid gases in East China market
Air Liquide	Shaanxi	2000	Long-term contract with Datong coal group for its first phase of methanol project. Forecast capex for the project is c€60m and is expected to start in Q3 2012
Air Products	Shaanxi	8200	Long-term contract with PCEC for three ASU trains. These units will also supply liquid products to merchant market in the region and is expected to on-stream by Q3 2013
Air Products	Nanjing	1500	Long-term contract with Nanjing Chemicals to supply oxygen for its coal to syngas facility by 2014. Air Products already have two ASUs at this location for their petrochemical facility and merchant market

Source: Company reports, market data, Citi Investment Research and Analysis

Another upcoming technology is coal polygeneration where Integrated Coal-to-Chemicals is used to generate both chemicals and power. This process uses IGCC technology to produce power, which is currently the least taxing technology for clean power generation. This is seen as the next step of coal to chemicals projects but requires expertise in both power and chemicals, making it a complex situation for current industry players. It also requires substantial upfront investment, as these plants need a certain level of scale to be economical. Development of these projects largely depends upon the efficiency improvement of IGCC plants, which we discuss in our technology section later.

In this process, electricity is produced in conventional IGCC systems, while commodity chemicals (methanol, ammonia, and their derivatives such as olefins and acetic acid from methanol and fertilizers from ammonia) or liquid fuels (methanol, diesel, dimethyl ether (DME), and gasoline) are produced via state-of-the-art chemical processes.

Figure 90. Polygeneration from coal gasification



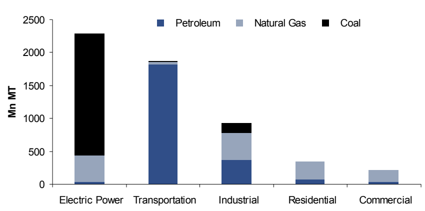
Source: Praxair

c) Coal gasification for power plants – Environmental megatrend

The US DoE expects world energy demand to increase by c1.7% CAGR 2010-2020E driven by demand from electricity generation and industrial usage (Figure 92). Current environmental focus and the increased scarcity of finite fossil fuels means renewable energy (including nuclear energy for electricity generation) is the fastest growing fuel this decade and we estimate it will increase its overall energy share from c16% in 2010 to c20% by 2020.

Carbon emissions are expected to play an important role in fuel choice

Figure 91. US carbon emissions by fuel



Source: DoE, CIRA

The next choice of fuel is natural gas which is believed to be available in abundance compared to other fossil fuels and is most clean in terms of carbon emissions. Technological advancement in US shale gas means it is also available cheaply for the world's largest economy and consumer of energy.

Liquid fuels, mostly derivatives of crude oil, are expected to maintain their overall energy share due to their dominance in transportation. In other sectors, the use of liquids fuel is on the decline since crude oil is the most expensive and scarce fossil fuel. Demand for coal is expected to grow least, despite being cheapest and most abundant fossil fuel. We believe the main reason for the decline in its energy share is mounting environmental concerns, as **coal emits c175% more CO2 than natural gas**, its closest comparator based on pricing.

Figure 92. World energy consumption by end-use sector and fuel – Quadrillion Btu

	Liquids			Natural Gas			Coal			Renewable			Total		
	2010	2020e	CAGR	2010	2020e	CAGR	2010	2020e	CAGR	2010	2020e	CAGR	2010	2020e	CAGR
Residential	10	9	-0.9%	22	23	0.8%	4	5	0.4%	0	0	0.0%	36	37	0.3%
Commercial Sector	5	4	-0.7%	9	10	0.9%	1	1	0.8%	0	0	0.0%	15	15	0.4%
Industrial Sector	53	59	1.1%	54	65	1.8%	44	54	2.2%	14	17	2.2%	165	195	1.7%
Transportation Sector	96	115	1.8%	4	4	0.8%	0	0	-6.7%	0	0	0.0%	100	119	1.8%
Electricity	10	9	-1.0%	39	47	1.9%	89	94	0.5%	68	103	4.2%	206	253	2.1%
Total	**173**	**196**	**1.2%**	**127**	**148**	**1.6%**	**139**	**154**	**1.1%**	**83**	**121**	**3.9%**	**522**	**619**	**1.7%**

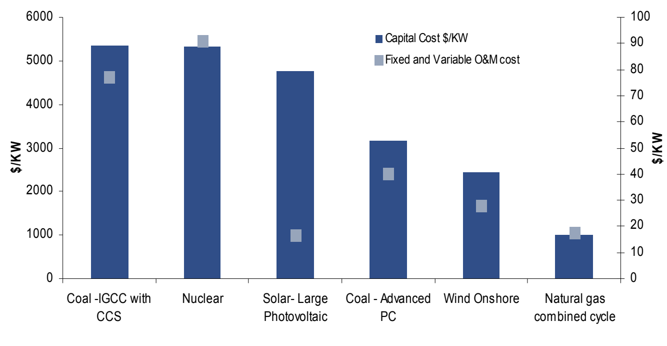
Source: DoE, Citi Investment Research and Analysis

Current economics and dynamics favour renewable and NGCC plants

Based on current capital costs and forecast fuel prices, LECO from coal-based plants are c62% higher than natural gas-based power plants

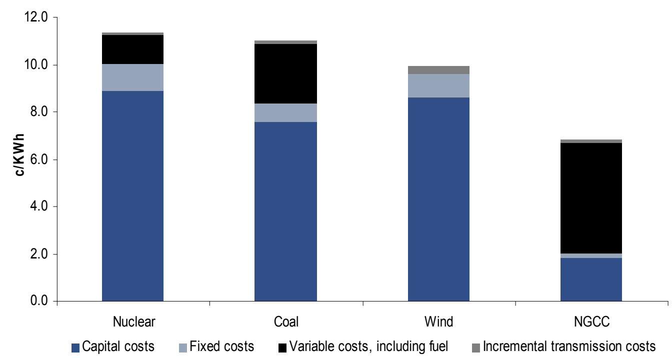
The DoE recently updated its forecast costs for building new power plants in US. The average cost of building a new IGCC plant has gone up significantly, up c37%, from last year's estimates. This is due to the increase in prices of basic materials in general and the availability of few vendors for the complex engineering requirements of new age coal plants. Thus most of the new unplanned additions should be either renewable sources of energy or natural gas-based power plants on the basis of lower upfront costs and low operating costs (due to the shale gas boom). As shown in Figure 94, the levelised electricity cost (LECO) of a natural gas-based plant is c62% lower than coal or nuclear fuel-based power plants.

Figure 93. Estimated cost to build and operate power plants -2011e



Source: EIA, Citi Investment Research and Analysis

Figure 94. Levelized electricity costs for new power plants - 2020



Source: EIA, Citi Investment Research and Analysis

But coal has quite a few advantages over both

In summary, the main theme that emerges is that coal based power generation is likely to remain key to the electricity industry and will require a carbon emission solution other than the replacement of existing plants.

There are few drawbacks with these new sources which weigh high in the decision-making for long-term capital investment. First, there are concerns regarding the stability of renewable power and in most cases they need expensive back up. For natural gas plants, fuel costs are an important factor which has been highly volatile in recent times. The DOE has assumed c$6/mmbtu as the long-term Henry hub price in its 2020 LECO scenario. Although this assumption looks reasonable given current conditions of the US natural gas industry, it is worth noting that natural gas prices in other parts of world are as high as c$16/mmbtu, trading on crude oil parity. If US gas producers decide to participate in the world LNG market, we believe US gas prices could go as high as c$11/mmbtu, which will be the breakeven point between IGCC and NGCC plants from an LECO prospective.

Thus we believe coal-based plants will maintain their attractiveness despite being under **cost** pressure in recent times. They also gain on **low variable operating cost**, which if increased even by c100% due to fuel prices changes, their LECO will increase by just c23% vs. c69% increase for a natural gas based plant.

Coal resources are in **abundance** for major power consuming nations such as the US, China, India and Australia and they would like to continue to utilise local resource rather than import expensive energy.

Coal-powered electricity in 2010 accounted for about 78% of total power generation in China, 63% in Australia/New Zealand, 62% in India, and 45% in the US. Moreover just adding new clean electricity capacity won't make the desired difference on emission levels. We believe the mega theme that emerges out of this discussion is the need for investment from emerging coal plants to make them emission compliant. Current technologies allow c95%-c100% carbon capture allowing coal to emerge as green fuel.

While gasification of coal for CTL/CTCM is driven by fuel economics, gasification of coal for power projects is driven by environmental megatrend (as of now)

As per the DOE database, c39% of gasification projects proposed in the next five years are power projects, broadly based in US. This is a completely new addition to coal gasification demand and the potential of this sector is significant. Most of these projects are in the demonstration phase, funded by governments under environmental commitments, as current technologies for coal gasification require substantial capital investment and require huge scale due to the need for low unit costs. These plants will also need to operate at high loadings to ensure operational efficiency.

We believe the impetus on R&D and an effective policy for the carbon market (see details in the carbon section) can make these technologies commercially viable post 2020. According to MIIT, a 500 MW coal power plant requires 10,000 tpd of oxygen for coal gasification technology. This means **c1,450 new ASUs** with average capacity of 3000tpd of oxygen will be required to **convert just c10%** of world coal-based power generation capacity. We have not included these estimates in our forecasts as they are beyond the foreseeable future but indicate substantial growth potential for the oxygen market.

Technologies for carbon capture and storage (CCS) and current developments

Currently the only proven CCS technology is amine scrubbing. It can recover c90% of CO2 but is highly energy-intensive and reduces the power output of a plant by c25%-30%. An alternative to this approach is oxy combustion technology, where either coal is converted to syngas using oxygen for the gasification process (commonly referred as IGCC plants) or coal is burned with pure oxygen under certain conditions to generate carbon dioxide only. This makes it simpler to capture CO2 from flue gas. We have listed the details of these key technologies below:

The post-combustion technique adds c76% to PC plant costs due to the additional capex for absorption systems and reduced plant efficiency of c25%. The cost of CO2 captured in this process is around c$58/MT.

- **Post-combustion:** The process of recovering and transforming low concentration CO2 from flue gases and make it viable for sequestration. Currently this process uses a chemical absorption process with an MEA based solvent. This technique has an advantage over IGCC as it **can be retrofitted to existing** coal-fired power and offers flexibility as it can be switched on and off without affecting the functionality of power plant. Also this technology is the only option for natural gas-based plants though carbon capture costs are higher than for coal-based power generation due to the relatively lower level of carbon emitted by natural gas plants. The main problem with this technique is the loss of efficiency of a plant as c25% of power produced by a power plant is consumed in this process. Currently lot of research is under way to improve this parasite power loss. Various new absorption materials are under testing to provide an effective alternative to traditional MEA. An alternative approach to capture CO2 is also gaining momentum, known as membrane absorption. The state of development

of these various approaches varies widely and currently MEA is the only option for post-combustion carbon capture.

Pre-combustion is most promising technique available, but since this option cannot be used for existing plants, it loses out on commercial scale to new UCPC plants which have c19% lower operating costs and c7% lower capital requirements. The cost of CO2 captured in this process is around c$43/MT.

- **Pre-combustion:** This process involves gasification of coal to produce syngas which is then converted to produce CO2 and H2 streams. The recovered CO2 is highly concentrated and can be compressed into liquid and transported to a storage site. The problem with this particular technology is that it **cannot be retrofitted to existing coal plants** and the current cost of new plants based on this technology, known as IGCC, is very expensive due to the **requirement of large air separation units**. This process has an energy penalty of c18% despite a c8% improvement in fuel efficiency of a plant. So far only two IGCC plants are operational in the US, both were constructed for demonstration purpose and are not considered as commercially viable, with another four are in various stages of development. Large-scale ASUs (c10,000 tpd or more) with improved operational efficiency could improve its viability but we do not expect large scale commercial roll out of these projects any time soon.

Oxy fuel is currently the most expensive technique among current CCS options due to requirement of expensive ASUs. But it is the most effective technique for existing plants. The cost of CO2 captured in this process is around c$52/MT.

- **Oxy-combustion:** In this process, coal is burned in pure oxygen instead of air, which improves the efficiency of existing plants and removes nitrogen from flue gas, allowing more effective and efficient capture of carbon from flue gas. This option **can be used for existing plants** but has a higher parasite energy problem than pre-combustion. Moreover energy efficiency gains are hard to realise when this method is used for old plants, pushing parasite limits further. As discussed above, more efficient large scale ASUs are essential for its commercialisation.

The major issue for all the techniques mentioned above is parasite power needs, which reduces the overall efficiency of power plants and increases LCOE by c40%-60%. For post-combustion technology, c54% of the power penalty is due to energy required for the chemical reaction to capture carbon from the flue steam and the rest is consumed by pumps, fans and compressors to produce a saturated stream of carbon for transportation and sequestration. For oxy fuel technology, overall efficiency loss is lower than PCC due to efficiency gained from the better combustion of fuel (c8%) but still parasite power loss accounts for c18%-c23%. Most of this power, **c59% of efficiency loss,** is due to power consumed by the ASU unit and the rest is consumed by the carbon compressors and fans.

We believe a c30%-40% reduction in carbon capture cost can make these technologies commercially viable as captured carbon can be used for Enhanced Oil Recovery (EOR). For details see our carbon section

Figure 95. Cost comparison of current CCS technologies

Reference plant	Post Combustion	Pre Combustion	Oxy Combustion
Net efficiency w/o capture	41.4	40.6	41.5
Net efficiency w/capture	30.9	33.1	31.9
Net efficiency penalty	10.5	7.5	9.6
% efficiency loss	**25%**	**18%**	**23%**
Overnight cost w/o capture ($/KW)	2161	2586	2263
Overnight cost w/capture ($/KW)	3808	3714	3959
Overnight cost increase ($/KW)	1647	1128	1696
% overnight cost increase	**76%**	**44%**	**75%**
LCOE w/o capture ($/MWh)	66	75	62
LCOE w/capture ($/MWh)	107	104	102
LCOE increase ($/MWh)	41	29	40
% LCOE increase	**62%**	**39%**	**65%**
Cost of Co2 avoided ($/tCO2)	**58**	**43**	**52**

Source: IEA, Citi Investment Research and Analysis

New technology background: ITM is a technology for gas separation that works by transporting ionized gas through a ceramic membrane. ITM's very high flux and high selectivity contribute to reductions in both capital and operating costs.

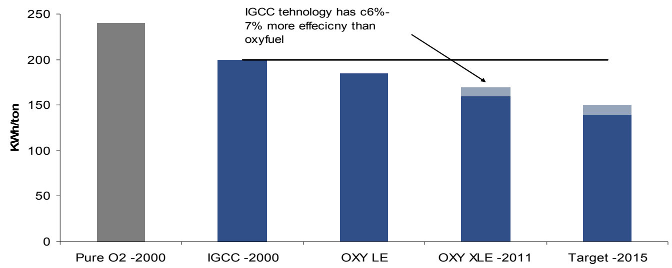
Thus improving the efficiency of ASUs or finding a cheaper way to produce bulk amounts of oxygen is the main area of research for industrial gas companies. Cryogenic separation is a mature technology and has involved over time. Current technology is capable of producing c8000 tpd ASU, and Air Liquide's ASU development programmes optimised for oxy-combustion, OXY LE (Low energy) and OXY XLE (Extra Low Energy), has already improved energy efficiency from traditional ASUs by c30%. Further improvement could yield **c10%-12% energy** efficiency gains, we believe, and these new generation ASUs are expected by the industrial gas majors to be commercialised by 2015. An alternative to ASU projects to produce economical oxygen is ITM technology conceptualised by Air Products. It is in the testing phase now, and Air Products has started construction of a c100tpd demonstration project in Louisiana which is partly funded by DOE. The ultimate aim is to produce a 2000tpd plant by 2015 and it is believed that these plants can ultimately deliver commercially-viable CCS technology.

Figure 96. ITM technology vs ASU

Application	Oxygen (sTPD)	Power (MW)	Capital for Oxygen	Power for Oxygen
IGCC	3200	458	35%	37%
Decarbonized Fuel	2400	300	35%	36%
Enrichment	1500	260	27%	69%
Oxy fuel	8030	500	48%	68%
GTL	12500	n/a	20%	n/a

Source: Air Products, Citi Investment Research and Analysis

Figure 97. ASU efficiency has improved over time



Source: Air Liquide, Citi Investment Research and Analysis

3) Healthcare — 6% p.a. growth forecast

The healthcare market for industrial gases includes medical gas supply, respiratory equipment for home care and medical hygiene products. Air Liquide, global leader of this segment among industrial gases, estimates that global market for industrial gases in 2009 was worth c€21bn (€4bn for medical gases, c€9bn for home care and c€8bn for medical hygiene).

We believe the main focus and market for industrial gases is oxygen, which is mostly provided to hospitals as bulk trade. The home care market is highly fragmented with specialist home care companies having the bulk of share instead of industrial gas companies, though overall the home care market is expanding rapidly.

Overall, we believe the global market can grow at c6% CAGR 2010-15E, with emerging markets growing at double the pace of the world market, albeit from a smaller base. Developed markets have c87% market share, with the US being the largest market followed by Western Europe and Japan. These markets are expected to grow by c4% CAGR, driven by an ageing population in Europe. The main industrial gases used for medical purposes are:

Oxygen is the main industrial gas used for medical purposes

- **Oxygen** — used to boost blood oxygen levels. It is also used to aid breathing, for example for those suffering from respiratory diseases and during operations. Most oxygen treatments use a mix of oxygen in varying concentrations with other gases. Oxygen supply schemes and added value services represent about 85% of the market and should continue to do so.

- **Nitrous oxide** — This is used both as an anaesthetic (inhalational anaesthesia) in combination with other drugs and as an analgesic without loss of consciousness when mixed with oxygen (this is gas and air mixture used on maternity wards).

- **Specialty gases** — **Nitrogen** for cryotherapy (removal of warts in dermatology) and in cryconservation, to preserve blood, cells, body fluids or tissue samples. **Carbon dioxide** for cryotherapy (as with nitrogen) and in keyhole surgery to enlarge and stabilise body cavities to improve visibility while operating. **Helium** — the refrigerant liquid in Magnetic Resonance Imaging (MRI). The magnetic fields used are produced by superconductive magnets, which can only operate at very low temperatures.

Most of the gases are delivered through pipelines or cylinders. All gases for medical use have to be approved by medical regulatory authorities and require high purity. While medical authorities maintain pricing pressure on companies to maintain low-cost health benefits, stable volume and steady growth makes this business quite attractive.

Growth drivers

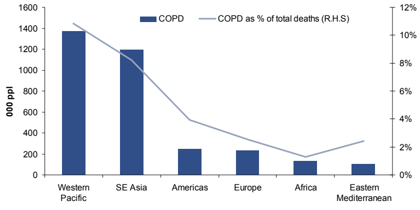
Respiratory diseases, sleep apnea and the ageing population are key growth drivers for the medical gas-related market. Industrial gas companies are also growing their share in the fast-growing home care market as the current trend is to apply oxygen therapies at home to avoid expensive hospitalisation.

a) Chronic Obstructive Pulmonary Disease (COPD)

The WHO estimates 600 million people worldwide have COPD

Chronic Obstructive Pulmonary Disease, or COPD, refers to a group of diseases that cause airflow blockage and breathing-related problems. It includes emphysema, chronic bronchitis and in some cases asthma. Currently COPD accounts for c6% death cases around the world and is likely to be third biggest cause of death by 2020. Treatment of choice for COPD patients is Long Term Oxygen Treatment (LTOT) **oxygen therapy** which aids lungs to perform normal gas exchange. The main reason behind COPD is smoking tobacco, while rising pollution levels in urban cities with increasing urbanisation also plays role, creating asthma-related problems.

Figure 98. Annual deaths due to COPD

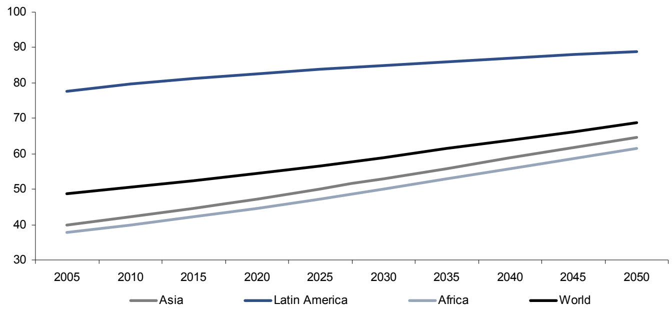


Source: WHO, CIRA

Smoking tobacco is in decline among new generations with growing awareness about lung cancer and other related diseases. But smoking does not instantly create COPD-related problems, and thus the growth of this market lies with the older smoking population which is now entering in their sixties. 60+ is fastest growing age group in the world and according to WHO c17% of world population will be 60+ by 2025, up from c13% in 2011.

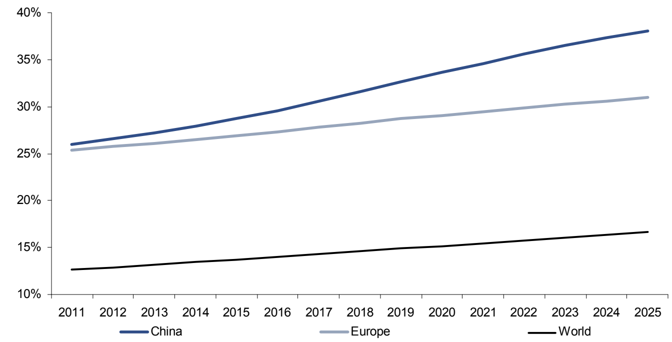
This world-wide phenomenon is much more discernible in China, Japan and Europe where ageing populations are well above average. Rapid urbanisation due to the industrialisation of developing economies is another factor which should contribute significantly towards COPD-related diseases. According to Air Liquide estimates, there were **c2.5m COPD patients on LTOT in 2007**, mostly based in developed nations (c2.2mn). With increasing urbanisation, an ageing population, increasing health awareness and economic development, we expect **LTOT patients** will increase to **c10.5m by 2025**, mostly driven by developing economies like China.

Figure 99. Urbanisation trend of emerging markets



Source: UN

Figure 100. 60+ population as % of total population



Source: WHO, Citi Investment Research and Analysis

b) Obesity and sleep apnea

Rising obesity levels in developed and developing markets is a key driver of Sleep Apnea Syndrome (SAS)

Sleep apnea occurs when the soft tissue collapses in the airway during sleep resulting in an involuntary blockage of the windpipe, resulting in poor quality and disjointed sleep. The condition affects nearly 34% of US adults. Additional fat around the neck constricts the airway, increasing the likelihood of apneas occurring. While many patients deal with sleep apnea through positional therapy, weight loss, oral appliances (that keep the airway open) or surgery, patients with severe obstructive sleep apnea often choose to go down the route of Continuous Positive Airway Pressure (CPAP).

As levels of obesity rise in the world, sleep apnea could become an even more widespread problem. According to the WHO worldwide obesity has reached epidemic proportions globally, with more that 1.5bn adults overweigh and at least 500mn of them clinically obese. This number is expected to increase further in next five years to c2.3bn adults being overweight and c700m people qualified as obese. Accordingly, the number of patients equipped for the treatment of SAS is expected to **increase to c25m (c15m in developed and c10m in emerging markets**) by 2025, **up from c3.5m** patients equipped in 2007 (almost all of whom were in DM.

c) Cost Containment and the role of Homecare

The respiratory homecare market is a fast-growing market largely as technology progress enables patients to be cared for outside the hospital setting in their own homes. There are two major reasons behind the drive to get patients out of hospitals and into their homes:

- First, the cost. Most of these patients do not need 24-7 treatment from a hospital, so keeping them as in-patients places an increasing burden on healthcare systems.
- Second, patients' comfort and desire to be in their own surroundings. This is particularly the case with patients who have a limited amount of time to live such as those with lung cancer (only 14% of those with lung cancer survive for longer than five years, the second highest death rate of cancers after pancreatic cancer). Many of these patients want to live their final days in as normal a fashion as possible and this means living in their own homes rather than in hospital.

Overall a very stable business with c6% CAGR global growth

Our c6% CAGR growth forecast is well supported by megatrends of an increasing and ageing population, demographic trends and rising obesity levels. In addition to these, other healthcare services like hygiene management and new products, like mix of helium and oxygen to treat asthma, can further fuel prospects for industrial gas companies. The healthcare market is relatively a very stable market and hence we do not expect any noteworthy impact from the current economic downturn on future growth prospects.

Nitrogen

Nitrogen is an inert gas which comprises 78% of the earth's atmosphere. It is a colourless, odorless, tasteless and non-toxic gas, liquid at -195.8C. Due to its inert properties, it is widely used in chemical, refining and metal processing. It is widely produced using cryogenic distillation in ASU or through membrane technologies. Traditional applications of nitrogen are:

- **Chemical Processing** – To inert vessels and oxygen-sensitive chemicals, creating an oxygen-deficient environment that reduces safety hazards; to propel liquids through pipelines; and to manufacture ammonia.
- **Refining** – To improve recovery and maintain pressure in oil and gas reservoirs; to blanket storage tanks (for safety) and product loading/unloading; to purge pipelines; and to strip volatile organic compounds (VOCs) from waste streams or to cool vent streams.

Nitrogen is widely used as a low cost inert gas to ensure safety and quality of products

- **Electronics** – Nitrogen is used to prevent oxidation in the manufacture of semiconductors and printed circuits. It is also used to enhance solvent recovery systems by eliminating the use of chlorofluorocarbons for cleanup.
- **Metal Processing** and **Fabrication** – Nitrogen protects metals such as steel, copper and aluminum during annealing, carburising and sintering operations in high temperature furnaces. It is also used to cool extrusion dies and to shrink fit metal parts. It is used as a purge gas with stainless steel tube welding and supports plasma cutting.
- **Food** – Nitrogen is used to extend shelf-life in packaged foods by preventing spoilage from oxidation, mold growth, moisture migration and insect infestation. It also allows rapid freezing and refrigeration perishables during transport.
- **Glass Manufacturing** – Nitrogen is used to cool furnace electrodes and prevent oxidation during manufacturing. Also, it lowers air temperatures for optimum cooling rates.
- **Research** and **Health Services** – To freeze and preserve blood, tissue, semen and other biological specimens; to freeze and destroy diseased tissue in cryosurgery and dermatology; and to pre-cool or insulate Magnetic Resonance Imaging (MRI), conserving the more costly helium.
- **Concrete Cooling** – To keep ready mixed concrete at the temperature needed to meet critical specifications.
- **Construction** – By suppressing the pour temperature of concrete mixtures, nitrogen inhibits the formation of cracks. It is also used to stabilise the ground as in the restoration of the Leaning tower of Pisa.

Growth drivers

We expect bulk of liquid nitrogen market to grow in line with industrial growth of chemical and refining business

We believe bulk of nitrogen market will continue to be chemicals and refining industries. Thus we expect nitrogen usage to grow in line with growth of these industries, **c2%-3% for developed markets** and **c5%-6% CAGR 2010-15E for emerging markets**.

For the tonnage business, we expect steel industry to be key driver for nitrogen. With increasing use of powdered coal, nitrogen usage is increasing rapidly for inerting and blanketing applications. Nitrogen creates a protective atmosphere which prevents the oxidation of low-carbon steel and provides carbon controlled atmospheres for neutral hardening, carburising, decarburising and carbonitriding of steel. As discussed in the oxygen section, we expect the steel industry in developed markets to grow **at c2%-3% CAGR 2010-15e,** while developed markets are expected to grow **c8%-12% CAGR 2010-15e.** We believe the nitrogen market will grow at a similar pace ass most of the steel producers using oxygen will also use nitrogen, produced from dedicated ASU.

We have not included EOR related demand for nitrogen in our forecasts

Apart from above mentioned uses, nitrogen **has good potential** for its usage in Petroleum industry where it is used to recover additional oil from wells **(EOR**). This technique is widely used in US and we except the growing scarcity of hydrocarbons will further enhance investment into this technology. In latest the development, Praxair signed a long-term contract with ExxonMobil to build and operate an ASU to supply nitrogen for EOR operations at its Texas gas processing plant. This plant is due to start up in 2H2011 and will supply c85mcf/d of nitrogen.

But we have **not considered** this growth potential for nitrogen in our forecasts due to two reasons: **1) uncertain oil prices** – the oil price required for the economic application of EOR technique is c$45-$60/bbl. While current oil prices are much more than this, investment into EOR is a long-term decision and requires the conviction that oil prices will remain high; **2) CO2 as alternative** – nitrogen is cheaper than CO2 as it can easily be produced at site in bulk quantities using large ASUs. But the current drive of CCS favours using carbon instead of nitrogen as it solves the problem of carbon emissions and thus CO2 can get favourable economies in the form of tax benefits and royalty rebates.

Argon

Argon is an inert, colourless and odourless gas. It boils at -186C and is distributed in its liquid or compressed form. Argon accounts for c1% of worldwide volume sales, but with an average selling price of c13x that of nitrogen or oxygen, it is the third-largest segment. Argon is produced as by-product of oxygen, hence its production is often a limiting factor to growth rather than underlying demand.

Production

Argon is separated from the other components of air by cryogenic distillation. It is distributed either in liquid or gaseous form. The largest market for Argon is the US with c50% of industrialised market production. Because of scale issues and associated costs, argon can only be economically produced as a by-product from large ASUs.

Applications

Argon is consumed mainly in the stainless steel and fabricated metal products industries; about 80% of argon consumed in the US is used in these applications. In the fabricated metal products area argon is used mainly in shielding applications for welding. In primary metals argon is mainly used in the steel industry in furnaces (depending on the use either to protect the metal from oxidation, increasing surface area exposed to oxygen, improving productivity and metal quality); this is likely to remain the main end market. Argon is also used in high-temperature argon plasma torches to prevent emissions of environmentally hazardous heavy-metal dusts. Argon has replaced nitrogen because it does not generate nitrogen oxides. Applications in electronics and glass industries are growing fast but the volumes used here are still quite low.

Figure 101. US market for Argon - 000 cubic meters, liquid

End user	Application	2007	2012	Annual Growth - 2007-12	Share of US market	Comments
Welding	Protective gas for welding. e gas for plasma welding	271.8	292.8	1.5%	42%	Mature and low growth
Primary metals	Protective gas for primary metal industries. Stirring for furnaces	234.9	259.4	2.0%	36%	We expect strong growth in Asia -c8%-12% CAGR, in line with oxygen business
Electronics	Protective gas for semiconductor crystals	68	109.4	10.0%	10%	Expect even higher growth in Asian market
Lighting	Gas for filament lamps. Laser gas.	27.2	30	2.0%	4%	Small market
Others including glass and measurement engineering	Protective gas for optic fibres glass and for solar panel production, Spectroscopy	46.6	51.5	2.0%	7%	Cyclical and small market

Source: SRI, Citi Investment Research and Analysis

Growth drivers

In our opinion, the main driver for argon growth will be the stainless steel industry and electronics. As discussed earlier we expect the steel industry in developed markets to grow **at c2%-3% CAGR 2010-15E,** while developing markets are poised to grow **c8%-12% CAGR 2010-15E**. The electronics industry is another likely growth driver for argon; we expect its usage to grow at c15%-20% CAGR for Asian markets, albeit incremental volume will be much lower than the addition from the steel industry due to a lower base. Overall, **we forecast demand to increase by around 10% per annum in this segment.**

Synthetic Gases

Hydrogen and carbon dioxide are the main gases generated by chemical synthesis. Hydrogen remains a substantial market opportunity for industrial gas companies. We forecast **c15% CAGR 2011-15E** growth for this market, driven by refining dynamics and growing outsourcing trend. Hydrogen is used to reduce the sulphur content in motor fuels known as hydro treating process and also used to convert low value of gas oils to valuable lighter products under hydro cracking process.

Carbon dioxide also has the potential to be a high-growth gas but needs effective carbon capture and sequestration technology. We believe CCS can prove a substantial market for industrial gas companies and this market should crystallise in the next 5-7 years. We explain this in detail below.

Hydrogen – strong growth to continue

Hydrogen is the lightest of all gases. Commonly found in nature in compounds with other elements, it is the most abundant element in the universe (e.g. Water - H_2O). Colorless, odorless, tasteless and nontoxic, hydrogen exists as a gas at atmospheric temperatures and pressures, but its concentration in air is only about 0.00001%. It liquefies at -252°C.

Production Process

Hydrogen is produced in large quantities both as a principal product and as an industrial by-product using several methods. These include:

Steam reforming is the cheapest and widely used process for hydrogen production

- **Steam reforming** – reaction of natural gas (methane) or other light hydrocarbons (ethane and propane) with steam in the presence of a catalyst. This technology is considered mature, being the most efficient conversion method with c72% efficiency. But emphasis remains on developing alternative technology which can establish hydrogen as a renewable source of energy.
- **Electrolysis of water** – a process which transforms water into its elemental parts through the use of an electric current. This technology is **in an early phase** of development but considered as a good option to supplement renewable sources of energy such as wind power.
- **Ammonia/ Methanol dissociation** – the breaking up of ammonia or methanol into its simpler components, namely hydrogen and nitrogen. Production from this process **is c2x expensive** than steam reforming, hence merchant hydrogen is not produced from this process.
- **Partial oxidation** – a reaction of hydrocarbons (such as natural gas, naphtha, petroleum coke or coal) with oxygen to produce hydrogen and carbon monoxide. Hydrogen is a by-product of this technology and as such its production is **c35% expensive** than steam reforming. But as discussed earlier, we believe **coal gasification** is a megatrend and hence production of hydrogen from this source should catch up in future with improvement in technology.

In addition, hydrogen is obtained as a by-product of some refining and chemical production processes.

Production – Growing outsourcing trend

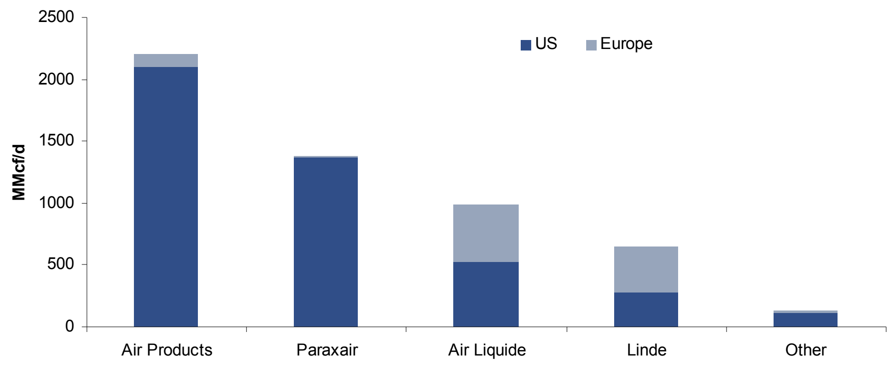
Globally, c31.3Mn MT of hydrogen was produced in 2010 with c15.4% of total demand outsourced to merchant producers

The hydrogen market has developed at a **pace of c6.2% CAGR 2005-2010** while the merchant market has grown by **c14%CAGR** in the same period. This shows a clear trend of increase in outsourcing activity which we believe will be one of the key drivers of growth for industrial gas companies. Currently US accounts for more than 60% of world hydrogen production, driven by the need for its refining industry, followed by Europe and Asia.

The merchant market for hydrogen is a highly consolidated market, with the **big four industrial players** accounting for more than **95% of market** share. As such, Air Products and Praxair are largest playesr in the US, whereas Air Liquide and Linde dominate the European market. Besides typical tonnage business, these companies also have extensive marketing networks, where they market and supply hydrogen (by purchasing it from producers which generate hydrogen as a by-product) to small-scale users, typically in the steel and electronics industries.

Air Products has a strategic alliance with Technip and they have executed 31 projects together since 1992

Figure 102. Current merchant hydrogen production capacity in US and Europe



Source: Company reports, Citi Investment Research and Analysis

Applications

We have described hydrogen application by various industries:

Main consumer (c75%) and driver of growth with increasing outsourcing trend

- **Petroleum refining** – It is the critical gas used to produce cleaner burning transportation fuels. Hydrogen is used to enhance the performance of petroleum products by removing organic sulphur from crude oil, as well as to convert heavy crude to lighter, easier to refine, and more marketable products. Hydrogen's use in reformulated gas products helps refiners meet Clean Air Act requirements

Most of the production is captive

- **Chemical processing** – It is primarily used to manufacture ammonia and methanol, but also to hydrogenate non-edible oils for soaps, insulation, plastics, ointments and other specialty chemicals.
- **Food** – It is used to hydrogenate liquid oils (such as soybean, fish, cottonseed and corn), converting them to semi-solid materials such as shortenings, margarine and peanut butter. The aim is to increase the melting point.

Food, Pharma, Aerospace, Electronics and Metal accounts for less than 1% of merchant trade

- **Metal Production** and **Fabrication** – Hydrogen is used to serve as a protective atmosphere in high-temperature operations such as stainless steel manufacturing, commonly mixed with argon for welding. It is also used to support plasma welding and cutting operations.

- **Pharmaceuticals** – it is used to produce sorbitol used in cosmetics, adhesives, surfactants, and vitamins A and C.
- **Aerospace** – Hydrogen is used as a fuel in spacecraft.

Fuel cell technology is still in nascent stage

- **Fuel Cells** – A dependable and cost-effective source of hydrogen is crucial for fuel cell powered technology. Hydrogen is used as a fuel to power fuel cell generators that create electricity through an electrochemical process in combination with oxygen.

IGCC plants

- **Power generation** – Hydrogen serves as a heat transfer medium for cooling high speed turbine generators. It is also used to react with oxygen in the cooling water systems of boiling water nuclear reactors to suppress intergranular stress corrosion cracking in the cooling system.

Growth drivers – Refining industry and outsourcing

Petroleum refinery operations produce and consume large volumes of hydrogen. However, the trend has been for refineries to become net deficient in hydrogen, which creates the need for new sources. These can either be captive or via supply schemes. The trend has been for a growing proportion to be outsourced.

Refinery operations can be broadly divided into Fluid Catalyst Cracking (FCC), Catalytic Reforming, Hydrotreating and Hydrocracking. Only reforming processes liberate hydrogen.

Figure 103. U.S refinery capacity for major hydrogen producing and consuming operations

Process	Capacity -Kboed	Hydrogen consumption - scf per bbl	Comment
Fluid Catalyst Cracking	5663	30-77	Produces hydrogen through dehydrogenation reactions. Hydrogen produced is of low purity and used as fuel gas.
Catalytic Reforming	3583	600-1600	Produces hydrogen in process of converting naphtha into high octane reformate for use in gasoline blending. Biggest source of captive hydrogen production
Hydrotreating	13929	30-1500	Uses hydrogen for sulfur removal and to reduce concentration of other contaminants to meet regulatory standards
Hydrocracking	1680	800-2500	This process converts low value, low hydrogen rich content like gas oil to gasoline. This is the biggest driver of demand for dedicated hydrogen producing units

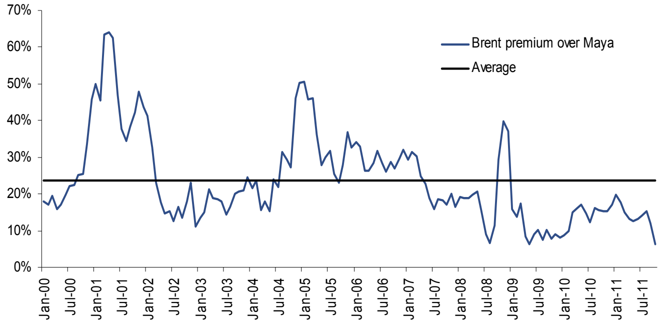
Source: Oil & Gas Journal, Citi Investment Research and Analysis

Heavy and sour crude economics will drive demand for hydrogen

Refineries' processing of light and sweet crude does not require extensive hydrotreating and hydrocracking and are self sufficient for their hydrogen needs. Thus the merchant market for hydrogen is dependent upon addition of heavy and sour crude slate in refining system, which we believe is increasingly becoming choice of new capacity additions. We explain reasons behind this below.

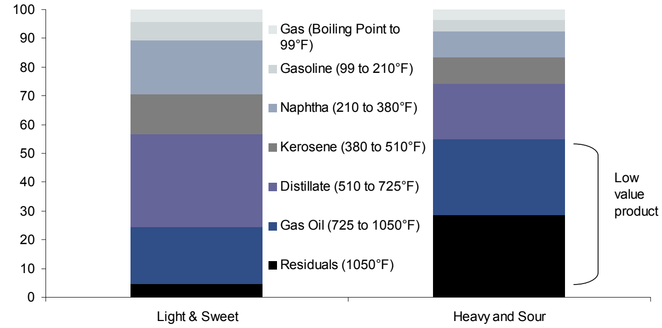
a) Light and heavy crude spread

Figure 104. Brent premium over Maya



Source: Bloomberg, Citi Investment Research and Analysis

Figure 105. Composition of generic light and heavy crude



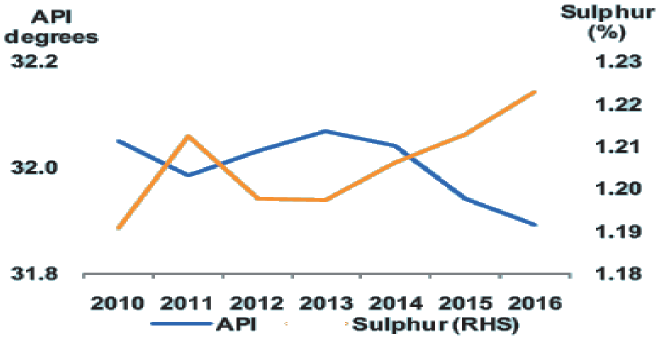
Source: IEA, Citi Investment Research and Analysis, Light- API 34.8, Sulphur 0.3%, Heavy- API -22, Sulphur -4.9%

Brent commands a premium over heavier crude like Maya (Mexico) because lighter crudes have higher contents of valuable products compare to heavy crude. The simple average of this premium for last ten years is c24%, but removing periods of abnormal premium (due to supply disruptions), we believe the normalised average discount is **c15%**. **Trade of this premium** is **hydrocracker**, where we estimate that **2 mcf of hydrogen** and one barrel of oil can be used to **manufacture 1.3 barrels** of light product. At c$4.5/mcf of natural gas price in US, we estimate cost of producing hydrogen is c$2.75/mcf. Thus assuming $100/bbl light crude price and applying c15% heavy crude discount, we estimate upgrading a heavy barrel could provide c**$10/bbl gross refining margin**.

b) Additional barrel of crude is heavy and sour

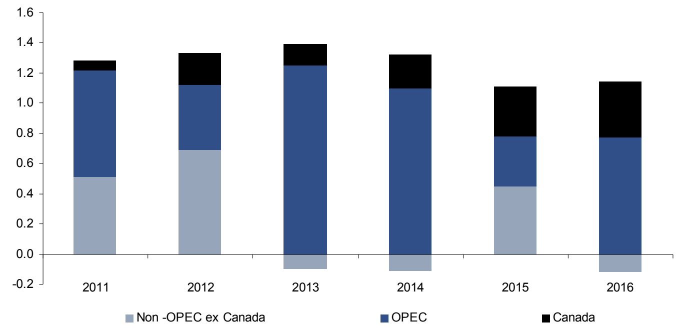
As per IEA forecasts, the majority of additional crude supplies will come from OPEC and Canadian oil sands. Gulf crude typically has between 1.8% to 2.8% sulphur content compared to US and North Sea crude, which contain about 0.5% sulphur. Also Canadian oil sands on average have API gravity of less than 25, compared to current world's average crude API gravity of c32. To refine this additional sour and heavy crude, additional hydrotreating and hydrocracking units will be required. The IEA estimates **c6mn bp/d** of gross capacity additions to coking, hydrocracking, residue hydrocracking, visbreaking, FCC or RFCC capacity will be installed in 2011-15e. One bbl of heavy crude consumes c1.2-3mcf of hydrogen. Thus we deduce that even c30% of outsourcing of new units will increase demand for merchant hydrogen by c3.8bcf/d or c70% increment in current merchant capacity, **implying c14% CAGR 2010-15e**.

Figure 106. Global crude quality (excluding condensate) 2010-16e



Source: IEA, Citi Investment Research and Analysis

Figure 107. c30%-35% of addition crude will be heavy Canadian oil



Source: IEA, Citi Investment Research and Analysis

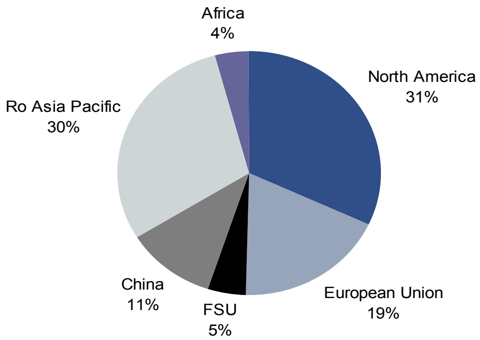
c) Tighter environmental regulation globally

Emission standards define the maximum amount of pollutants that can be released in the environment. Various emission standards are in place in US and Europe and usually the rest of the world follows these standards with a lag impact. Euro 5 was latest emission standard implemented by the European Union from Sep 2009 which stipulated the reduction of sulphur content in EU gasoline to 10 mg/kg from 50mg/kg.

Post this, many Asian countries like India and China have adopted Euro 4 emission norms, though selectively. The EU is also planning to launch Euro 6 norms from 2015, which stipulates a further 50% reduction in NOx emissions from Euro 5 standards. Thus to meet this new specifications, additional hydrotreating facilities are required for both existing refineries and new additions/expansions.

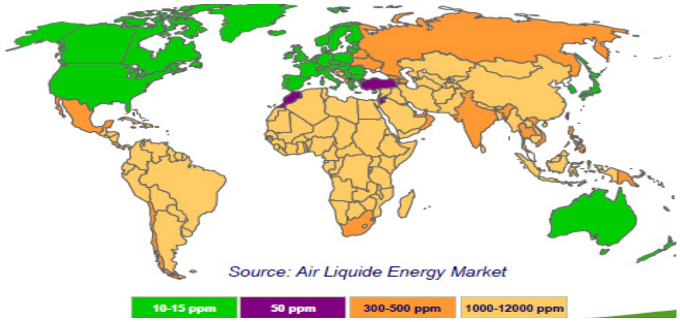
According to IEA estimates**, c6.3 mn** bbls/d of desulphurisation capacity will be added in 2011-15 worldwide. c82% of these additions will come from emerging markets, c14% of this from North America (primarily to process heavy and sour Canadian crude) and the rest from Europe. c30% of this new hydrogen requirement outsourced to industrial gases would result in c1.1 bcf/d of additional market or c20% of current merchant capacity.

Figure 108. Oil product consumption by region – 2010



Source: Citi Investment Research and Analysis, BP stats review

Figure 109. Regulatory Diesel Sulphur Concentration

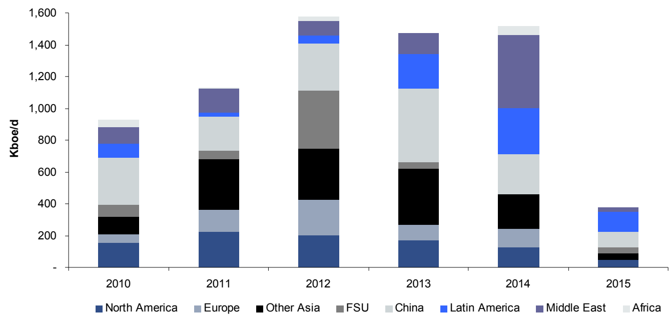


Source: Air Liquide

The incremental demand that we believe will be outsourced would roughly double the scope of the market available to the industrial gases group.

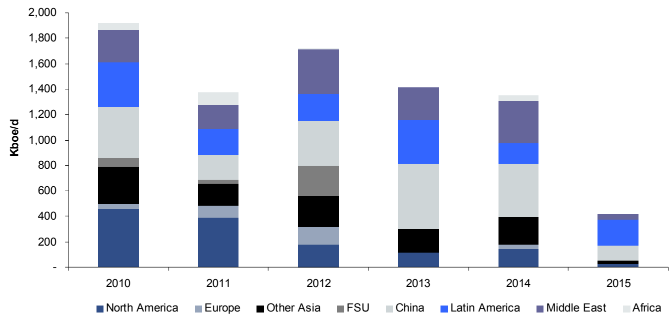
Increased desire for operational efficiency and outsourcing – Currently c15% of the total hydrogen market is outsourced, up from c10% in 2005. We believe this trend will continue and outsourcing of additional hydrogen requirement will be at an increased rate of c30% by 2020. The refinery industry is in the process of improving its existing efficiency and increasingly wants to utilise the expertise of industrial gas companies for hydrogen generation.

Figure 110. Upgrading Capacity Additions



Source: IEA, Citi Investment Research and Analysis

Figure 111. Desulphurisation Capacity Additions



Source: IEA, Citi Investment Research and Analysis

Figure 112. Typical refinery Hydrogen consuming process

Process	Feedstock	SCF/bbl of FEED
Hydrotreating	FCC naphtha	475
Desulfurization	High-sulfur gas oil	210
to 0.05 weight percent sulfur		
	FCC gas oil	600
	Atmospheric (long) residue	950
Dearomatization	Gas oil (after desulfurization)	150
to 20 volume percent aromatics		
to 10 volume percent aromatics	Gas oil (after desulfurization)	350
Hydrogenation	FCC cycle oils	1,650
	Benzene	4,500
Hydrocracking	Vacuum gas oil	1,200-2,500
	Atmospheric (long) residue	1,200-3,000

Source: SRI, Citi Investment Research and Analysis

Growth in hydrogen consumption is expected to grow in new applications.

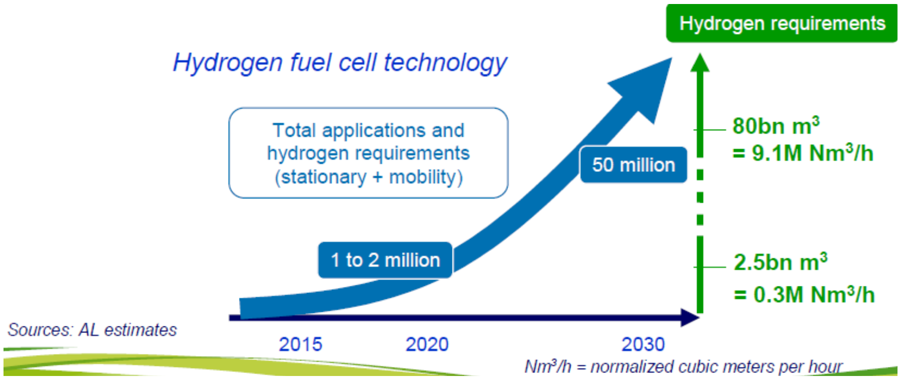
Demand growth in other industries – One of the fastest growing applications other than refining business is **steel annealing**. Traditionally, atmospheres of about 10% hydrogen and 90% nitrogen have been used. Increasingly, 100% hydrogen atmospheres are being adopted. We believe this will drive demand for hydrogen for the steel sector at c6% CAGR 2010-15E, albeit on a very low base compared to refinery demand. The **electronics industry** uses hydrogen for a protective atmosphere (annealing, bonding, etching and crystal growth), as a carrier gas and as a reducing atmosphere (**polysilicon production**). Minor end uses include hydrogen as a clean fuel for the production of optical fibres (core networks, home networks, multimedia applications, etc).

Future Applications - Hydrogen as a source of energy

Hydrogen is the cleanest fuel available. There is an undergoing project development in fuel cells technology.

When hydrogen is burnt the only by-product is water, making it the cleanest fuel available. It could either be used in modified internal combustion engines or in fuel-cell powered cars. Either way, if hydrogen is adopted as a fuel the potential growth opportunities are substantial – the biggest potential for hydrogen comes from the automotive industry. Hydrogen fuel cells are quiet and can achieve efficiencies that are **two-to-three times greater** than internal combustion engines. The growth rate for hydrogen from this sector is forecast at **7.37%** in the period 2011-2015E.

Figure 113. Hydrogen Consumption for Fuel Cell Technology



Source: Air Liquide

A number of projects are developed to introduce hydrogen as a source of energy

The Horizon Hydrogen Energy (**H2E**) innovation programme, coordinated by **Air Liquide**, represents an overall investment in research and technology of **€190m in 2011-2015**. H2E aims at building sustainable and competitive hydrogen energy solutions. The research and development will cover the full hydrogen energy value chain. In particular, it will investigate the development of innovative technologies for hydrogen production using renewable energy, hydrogen storage and industrialisation of fuel cells. H2E will include a programme of demonstrations and educational measures to familiarise the wider public with this new, cleaner energy source.

Linde Group and a number of leading companies (Daimler. EnBW, OMV, Shell, Total, Vattenfall and NOW) have signed up to create nationwide hydrogen supply infrastructure in Germany with support from the German Ministry of Transport. The aim is to promote and enable the production and use of electric vehicles with fuel cells. The initiative targets a nationwide rollout of hydrogen fuelling stations by 2015.

In the **European Integrated Hydrogen Project (EIHP**), several companies joined forces to improve the coordination of licensing and approval procedures needed for putting hydrogen powered vehicles on the road. In Phase I, a total budget of €2.5m was consumed. The second phase of the project developed the draft regulation documents for Europe to a global regulation for hydrogen-fuelled road vehicles.

Distribution and storage infrastructure issues **also still need to be resolved** and it seems likely that hydrogen would only make sense as a fuel source for fuel cell powered cars. R&D to push the boundaries on this technology is growing. One such initiative is HyChain, an EU-funded programme involving €38m (of which €17m is provided by the EU) in 4 countries involving 10 companies – the objective is to deploy 180 H2-driven fuel cell vehicles.

Air Liquide is committed to enabling the establishment of a H2 energy infrastructure and is working on a range of projects towards the development of the complete H2 energy supply chain. Much of this work is undertaken by the company's wholly-owned subsidiary, Axane, whose mission is "to develop and commercialise fully integrated systems that produce energy from hydrogen-powered fuel-cells". Air Liquide has set up refueling stations in the US and Spain and will be supplying five fuelling systems for General Motors in the US by the end of 2007.

Linde is involved in the LIFECar project, which aims to demonstrate the performance of a fuel cell sports car. Linde is developing the H2 refuelling plant for this £1.9m project funded by the UK Department of Trade and Industry (DTI). Linde is also involved in establishing H2 fuelling stations Shanghai, Germany and the UK.

New Methods to produce Hydrogen are in development phase

New methods of hydrogen production may become important in the future. Steam-reforming technology is mature and has little scope for improvement in production economics; it is also based on fossil fuels and uses natural gas as feedstock. Research in hydrogen-fuelled fuel cells has triggered improvements in hydrogen-generation technology.

The Airgas-Nuvera cooperation is focused on the material handling of hydrogen generators.

In 2009, Airgas and Nuvera entered into an agreement to provide PowerTap hydrogen generators to the material handling market. Nuvera will manufacture the system and Airgas will distribute, install and support the system. In 2008, HydroGen Corporation announced the start-up of a full-scale Phosphoric Acid Fuel Cell (PAFC) commercial demonstration plant using by-product hydrogen to generate electricity at ASHTA Chemical's Ashtabula chlor-alkali facility in Ohio. Industry sources estimate that the commercialisation of fuel cell vehicles in the United States could begin as early as 2020. As many as two million vehicles could be on the road driven by hydrogen power, according to estimates provided by the National Research Council. Companies are focusing on the infrastructure to support such deployment concurrently with cost-effective and safe supply of hydrogen.

Focus on ceramic membrane technology to replace steam reforming

Another method under examination is the **direct conversion of methane to synthesis gas** (a mixture of carbon monoxide and hydrogen). Two projects have been announced to develop this technology. **Air Products** and Chemicals will lead an eight-year**, $84 million research** project that will culminate in the construction of a **15 MMcf/d** pre-commercial scale plant at Air Products and Chemicals' industrial gas complex in La Porte, Texas. The main component in this technology is a **ceramic membrane** that was discovered in the early 1990s which separates oxygen from air and uses it to break apart methane. The resulting mixture is synthesis gas.

A separate alliance, which includes BP, **Praxair,** Seattle Specialty Ceramics and the University of Missouri at Rolla, is also working to develop **ceramic membrane** technology for conversion of natural gas to synthesis gas, suited for the gas to liquid market. BP Chemicals is involved in selective partial oxidation research. Praxair plans to focus on separation and purification of hydrocarbons through its subsidiary, Praxair Surface Technologies. It is estimated that the timeframe for the technology to become a commercial reality may be five to ten years away.

Linde has developed a technology to produce hydrogen from **biogenic raw materials**. With the ongoing emphasis on biofuels, plenty **of glycerin** is expected to be generated in the production of biodiesel.

But all these technologies are far from commercial and any meaningful conversion to hydrogen based energy is still beyond foreseeable future. That said, we believe these developments provide good indication of a **long-term growth opportunity** for industrial gases

Carbon Dioxide

CO2 is a by product and is not produced specifically through air separation units due to its low volume in the atmosphere

Carbon dioxide is a colourless, odourless and inert gas constituting only 0.036% of the atmosphere by volume. It is 52% heavier than air and when concentrated, it can be liquefied and can be further compressed to solid form (called 'dry ice'). The food and beverage industry is the key consumer of commercially produced liquid CO_2. Since most of the CO_2 is produced as a by-product, maintaining regional and seasonal balance is a major challenge. Its consumption in mature markets is expected to grow at c0.7%-1.5% CAGR for next five years whereas China is expected to grow at c15%-20%, albeit on a very low base.

Food and beverages has c72% market share of commercial CO2 production

Commercial trade of CO_2 is usually in liquid form, though large quantity of gaseous CO_2 is used for enhanced oil recovery (EOR) in the US. Since most of the gaseous CO_2 is provided by natural deposits and gas fields of oil and gas producers, industrial gas companies' main market for CO_2 is the food and beverage industry with c72% market share. It is also used for welding operations and for various chemical processes.

Figure 114. Industrial production of Liquid CO2 in mature markets

000 MT	US			Western Europe			Japan		
	2009	2014	Growth	2009	2014	Growth	2009	2014	Growth
Food Industry	4373	4645	1.2%	750	869	3.0%	99	104	1.0%
Beverage Carbonation	980	925	-1.1%	1500	1616	1.5%	101	96	-1.0%
Oil and Gas Recovery	454	635	7.0%	0	0	0.0%	0	0	0.0%
Other	1325	1461	2.0%	762	847	2.1%	489	507	0.7%
Total	7131	7666	1.5%	3012	3332	2.0%	689	707	0.5%

Source: SRI Consulting, Citi Investment Research and Analysis

Sources

CO_2 is generated as a by-product of several industrial processes. It also exists as natural deposits trapped in the earth's crust. Major CO_2 production (and not generation) sources are:

- **Ammonia:** Most of the CO_2 is recovered at ammonia production facilities. Hydrogen (or synthesis gas) produced by the steam reforming of natural gas feedstock produces 99.8% pure CO_2 and it can be further enhanced using amine treatment. In Western Europe, it is estimated that c80% of CO_2 is produced from ammonia plants.

Ammonia and Ethyl Alcohol are the main source of commercial CO2 production as they provide fairly pure and highly concentrated carbon stream

- **Ethyl Alcohol:** CO_2 is produced as a by-product of fermentation processes used for producing ethanol. In countries like UK, US and Brazil, this has emerged as a significant source of commercial CO_2. Unlike ammonia production, ethanol production is not seasonal; hence these plants can provide steady supply to producers and end users.
- **Natural deposits:** In the US, several large natural deposits are specifically developed to supply CO_2 to oil fields for EOR operations. Natural deposits of carbon dioxide are fairly pure which make them popular source for use in food and beverage applications as well.
- **Flue gases:** Combustion of all carbonaceous materials emits gases with c4-12% CO_2 concentrations. Energy intensive facilities like blast furnaces of steel manufacturing generate large quantities of CO_2 though recovered CO_2 is not considered suitable for use in food grade due to presence of undesirable compounds. Also the cost to purify this relatively low concentration CO_2 stream is not commercially viable. This particular source is expected to grow once carbon sequestration becomes mandatory by law with improved CCS techniques and an established carbon trading system.

Purification Process

CO_2 recovered from above sources is first entrapped in an absorbent like monoethanolamine or hot potassium carbonate solution. Then it is further purified to remove traces of sulfurs and organic impurities through purification processes. Choice of purification process depends upon end usage, purity requirement, source of stream and availability of technology. The purity requirement for food and beverages sector is more than 99.9% but industrial inerting and EOR does not require that level of purity. Usually commercially traded CO_2 is food grade and is primarily traded in liquid and solid form (dry ice).

Production

Industrial gas companies are normally involved in liquid carbon production though they do have some share in gaseous CO2 which is primarily used for EOR in the US

Most carbon dioxide is sourced as a by product of various processes. Industrial gas companies may collect this "waste" and then market liquid carbon for varied purposes according to purity of the carbon stream recovered.

The North American market is highly concentrated but dominated by the four gas majors. These companies have even higher share if marketing is added to their producing capacities. Since large quantities of CO_2 for EOR is supplied through natural sources and by oil producing companies, we limit our discussion in this section to Liquid CO_2 which is main area of focus of Industrial gas companies (for now).

In Western Europe c80% of production is through ammonia plants with large players accounting for c41% market capacity. In other regions, the market is fragmented among various small players, with no noticeable capacity for large players. We believe this presents an opportunity for them to expand in fast growing emerging markets. Praxair is already building c100 KT plant in Thailand which will be completed by year end.

Figure 115. CO2 production capacity- Excluding CO2 generated and produced by oil producers

000 MT	USA	Canada	Mexico	W Europe	C Europe	Africa and Middle East	Japan	China	Total
Airgas	1747	0	0	0	Na	na	na	na	1747
Air Liquide	907	501	0	1105	Na	na	na	na	2512
Air Products	143	0	0	0	Na	na	na	na	143
Linde	2972	0	35	502	234	na	na	na	3743
Praxair	1640	844	364	560	Na	na	na	na	3408
Others	3891	336	126	3131	3418	177	1691	5000	17769
Total	**11299**	**1680**	**525**	**5298**	**3652**	**177**	**1691**	**5000**	**29321**

Source: SRI Consulting, Citi Investment Research and Analysis

Carbon dioxide applications

- **Food processing** – The food industry is the largest consumer of merchant carbon dioxide. It is mainly used as a freezing agent to keep meat products fresh. Liquid nitrogen is a close competitor of "dry ice" and given same price for both products, the choice of preserving agent mainly depends upon availability. Approx 4-6 kilogrammes of liquid CO2 is consumed per 100 kilogrammes of fresh or fresh/frozen meat product**.**

Food and beverages is a mature market and accounts for c72% of market share

- **Beverage Carbonation** –Carbon dioxide is used in beverage carbonation. A natural anti-microbial, CO2 is also used to increase the shelf life of juice and dairy products, protecting taste and texture, thus reducing the need for other preservatives. c80% of the carbon dioxide consumed in beverage carbonation is used in soft drinks and most of the remainder is used in beer and sparkling wine.

- **Metal Fabrication** – CO2 is widely used in Japan for welding and metal fabrication in its automotive industry as a substitute for expensive argon gas which is used in Western Europe.
- **Water/Wastewater Treatment** – Carbon dioxide is a cheap source to treat sulphuric-acid systems and can be used to replace harsher acids for the alkaline neutralisation process. It is effective for Industrial and municipal wastewater treatment which must be neutralised before being discharged to the environment.
- **Fire Fighting** – Carbon dioxide smothers fires without damaging or contaminating materials and is used for fighting fires when water is ineffective, undesirable or unavailable.

Agriculture and Chemical use of carbon is in nascent stage

- **Plant Growth** – Carbon dioxide systems greatly improve growth and quality of plants in the greenhouse. Increasing concentrations of the gas results in larger, healthier and faster-growing plants and lower operating costs, especially during the winter, when it can reduce heating costs by 50%.
- **Energy Source** – Storage of carbon dioxide at its triple point (the temperature-pressure combination at which carbon dioxide can exist simultaneously as a solid, liquid or gas) is being tested as a means of providing closed-loop refrigeration in order to shift electrical-energy demand to off-peak consumption hours. Under test in Japan, the process offers the potential to customers to shift electrical load while maintaining temperatures as low as minus 60°F (-51°C).
- **Cleaning and Solvent Extraction** – In its supercritical state (87.9°F (31.1°C) and 1070.6 psia (7.38MPa)), carbon dioxide becomes a versatile solvent. It can replace chlorinated fluorocarbons to clean equipment components. It also can replace many volatile organic chemicals for operations such as decaffeinating coffee or extracting fat from food products.

Carbon Capture and Storage – Environment Megatrend

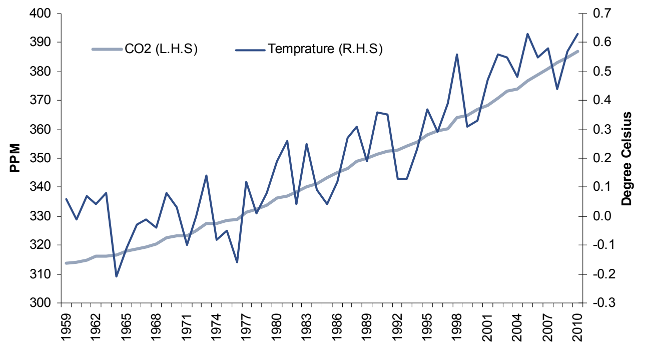
Carbon Oxide Emissions - Some background

At current level of emission rate, critical 450ppm level will be achieved within 27 years

Carbon dioxide is responsible for about two-thirds of the greenhouse effect in the atmosphere – a process that retains the sun's energy. Naturally occurring greenhouse gases keep the planet's atmosphere about 33^{o}C higher than it would otherwise have been, making the planet habitable.

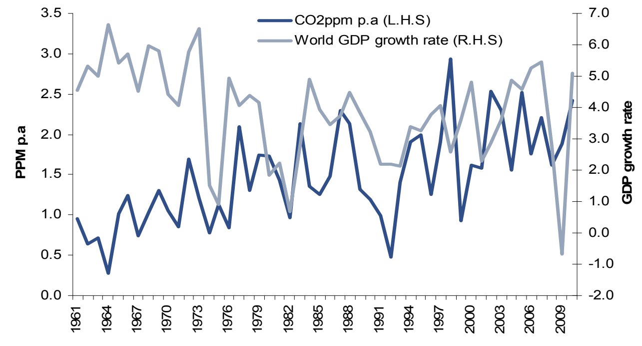
Carbon dioxide concentrations in the atmosphere are increasing at the fastest pace in recorded and geologically analysable history due to the burning of fossil fuels. The average CO_2 concentration in the atmosphere was 280ppm in pre-industrial times and has now risen to c390ppm. More alarming is the incremental rate of additional carbon released in the atmosphere. This rate has gone up in last 50 years from c0.85ppm p.a. in 1951-61 to c2.2ppm p.a. Increasing concentrations of carbon dioxide are causing global warming and it is estimated that the earth's temperature has already increased by 0.7^{o}C. The current target of IEA is to maintain 450ppm level by 2030 and has defined various energy options and scenarios to achieve this. For details please see our Australian team's note *World Energy and Carbon Outlook - Climate Change Targets Challenging under OECD/IEA Projections*.

Figure 116. Global temperature is on rise with rising CO2 concentration



Source: NOOA, Citi Investment Research and Analysis

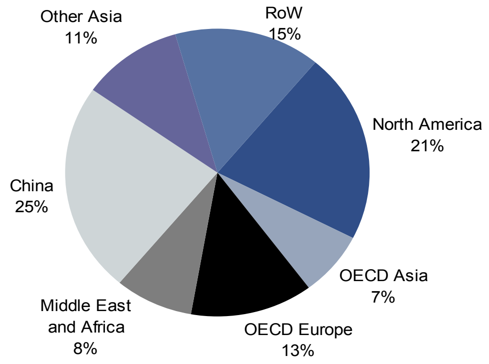
Figure 117. But so far CO2 emissions are linked to world GDP growth



Source: World Bank, Citi Investment Research and Analysis

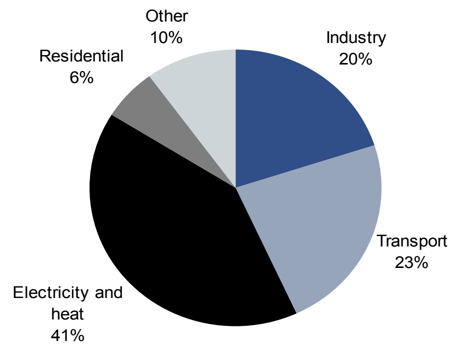
So far carbon emissions are closely linked to GDP growth as c83% of emissions are due to use of fossil fuels used in electricity generation, transportation and Industrial processes. On a regional basis, North America, China and Europe are the leading carbon dioxide generators, being the leading industrialised economies of the world.

Figure 118. Carbon Emissions by major regions



Source: IEA, Citi Investment Research and Analysis

Figure 119. Carbon Emissions by sector



Source: IEA, Citi Investment Research and Analysis

Political efforts and market mechanisms to capture carbon emissions

To tackle increasing emissions, a Protocol was set in Kyoto, Japan in which binding emission targets were set for 37 industrialised countries and the EUfrom 2008-2012. The burden of reducing emissions was set more stringently on developed nations and developing nations were encouraged to reduce emission levels. Besides national level measures, three market-based mechanisms were devised:

These initiatives were to encourage CCS related investments with main financial burden on developed rich nations

- **Emission trading**: Under this, if any particular unit emits less carbon than its allocated quota, it can sell it to other units which are emitting carbon over their targets. The purpose was to establish active carbon market and encourage investments in CCS technologies. Currently the European Union emissions trading scheme is the largest in operation.
- **Clean Development Mechanism:** This allows a country to implement an emission-reduction project in developing countries. Such projects can earn saleable certified emission reduction (CER) credits, each equivalent to one tonne of CO_2, which can be counted towards meeting Kyoto targets. A CDM project activity might involve, for example, a rural electrification project using solar panels or the installation of more energy-efficient boilers.

- **Joint implementation:** This allowed countries to invest in other regions to reduce emissions and take carbon credit for its targets**.** This mechanism's aim is to encourage investment by developed rich nations into most economical manner while benefiting developing nations from foreign investments.

The Kyoto protocol is due to expire in 2012 but no concrete mechanism and protocol is globally accepted to replace this. The UN, in its latest meeting at Cancun, Mexico, decided to create a green climate fund to be worth of $100bn by 2020 and has the objective of securing a successor to the Kyoto Protocol.

UN climate change conference held in Durban, South Africa failed to provide any concrete steps to replace the Kyoto protocol

But nothing was agreed as to how the fund would be financed and whether or not developing nations will have binding targets. The UN climate change conference held in Durban, South Africa from 28 November-9 December failed to provide any near-term solution. The main issue for the current impasse on carbon captures is the associated cost, which has become an issue of controversy among developed and developing nations. Due to the substantial cost associated with carbon capture, global political consensus is hard to reach at. It remains unclear whether there is the political will to reach agreement on a Kyoto extension.

CCS could be one of the biggest growth drivers for Industrial gases

CCS should provide boost to engineering division of industrial gas companies in long term and provide an attractive market for their gas supply business in the medium term

Carbon dioxide capture and storage to reduce greenhouse gas emissions could be a major environment megatrend. Linde expects that the carbon capture and CO_2 distribution market will grow from virtually nothing to c.€45-€75bn from 2020 to 2030. Though this seems a long-term ambition, this is possibly one of the most important megatrends which we believe could start crystallising by the latter half of the decade. Another near-term application of CCS is the EOR market, which Linde expects will be worth c€1-1.5bn in 2015 and grow to c€4-€5bn by the end of the decade.

Figure 120. Carbon capture potential market size projection by Linde

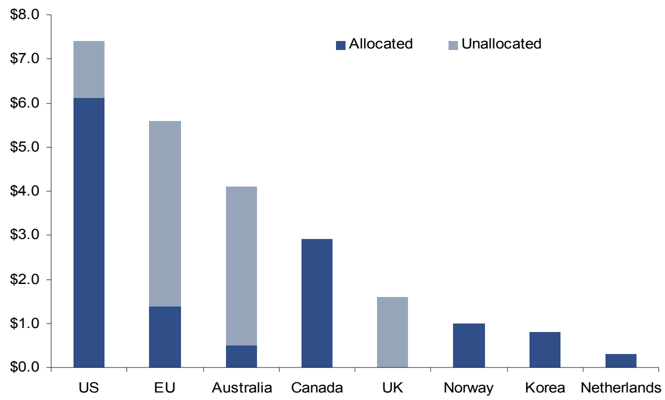
Role	Assumptions	2015	2020	2030
EOR	Single to double digit number of large N2 EOR/NRU projects Double digit number of large CO2 EOR projects including Industrial CO2 capture and pipeline (overlapping w/CCS)	€1-€1.5 bn	€4-€5 bn	€18-€35 bn
Carbon Capture & Clean Coal	Triple-digit number of 1 GW Carbon Capture (1.5 Gt/a CO2 at €25-€40/t)	0	0	€30-€50 bn
CO2 networks	Installation of significant pipeline network and corresponding compression (1.5 Gt/a handling fee CO2 at €10-€15/t)	small	€ 1 bn	€15-€25 bn

Source: Linde

Worldwide, there are 74 large scale integrated carbon capture for which various governments has announced public funding to the extent of c$23.7 bn

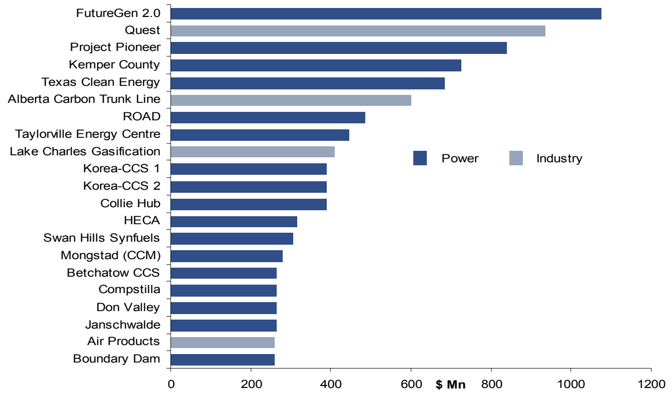
As discussed in our oxygen section, technologies to capture carbon are not economically viable and hence require government support. We have analysed data from Global CCS institute which has listed 74 large scale integrated CCS projects (Figure 127). These projects are mainly funded by governments around the world, either through direct financial support like grants or through tax credits. As shown in Figure 121, c55% of the public funding is already allocated to specific projects. The European Commission and Australia are in process of allocating remaining funds through competitive tendering processes. These funding projects do not include emerging markets like China where projects are supported by both state-owned enterprises and the international community. In addition, the UK has committed to support three additional projects beyond the current demonstration competition process. The funding commitment to support this policy is yet to be announced, but according to estimates made in 2009, the total support required for a programme of four demonstration projects could be in the range of £7.2-9.5bn. It looks unlikely the UK will release any funds soon though.

Figure 121. Public funding support is already c$23.7bn for these projects



Source: Global CCS institute, CIRA

Figure 122. Large scale projects receiving public funding



Source: Global CCS institute, CIRA

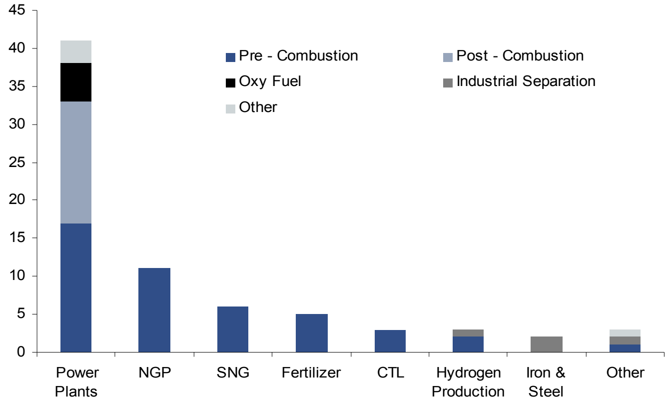
Air Liquide has been awarded E&C contact for c$1.1bn project funded by DOE

Power generation is one the biggest beneficiaries of these projects being largest source of carbon emissions. In terms of technology, pre-combustion remains the most widely used being the most advanced of the current three technologies but post-combustion is equally applied in power sector. One of the biggest projects by capex, (c$1.1bn funded by DOE) FutureGen 2.0, will be world's first full scale oxy-combustion power plant. The engineering & construction related contract was awarded to Air Liquide and its technology partner. This plant will have capacity to capture and store c1.3mn tonnes of CO2 each year, reducing power plant carbon emissions by c90%.

While public funding is expected to continue to flow for these projects, we believe worldwide development of these projects requires efficient and commercial viable carbon capture technology and a cheap and viable source of geological storage. We have discussed in our oxygen section in detail about current available technologies and financial costs to capture carbon.

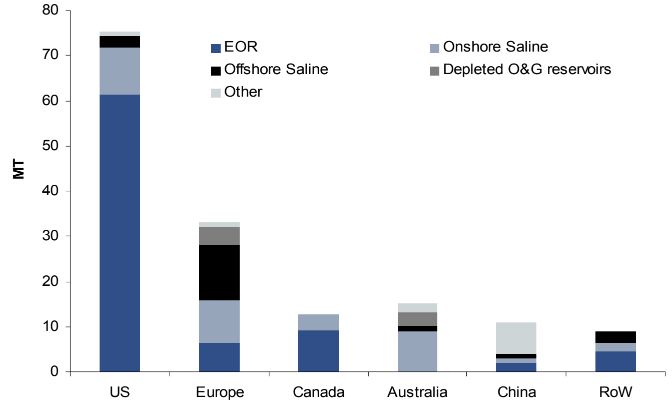
As discussed, none of the above technology is commercially viable as one tonne of CO_2 capture can be as high as $150/MT. While various R&D projects are underway to improve upon CO_2 capture technology, we believe the commercial market for CO_2 is already available in the form of Enhanced oil recovery (EOR). This technique is widely used in the US and can be used in Europe in similar fashion, especially in the North Sea, where carbon capture is an essential requirement and declining oil production is a concern. We discuss EOR and its benefits in detail in the next section.

Figure 123. Projects by capture type and industry sector



Source: Global CCS institute, CIRA

Figure 124. Volume of CO2 by storage (Mn MT) and region



Source: Global CCS institute, CIRA

EOR can offer solution by providing large carbon market

In CCS, typically c75% of costs are incurred towards carbon capture and rest is required for carbon transportation and storage in a suitable geological site. Though captured carbon can be sold for various commercial uses discussed in our liquid carbon dioxide section, those uses neither provide permanent carbon capture nor they have necessary size and scale to use full scale carbon emissions.

Saline formation storage, either onshore or offshore provides viable geological storage site but commercial value is negative in terms of transportation cost. In contrast, CO_2 can be used for EOR which can use carbon on large scale and provide for transportation and storage cost by recovering valuable oil reserves. Injection of CO_2 helps lower the oil viscosity and trapping forces in the reservoir. This helps making oil mobile and thus help recovering oil which otherwise was not recoverable. In our list of 74 key projects, 34 projects are using EOR as end use of carbon.

US is already using CO2 for EOR with c10m MT of carbon captured from chemical and gas treating plants and c44m MT of CO2 from natural sources

Currently there are 18,077 active oil wells worldwide (17,112 in US alone) which use CO_2 injection for EOR. North America has 58 years of experience in this technique with c3500 miles of underground pipeline used to transport CO_2 from various natural reservoirs of CO2 and industrial sites to oil fields. The largest of them is the Dakota Gasification Plant in the USA, which captures around 2.4 million tonnes of CO_2 annually, used for EOR in the Weyburn project in Canada. Two other gas processing plants in the USA supply each 1.2 million tonnes annually to the Rangely and Shanon Ridge EOR fields.

DOE best practice scenario provides c85bn barrels in US can become technically recoverable if stable supply of CO2 can be provided at $15/MT, assuming oil prices around $70/bbl and investment hurdle rate of 25%.

Currently there are 105 CO2- EOR projects in US providing c250 kboe/d of incremental oil production. Since 1986, a c1.5bn barrel of oil has been recovered through this process. DoE best practice scenario provides c85 bn barrels in US can become technically recoverable if stable supply of CO_2 can be provided at $15/MT, assuming oil prices around $70/bbl and investment hurdle rate of 25%. O&G company's returns are usually less than 25% ROR, and with oil prices hovering around c$100/bbl, DOE estimates $60/MT can be provided for carbon with 15% as financial hurdle rate. Assuming $15/Mt as transportation cost, this can still provides $45/MT of value to carbon industry making it financially viable for improved carbon capture technologies. Apart from commercialization of carbon, other key benefits of CO_2-EOR can be summarised as:

- **Large market for captured CO_2**: The size of market in US alone could be 7,500 million metric tonnes between now and 2030. This would be enough to provide support to 49 GW coal based capacity for carbon capture, i.e. c.15.5% of existing US coal based electricity generation capacity.

CO2 based EOR puts carbon sequestration as commercial opportunity instead of just environmental burden

- **Natural storage:** Storing CO_2 with EOR helps bypass need to assign the long-term liability for the injected CO_2 into geological structures remains an issue.
- **Permanent Capture:** Carbon captured in EOR is permanently stored underground unlike its current use for production of fertilizers which ultimately release carbon in environment upon usage.
- **Boom to oil production:** Use of CO_2 for EOR could increase depleting oil production. We estimate that if all captured CO2 is used for EOR in US, then oil production could increase by c3.0 Mbp/d to c3.6 Mbp/d, or c4% of world production.
- **Long term CCS infrastructure:** Once infrastructure in place, this can be used for further storage of CO_2 in saline formations.

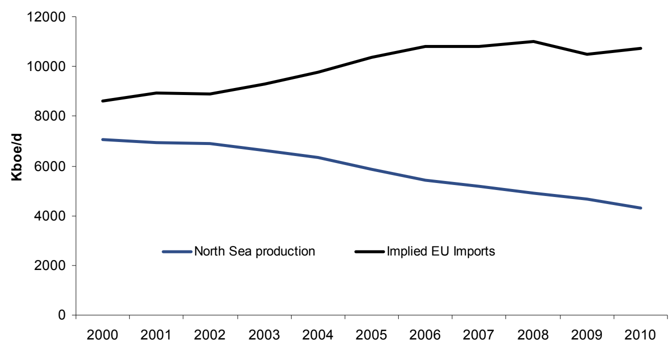
North Sea (primarily UK and Norway) region can be another big investor in CO2 EOR technology.

Considering commercial value for EOR and other environmental benefits, we believe this technique can be widely applied not just in US but in other parts of the world as well, especially the North Sea. Oil production in Europe has declined by c40% in last 10 years and the current decline rate is around 8% p.a.

As per detailed study report conducted on behalf of the North Sea Basin Task Force, CO_2-EOR in the UK sector alone could provide an incremental 2bn bbls of oil from 37 fields, with the five largest UK fields contributing c1.1bn bbls. Similarly the Norwegian sector has a potential of c1.8bn bbls of oil from 22 fields, with five largest Norwegian fields contributing c1.1bn bbls.

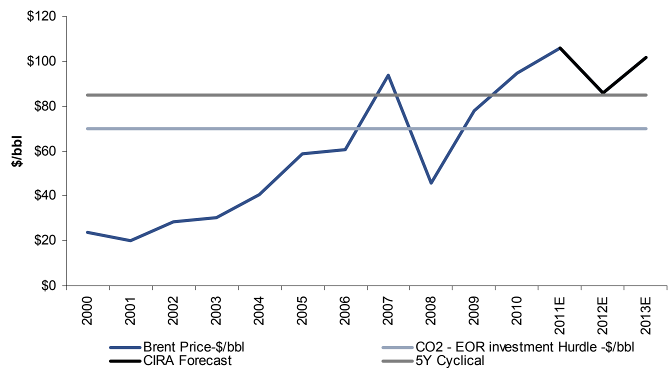
Though CO_2-EOR remains a major engineering challenge and requires a high degree of risk taking due to high upfront investment and the uncertain macro environment, we believe the world oil cycle is going to sustain oil prices above $80/bbl in long term, warranting investment in EOR techniques. On top of that, these investments should get government support in terms of taxation, royalties given its environmental benefits.

Figure 125. European production is declining making it depended on expensive oil imports



Source: BP, Citi Investment Research and Analysis

Figure 126. Oil prices are hovering around $100/bbl, warranting investment in CO2- EOR which is cost competitive at $70/bbl price



Source: Bloomberg, Citi Investment Research and Analysis

Coal Bed Methane

ECBM is another technology where CO2 can be used for commercial purpose. Key markets for ECBM application are US, Canada, China and Australia

Carbon dioxide can also be used to release methane (natural gas) from geologically challenging coal seams. Coal beds typically contain large amounts of methane-rich gas that is adsorbed in the coal. When CO_2 is injected into the coal bed, because it has a higher adsorptive index, it displaces the methane, which can then flow through natural fractures in the rock and into a well for delivery to the surface. US coal resources are estimated at 6 trillion tonnes, and 90% of it is currently un-mineable due to the geological challenges of seam thickness, depth, and structural integrity. Since many of the large coal seams are near electricity generating facilities, steady supply of CO2 can be made available by little investment into pipeline transportation.

Worldwide, it is estimated that c143tcm of gas is available in form of CBM. The biggest reserves other than US are in Canada, Russia, China and Australia with at least c72tcm of CBM gas reserves. According to a study done by Petrochina, c10bn MT of CO2 can be stored in eight main coal-beds in China by using Enhanced Coal Bed Methane (ECBM) technique. Apart from carbon storage, CO2 usage can enhance the methane resources of China from c736bcm to c1263 bcm, unlocking c$74bn worth of gas assuming $4/mmbtu value for incremental gas produced.

This technology is still **in its early stages** and various debate remains regarding various engineering solutions and their associated carbon impact. For details on coal seam gas and its relative position in energy market, please refer to our Asian team's note *Coal Seam Gas – Demystifying Fugitives - Claims, Counter-Claims, and Engineering Solutions*.

Figure 127. Key projects investing in CO2 capture

Asset Lifecycle Stage	Project Name	Country	Volume CO2	Operation Date	Facility Details	Capture Type	Transport Length	Transport Type	Storage Type
Operate	Century Plant (formerly Occidental Gas Processing Plant)	United States	8.5 Mtpa	2010	Natural Gas Processing	Pre-Combustion	256 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Operate	Enid Fertilizer	United States	0.68 Mtpa	1982	Fertiliser Production	Pre-Combustion	192 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Operate	Great Plains Synfuel Plant and Weyburn-Midale Project	Canada	3 Mtpa	2000	Synthetic Natural Gas	Pre-Combustion	315 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Operate	In Salah CO2 Storage	Algeria	1 Mtpa	2004	Natural Gas Processing	Pre-Combustion	14 km	Onshore to onshore pipeline	Onshore Saline Formations
Operate	Shute Creek Gas Processing Facility	United States	7 Mtpa	1986	Natural Gas Processing	Pre-Combustion	190 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Operate	Sleipner CO2 Injection	Norway	1 Mtpa	1996	Natural Gas Processing	Pre-Combustion	Minimal (storage on site)	Offshore to offshore pipeline	Offshore Saline Formations
Operate	Snøhvit CO2 Injection	Norway	0.7 Mtpa	2008	Natural Gas Processing	Pre-Combustion	150 km	Onshore to offshore pipeline	Offshore Saline Formations
Operate	Val Verde Natural Gas Plants (formerly Sharon Ridge)	United States	0.4 - 1.3 Mtpa	1972	Natural Gas Processing	Pre-Combustion	132 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Execute	ADM Illinois Industrial Carbon Capture and Sequestration Project	United States	Up to 1 Mtpa	2013	Chemical Production	Industrial Separation	1.6 km	Onshore to onshore pipeline	Onshore Saline Formations
Execute	Agrium CO2 Capture with ACTL	Canada	0.585 Mtpa	2014	Fertiliser Production	Pre-Combustion	234 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Execute	Boundary Dam Integrated Carbon Capture and Sequestration Demonstration Project	Canada	1 Mtpa	2014	Power Generation	Post-Combustion	100 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Execute	Gorgon Carbon Dioxide Injection Project	Australia	3.4 - 4 Mtpa	2015	Natural Gas Processing	Pre-Combustion	10 km	Onshore to onshore pipeline	Onshore Saline Formations
Execute	Kemper County IGCC Project (formerly Plant Ratcliffe)	United States	3.5 Mtpa	2014	Power Generation	Pre-Combustion	75 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Execute	Lost Cabin Gas Plant	United States	1 Mtpa	2012	Natural Gas Processing	Pre-Combustion	370 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Define	Air Products Steam Methane Reformer EOR Project	United States	1 Mtpa	2012	Hydrogen Production	Pre-Combustion	Not specified	Onshore to onshore pipeline	Enhanced Oil Recovery
Define	Bełchatów CCS	Poland	1.8 Mtpa	2015	Power Generation	Post-Combustion	51 – 100 km	Onshore to onshore pipeline	Onshore Saline Formations
Define	Coffeyville Gasification Plant	United States	0.85 Mtpa	2013	Fertiliser Production	Pre-Combustion	112 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Define	Eemshaven CCS	Netherlands	1.2 Mtpa	2017	Power Generation	Post-Combustion	Not specified	Ship/Tanker	Enhanced Oil Recovery
Define	Emirates Steel Industries	United Arab Emirates	0.8 Mtpa	2015	Iron and Steel Production	Industrial Separation	50 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Define	Green Hydrogen (formerly Air Liquide)	Netherlands	0.55 Mtpa	2016	Hydrogen Production	Industrial Separation	600 km	Ship/Tanker	Enhanced Oil Recovery
Define	Hydrogen Energy California Project (HECA)	United States	2 Mtpa	Not specified	Power Generation	Pre-Combustion	6.4 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Define	Hydrogen Power Abu Dhabi (HPAD)	United Arab Emirates	1.7 Mtpa	2017	Power Generation	Pre-Combustion	201 – 250 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Define	Lake Charles Gasification	United States	4.5 Mtpa	2014	Synthetic Natural Gas	Pre-Combustion	Not specified	Onshore to onshore pipeline	Enhanced Oil Recovery
Define	Medicine Bow Coal-to-Liquids Facility	United States	3.6 Mtpa	2015	Coal-to-liquids (CTL)	Pre-Combustion	Not specified	Onshore to onshore pipeline	Enhanced Oil Recovery
Define	Northwest Upgrader Refinery with ACTL	Canada	1.2 Mtpa	2014	Oil Refining	Pre-Combustion	234 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Define	OXYCFB 300 Compostilla Project	Spain	1.1 Mtpa	2015	Power Generation	Oxyfuel Combustion	120 km	Onshore to onshore pipeline	Onshore Saline Formations
Define	Porto Tolle	Italy	1 Mtpa	2015	Power Generation	Post-Combustion	101 – 150	Onshore to offshore pipeline	Offshore Saline Formations
Define	Project Pioneer	Canada	1 Mtpa	2015	Power Generation	Post-Combustion	90 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Define	PurGen One	United States	2.6 Mtpa	2017	Power Generation	Pre-Combustion	160 km	Onshore to offshore pipeline	Offshore Saline Formations
Define	Quest	Canada	1.2 Mtpa	2015	Hydrogen Production	Pre-Combustion	84 km	Onshore to onshore pipeline	Onshore Saline Formations
Define	Rotterdam Opslaf en Afvang Demostratieproject (ROAD)	Netherlands	1.1 Mtpa	2015	Power Generation	Post-Combustion	≤50 km	Onshore to offshore pipeline	Offshore Depleted Oil and Gas Reservoirs

Define	Spectra Fort Nelson CCS Project	Canada	2.2 Mtpa	2015	Natural Gas Processing	Pre-Combustion	20 km	Onshore to onshore pipeline	Onshore Saline Formations
Define	Taylorville Energy Center	United States	3 Mtpa	2016	Power Generation	Pre-Combustion	≤50 km	Onshore to onshore pipeline	Onshore Saline Formations
Define	Tenaska Trailblazer Energy Center	United States	5.75 Mtpa	Not specified	Power Generation	Post-Combustion	201 – 250 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Define	Texas Clean Energy Project	United States	2.5 Mtpa	2014	Power Generation	Pre-Combustion	≤50 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Define	ULCOS - Blast Furnace	France	0.7 Mtpa	2016	Iron and Steel Production	Industrial Separation	51 – 100 km	Onshore to onshore pipeline	Onshore Saline Formations
Define	Vattenfall Jänschwalde	Germany	1.7 Mtpa (1.4 Mtpa Oxyfuel + 0.3 Mtpa PCC)	2015	Power Generation	Oxyfuel Combustion	51 – 100 km	Onshore to onshore pipeline	Onshore Saline Formations
Evaluate	Bow City Power Project	Canada	1 Mtpa	2017	Power Generation	Post-Combustion	≤50 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Evaluate	Browse Reservoir CO2 Geosequestration	Australia	3 Mtpa	2017	Natural Gas Processing	Pre-Combustion	Not specified	Unspecified pipeline	Saline Formations or Depleted Gas Reservoir
Evaluate	C.GEN North Killingholme Power Project	United Kingdom	2.5 Mtpa	2015	Power Generation	Pre-Combustion	Not specified	Onshore to offshore pipeline	Offshore Saline Formations
Evaluate	CarbonNet Project	Australia	1.2 Mtpa	2018	Power Generation	Various	51 – 100 km	Onshore to offshore pipeline	Offshore Saline Formations
Evaluate	Cash Creek Generation	United States	2 Mtpa	2015	Power Generation	Pre-Combustion	Not specified	Onshore to onshore pipeline	Enhanced Oil Recovery
Evaluate	Collie - South West CO2 Geosequestration Hub (Collie Hub)	Australia	2.45 Mtpa	2015	Fertiliser Production	Pre-Combustion	51 – 100 km	Onshore to onshore pipeline	Onshore Saline Formations
Evaluate	Don Valley Power Project (formerly Hatfield)	United Kingdom	4.75 Mtpa	2015	Power Generation	Pre-Combustion	175 – 425 km	Onshore to offshore pipeline	Enhanced Oil Recovery or Offshore Saline Formations
Evaluate	Emirates Aluminium CCS Project	United Arab Emirates	2 Mtpa	2017	Power Generation	Post-Combustion	351 – 400 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Evaluate	Eston Grange CCS Plant	United Kingdom	2.5 Mtpa	2016	Power Generation	Pre-Combustion	225 km	Onshore to offshore pipeline	Offshore Saline Formations
Evaluate	Full-scale CO2 Capture Mongstad (CCM)	Norway	1 Mtpa	Not specified	Power Generation	Post-Combustion	Not specified	Onshore to offshore pipeline	Not specified
Evaluate	FutureGen 2.0 Oxy-Combustion Large Scale Test	United States	1.3 Mtpa	2016	Power Generation	Oxyfuel Combustion	≤50 km	Onshore to onshore pipeline	Onshore Saline Formations
Evaluate	Getica CCS Demonstration Project	Romania	1.5 Mtpa	2015	Power Generation	Post-Combustion	40 km	Onshore to onshore pipeline	Onshore Saline Formations
Evaluate	GreenGen IGCC Project	China	2 Mtpa	2016	Power Generation	Pre-Combustion	151 – 200 km	Onshore to onshore pipeline	Various
Evaluate	Indiana Gasification	United States	4.5 Mtpa	2015	Synthetic Natural Gas	Pre-Combustion	Not specified	Onshore to onshore pipeline	Enhanced Oil Recovery
Evaluate	Kentucky NewGas	United States	5 Mtpa	2017	Synthetic Natural Gas	Pre-Combustion	≤50 km	Onshore to onshore pipeline	Onshore Saline Formations
Evaluate	Korea-CCS 1	Republic Of Korea	1.2 Mtpa	2017	Power Generation	Post-Combustion	Not specified	Ship/Tanker	Offshore Saline Formations
Evaluate	Mississippi Gasification (Leucadia)	United States	4 Mtpa	2015	Synthetic Natural Gas	Pre-Combustion	176 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Evaluate	Peel Energy CCS Project (formerly Hunterston Power Station)	United Kingdom	2 Mtpa	2016	Power Generation	Post-Combustion	301 – 350 km	Onshore to offshore pipeline	Offshore Depleted Oil and Gas Reservoirs
Evaluate	Pegasus Rotterdam	Netherlands	2.5 Mtpa	2017	Power Generation	Oxyfuel Combustion	101 – 150 km	Onshore to offshore pipeline	Offshore Depleted Oil and Gas Reservoirs
Evaluate	Peterhead Gas CCS Project	United Kingdom	1 Mtpa	2016	Power Generation	Post-Combustion	Not specified	Onshore to offshore pipeline	Offshore Depleted Oil and Gas Reservoirs
Evaluate	Quintana South Heart Project	United States	2.1 Mtpa	2017	Power Generation	Pre-Combustion	Not specified	Onshore to onshore pipeline	Enhanced Oil Recovery
Evaluate	Riley Ridge Gas Plant	United States	2.5 Mtpa	2015	Natural Gas Processing	Pre-Combustion	Not specified	Onshore to onshore pipeline	Enhanced Oil Recovery
Evaluate	Sinopec Shengli Oil Field EOR Project	China	1 Mtpa	2014	Power Generation	Post-Combustion	≤50 km	Unspecified pipeline	Enhanced Oil Recovery
Evaluate	Southland Coal to Fertiliser Project	New Zealand	1 Mtpa	2018	Fertiliser Production	Pre-Combustion	100 km	Onshore to onshore pipeline	Onshore Saline Formations
Evaluate	Swan Hills Synfuels A" In-Situ Coal Gasification/Power Generation Project"	Canada	1.4 Mtpa	2015	Synthetic Natural Gas	Pre-Combustion	51 – 100 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Evaluate	Sweeny Integrated Gasification Combined Cycle Power Project	United States	5 Mtpa	2016	Power Generation	Pre-Combustion	≤50 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Evaluate	UK Oxy CCS Demonstration Project (formerly Drax)	United Kingdom	2 Mtpa	2016	Power Generation	Oxyfuel Combustion	Not specified	Onshore to offshore pipeline	Offshore Saline Formations

Evaluate	Wandoan CCS Project	Australia	Up to 2.5 Mtpa	2017	Power Generation	Pre-Combustion	≤50 km	Onshore to onshore pipeline	Onshore Saline Formations
Identify	Coolimba Power Project	Australia	2 Mtpa	2020	Power Generation	Not Specified	51 – 100 km	Onshore to onshore pipeline	Various
Identify	Dongguan Taiyangzhou IGCC with CCS Project	China	1 Mtpa	2017	Power Generation	Pre-Combustion	101 – 150 km	Onshore to offshore pipeline	Offshore Depleted Oil and Gas Reservoirs
Identify	Good Spring IGCC	United States	1 Mtpa	2014	Power Generation	Pre-Combustion	≤50 km	Onshore to onshore pipeline	Various
Identify	Korea-CCS 2	Republic Of Korea	1.2 Mtpa	2019	Power Generation	Not Specified	Not specified	Ship/Tanker	Offshore Saline Formations
Identify	Lianyungang IGCC with CCS Project	China	1 Mtpa	2015	Power Generation	Pre-Combustion	201 – 250 km	Onshore to onshore pipeline	Enhanced Oil Recovery
Identify	Maritsa Thermal Power Plant CCS Project	Bulgaria	2.5 Mtpa	2020	Power Generation	Post-Combustion	Not specified	Onshore to onshore pipeline	Onshore Saline Formations
Identify	Shenhua Coal to Liquids Plant Project (Ordos)	China	1 Mtpa	2020	Coal-to-liquids (CTL)	Pre-Combustion	Not specified	Onshore to onshore pipeline	Onshore Saline Formations
Identify	Shenhua/Dow Chemicals Coal to Chemicals Plant Project (Yulin)	China	5 Mtpa	2019	Coal-to-liquids (CTL)	Pre-Combustion	Not specified	Onshore to onshore pipeline	Various

Source: Global CCS Institute

Acetylene

Acetylene (C2H2) is a colourless, highly flammable gas used as an intermediate in chemical manufacture and as an industrial fuel gas for cutting and welding. Since compression and transportation of acetylene is not practical for large-scale chemical use because of its flammable and explosive nature, almost all acetylene for chemical synthesis is consumed at or near the production site and mostly produced by captive process.

Use of Acetylene has declined steadily in developed markets due to development of cheaper substitutes. In the past, Acetylene was used to produce Acrylic acid which is now replaced by propylene. It was also used to produce VCM which is now produced from Ethylene, although China still uses it for production of VCM. It is estimated that c5.2m MT of Acetylene was consumed in 2010 of which c92% was produced and consumed by China. Overall, we expect the Acetylene market to grow at 7.2% CAGR 2010-15E mainly driven by Chinese chemical demand.

Acetylene market is driven by China due to its usage in production of VCM and VAM

Figure 128. Consumption is driven by China with c7.7% CAGR growth (2010-15e)

	Capacity	Production	Consumption		CAGR -
	2010	2010	2010	2015E	2010-15E
United States	121	104	109	117	1.4%
Europe	211	166	165	173	1.0%
CIS	89	73	73	79	1.6%
Japan	127	69	69	69	0.0%
China	6,726	4,738	4,732	6,865	7.7%
Total	**7,274**	**5,150**	**5,148**	**7,304**	**7.2%**

Source: SRI consulting, Citi Investment Research and Analysis

Production

Acetylene is mainly produced from Calcium carbide in China due to availability of cheap coal resources

Acetylene is mainly produced by reacting Calcium carbide with water. It can also be produced through hydrocarbons cracking or as a by product of Ethylene. BASF is the main producing company in US which uses it for in house production of 1,4-butanediol and derivatives. In Canada, Air Liquide, Air Products and Praxair are main producers of acetylene and supply it for metalworking applications. BASF remains the biggest producer in Europe using it for captive production though Linde and Air Liquide have small production plants in Bulgaria, Romania, Hungary and Croatia catering industrial users. In China, acetylene is mainly produced by local producers of VCM and VAM. In rest of Asia, there are c.80 non-chemical producers of acetylene, making it a highly fragmented market.

BASF is largest producer of acetylene in US and Europe using it for captive purpose whereas industrial gas companies are marginal players catering industrial demand

Figure 129. Acetylene production capacity by production process, 2011E (000 MT)

Annual capacity	US	Europe	Japan	China	Total	% of Total
Natural gas	84	0	0	181	265	4%
Calcium Carbide	16	11	120	6545	6692	93%
Ethylene Co product	20	12	7	0	39	1%
Other hydrocarbon streams	0	188	0	0	188	3%
Total	**120**	**211**	**127**	**6726**	**7184**	**100%**

Source: SRI consulting, Citi Investment Research and Analysis

Applications

Acetylene is primarily used for chemicals where it serves as a raw material for VCM, VAM and synthesis of acetylenic chemicals, primarily 1,4-butanediol (an important building block for fine chemical synthesis). Industrial gas companies have little market in this segment as most of the production is captive. For industrial use, Acetylene is a traditional gas used for metal welding and cutting in the manufacturing industry.

Figure 130. Acetylene consumption by chemical and industrial use (000 MT)

Annual capacity	US	Europe	Japan	China	Total	% of Total
Vinyl Chloride Monomer	0	6	0	3655	265	4%
Vinyl Acetate Monomer	0	49	0	263	6692	93%
Acetylenic Chemicals	80	58	6	53	39	1%
Other	4	52	50	81	188	3%
Total Chemical	**84**	**165**	**56**	**4052**	**4357**	**86%**
Industrial use	**25**	**0**	**13**	**680**	**718**	**14%**
Total	**109**	**165**	**69**	**4732**	**5075**	**100%**

Source: SRI Consulting, Citi Investment Research and Analysis

End market for industrial gas companies is for industrial use which is poised to decline due to availability of cheaper and environmental friendly products

Industrial gas companies have market share in industrial use only as most of the production for chemical usage is in-house. The major industrial application for acetylene is oxy-acetylene torches used for metal cutting, metal brazing (joining two or more metal pieces together at very high temperatures) and welding. Acetylene cylinders are very heavy due to safety features and as such other fuel gases like propane, MAPP, LPG which can be packed in lighter cylinders are replacing acetylene in this sector. Its typical users are individuals involved in welding process where it is the only suitable fuel gas and now accounts for c80% of market share.

Pricing

Acetylene production from calcium carbide is more expensive than US gas based production

In the US, Acetylene prices are traded on contract for chemical use and closely follow natural gas price on which majority of production is based on. It was around \$1.9/Kg in 2008, \$1.7/Kg in 2009 and \$1.8/kg in 2010. Production based on calcium carbide is more expensive and the retail price for commercial-grade cylinder acetylene (98%, dissolved in acetone) sold to industrial gas end users in China was around \$2.88-4.61 per Kg in 2008, \$2.64-3.95 per Kg in 2009 and \$3.23-4.41 per Kg in 2010.

Speciality Gases

Two segments — noble gases and electronic gases

- Noble gas availability has been limited and so access to reserves of helium etc. have been critical to market success.
- The creation of large levels of oxygen demand (as previously discussed) raises the potential of significantly improved noble gas supply as these gases can be stripped out of the natural gas streams.
- We expect electronic gases, equipment and services demand overall to rise by about **8%-10% compound** over the next five years, although some cyclicality should still be expected.
- The continuing growth of the flat panel display (TFT LCD) market and use of LCD in greater numbers of consumer electronics has helped boost electronic chemicals and equipment demand.
- Successful restructuring could enhance the value of this segment, but portfolio change/consolidation, notably for the equipment businesses, is probably needed to address the dominance of the customer industries' purchasing power.

Noble gases

Speciality gases – mainly helium, krypton, neon, xenon and ozone – **represent 6%** of the worldwide market in US dollar terms, but only a very small volume share.

Helium

Helium is a tasteless, odorless, nonflammable, non-toxic, inert gas. The smallest of all molecules, helium is the second lightest elemental gas, after hydrogen.

Production

Helium is produced by:

- **Liquefaction Extraction** – Crude helium is extracted from natural gas streams using low-temperature liquefaction.
- **PSA** – This non-cryogenic process uses an adsorbent bed which selectively attracts contaminants from condensed crude helium.
- **Cryogenic System** – Crude helium is compressed and cooled before nitrogen is condensed and removed.

Applications

Helium gas has wide application in:

The largest use for gaseous helium is in welding.

- **Welding** – Helium provides an inert gas shield to protect the weld zone from the atmosphere. Many metals cannot be joined successfully without such a protective shield because of their vulnerability to oxidation. This is top of the range technology though so limited to highly critical, high added value components.
- **Inert atmosphere** – Helium is used to provide inert atmospheres in industrial applications such as bonding and soldering processes for semiconductor chip manufacture, fiber optic production and organic culture growth. Again demand is limited to high added-value end-products.

- **Lifting gas** – Helium's first use in lifting applications was as a non-flammable substitute for hydrogen in balloons and blimps. Current uses as a lifting gas include balloons for weather forecasting and atmospheric testing, blimps and toys, and party and gift balloons. This area could grow with the potential development of low-altitude communications networks using helium-filled balloons instead of satellites.

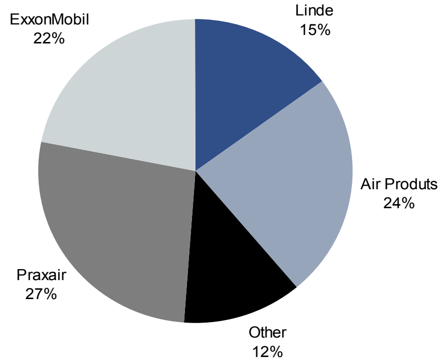
Fiber optic production has been a significant growth area in recent years.

- **Fibre-optics** – Optical fibres have an "inner core" and "outer sleeve" and helium is introduced in between to prevent the signal from bouncing out of the core. Growth in fibre-optics is expected to outpace the total growth during our forecast years.
- **Pressure/purging** – Helium is used as a pressurising agent and purge gas for the rocket's hydrogen fuel line. Helium was used in the Space Shuttle programme. It is estimated that each launch required about 200 thousand cubic meters (7-8 million cubic feet) of helium. NASA and the US DoD use helium for purging equipment in their liquid hydrogen/liquid oxygen rocket propulsion systems. NASA is using about 90-100 million cubic feet per year for this application.
- **Chromatography** – Helium is widely used as a carrier gas in gas chromatography, owing to its properties of low solubility, inertness and high thermal conductivity. It finds use in the pharmaceutical, food and beverage, environmental, medical diagnostics, and petroleum industries.
- **Leak detection** – Because helium is capable of escaping through tiny openings, has a high diffusion rate, and is easily detected in trace amounts, it is used to detect leaks or to verify the absence of leaks in products that require leak-proof systems for safety or long service life. Such products include piping systems for nuclear reactors, television tubes and hermetically sealed electronic equipment. In the automobile industry, helium is used to test air bag initiators, radiators and air conditioning units. Helium is also used to test process equipment in the semiconductor industry.
- **Heat transfer** – Helium is useful as a heat transfer medium because it is chemically inert, has a high thermal conductivity and remains gaseous under normal operating conditions. Higher operating temperatures can be attained with helium than with other gases, which results in higher operating efficiencies. Helium has been used in the manufacture of optical fiber and at gas-cooled nuclear reactors. A major end use is in medical NMR body scanners in hospitals.
- **Breathing mixtures** – Helium and oxygen are used as a synthetic breathing mixture for deep-sea divers working underwater at depths below 180 feet for extended periods of time. Helium is also used in breathing mixtures for asthmatics, since its rapid rate of diffusion opens up congested lungs more easily than ordinary air does. In anesthesia, helium is also used as a carrier gas. A mixture of helium and oxygen, termed heliox, is used in therapeutic applications for other breathing disorders including bronchitis, chronic obstructive pulmonary diseases and respiratory acidosis.
- **Other** – Helium is used in supersonic wind tunnels and also in laser eye surgery using a mixture of helium with neon. Helium is used in the electronics industry as a blanketing and carrier gas. It is also used for back-side temperature control to maintain uniform wafer temperature during critical deposition processes in the electronics industry.

Development of helium gas recovery and reclaiming systems is an increasing trend among producers.

Helium is a relatively expensive product and also has a finite source. Large consumers of helium have shown interest in reducing their consumption and cost, leading all the major industrial gas companies such as Air Liquide, Air Products, Linde, Matheson Tri-Gas and Praxair to develop helium recovery systems that are capable of recovering and reclaiming the gas.

Figure 131. Market Share of US Producers of Refined Helium in 2009



Source: SRI Consulting

About 65-70% of world helium production capacity is located in the United States; however, commercially significant quantities of helium are also currently produced in Algeria, Russia, Qatar, Australia and Poland. A small unit operates in China.

Figure 132. Production of Helium by Region in 2009

000cubic meters	2009	Global Market Share (%)
US	117,574	74%
Qatar	14,300	9%
Algeria	14,300	9%
Japan	12,711	8%
Russia	6,355	4%
Australia	4,767	3%
Other	3,178	2%

Source: SRI Consulting and CIRA

Demand for Helium

Minimum growth rate of helium gas demand is estimated at 3-4% p.a., whereas supply tightening will contribute to price increases until new sources enter the market after 2013.

World demand for helium in 2010 is estimated to be around 6.4 billion standard cubic feet (100-110 billion cubic metres) and the United States is the world's largest producer and consumer of helium. Historically, the US used to consume c50% of world production, but we expect that its share will fall to c43% by 2013 due to increasing demand from the Asian electronics industry. Helium demand rebounded strongly in 2010 after economic downturn as there are no alternates for helium use in the semiconductor industry, optical fibres, MRI and car air packs. Increasing requirements by the developing economies is likely to ensure a minimum growth rate of around 3-4% per year. With the supply situation getting tight, prices will likely keep increasing until new sources enter the market sometime after 2013.

Future demand growth is projected to come from high-tech manufacturers in China, Republic of Korea and Taiwan

Future growth of helium is expected to be driven by demand from electronics manufacturers in China, the Republic of Korea and Taiwan. Semiconductor manufacturing, flat panel display manufacturing and optical fibre manufacturing are all significant consumers of helium in Asian markets. While worldwide demand is only expected to grow by 3-4% per year, demand in these countries is growing by 10-20%. We believe industrial gas companies are well positioned to capture this growth as they increase their footprints in these markets.

Krypton/neon/xenon

The noble gases are colorless, odorless, tasteless, and nonflammable under standard conditions. Among all, xenon has a very low abundance in the atmosphere.

Neon, krypton, and xenon are obtained from air using the methods of liquefaction of gases, to convert elements to a liquid state, and fractional distillation, to separate mixtures into component parts. The prices of the noble gases are influenced by their natural abundance, with xenon the most expensive.

Noble gases are commonly used in lighting because of their lack of chemical reactivity.

In many applications, the noble gases are used to provide an inert atmosphere. Krypton is used in high-performance light bulbs, which have higher colour temperatures and greater efficiency, because it reduces the rate of evaporation of the filament more than argon; halogen lamps, in particular, use krypton mixed with small amounts of compounds of iodine or bromine. Neon is used for filling discharge tubes. The noble gases glow in distinctive colors when used inside gas-discharge lamps, such as "neon lights". These applications are in strong decline as LED lights take share.

Noble gases are used in excimer lasers, which have many industrial, medical and scientific applications.

The noble gases are used in excimer lasers, which are based on short-lived electronically excited molecules known as excimers. They are used for microlithography and microfabrication, which are essential for integrated circuit manufacture, and for laser surgery, including laser angioplasty and eye surgery. Some noble gases have direct application in medicine. Xenon is used as an anaesthetic because of its high solubility in lipids, which makes it more potent than the usual nitrous oxide, and because it is readily eliminated from the body, resulting in faster recovery. Xenon finds application in medical imaging of the lungs through hyperpolarised MRI.

The US market size for specialty gases is evaluated at $2.9bn. Demand for specialty gases is estimated to grow at 1% p.a. through 2013.

We estimate that the US market size for specialty gases is **c$2.9bn**. US specialty gas demand will **rise 1%** annually **through 2013**. Manufacturing will remain the largest market while health care grows the fastest. We believe analytical gases will outpace other applications due to the increasing need to monitor pollutants, maximise production efficiency, monitor product quality, and render diagnosis.

Electronic speciality gases

The gases used in the semiconductor industry can be classified into two main categories:

- **Blanketing and Carrier Gases** – This application takes the largest proportion of gases in the semis industry. Carrier gases (nitrogen, argon, helium) are used in production process to maintain the correct environment and control the processes. Nitrogen is the main gas used for blanketing and application.
- **Etching Gases** – Perfluorinated Compounds (PFCs) are used in semiconductor fabrication plants because they provide a uniquely effective process performance when etching and are a safer, more reliable source of fluorine, which is required for cleaning certain deposition process chambers. The use of PFC gases in these processes is crucial to the production of semiconductor devices, as there are no effective substitutes outside the fluorinated chemistries that could be used effectively. Nitrogen trifluoride is a key gas and Air Products is the leading provider. Silane is of major importance for all silicon-based manufacturing processes for products such as semiconductors, photovoltaic solar cells and flat panels.

Electronic Special Gases (ESG) accounted for almost 40% of all electronic gas sales in 2010. We estimate the global market value in 2010 for ESGs to be €1.5bn. We expect the global **ESG market to grow 10% year on year from 2010 to 2015**. Growth in demand for ESG products should be driven by the global market recovery following the global recession as manufacturers ramp up their volumes and supply. While demand will grow across all primary sectors (semiconductor, PV, LED, TFT-LCD), we anticipate strong growth for silane, nitrogen trifluoride and fluorine driven by TFT-LCD and thin film PV. Market conditions are currently relatively challenging as the electronics industry is in a destocking phase.

Air Liquide recently increased its **silane production** capacity to meet the growing needs of the **photovoltaic market**. With 80% of its revenues coming from Asian markets, the company's electronics business is targeting industry leaders in China, Taiwan, Korea and Southeast Asia. With management based in Asia, the business line looks to further invest in photovoltaics and precursor molecules.

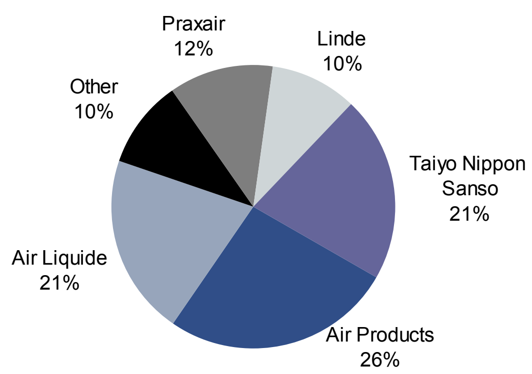
Growth in China is a key element of **Linde's Electronics strategy**. The biggest market for electronics gases in China is **solar**. Approximately 60% of the solar modules constructed in 2011 were manufactured in China. The fastest growth is coming from **LED**. This segment is driven by growing demand from display backlighting and general lighting and is supported by subsidies for MOCVD equipment from Chinese provincial governments. More than 50 companies are adding GaN production capacity in China in 2011 which has increased a total of more than 500 MOCVD tools.

There is also high growth in **TFT LCD**, supported by governmental incentives as well as by direct investments. BOE and CSOT are starting the first Gen8.5 fabs in China with more expected from Korean investors. Linde is well positioned in China thanks to strategic investments in infrastructure in recent years. 2011 highlights include the start-up of the first ultra high purity Ammonia plant in China and the start-up of Linde's market-leading SPECTRA-N ultra high purity on-site nitrogen generation plant to supply BOE B4 in Beijing.

Praxair is the largest industrial gas supplier to the **polysilicon market** and currently serves more than 50 photovoltaic manufacturing facilities worldwide.

Air Products supply critical materials and services to light-emitting diode (**LED**) and photovoltaic manufacturers. Other major end-markets for the company are silicon and compound semiconductors (ICs), TFT-LCDs, PV devices, LEDs, coatings, inks, adhesives and polyurethane production.

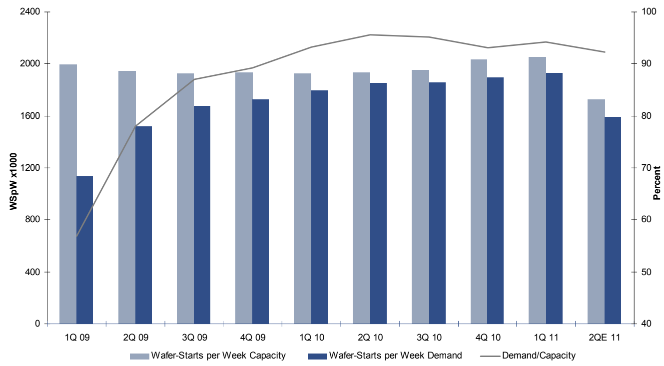
Figure 133. Global Electronics Industrial Gases and Speciality Chemicals Market Share, 2010



Source: Company reports, Citi Investment Research and Analysis

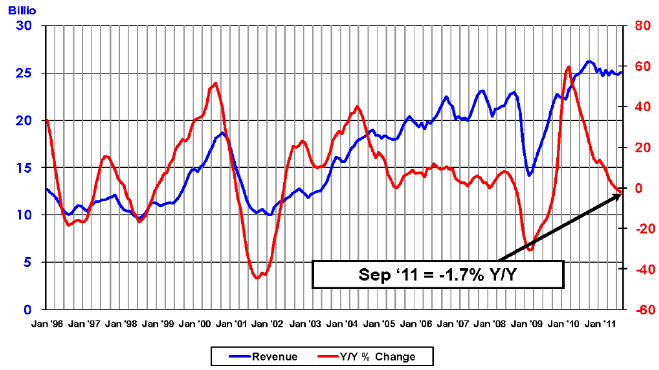
In 2010 the semiconductor market recovered from the global economic recession to achieve a record market size. Worldwide **sales of semiconductors for 2010** reached a record **$298.3bn** which represents a YoY increase **of 31.8%** and the Q3 2011 has experienced a **QoQ growth rate of 3.5%.**

Figure 134. Semiconductor Demand and Production Capacity, 2009-11



Source: SIA

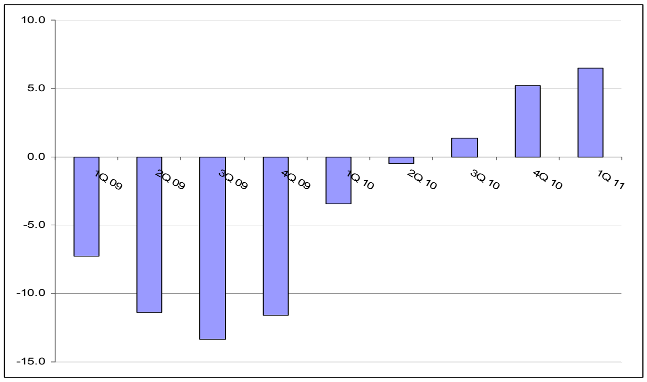
Figure 135. Worldwide Semiconductor Revenues and YoY % Change



Source: SIA

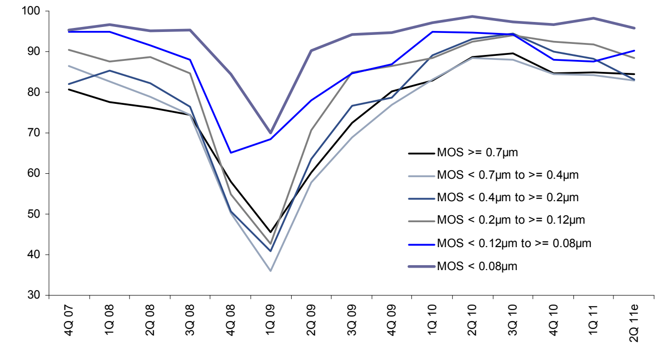
The capacity changes clearly reflected the macroeconomic conditions with growth plummeting in 2009 and recovering steadily since 2010. Utilisation rates have also entered a recovery process since the end of 2009, which reiterates the positive outlook for the industry overall.

Figure 136. IC Wafer Capacity Growth in %, 2009-2011



Source: SIA, Citi Investment Research and Analysis

Figure 137. Capacity Utilisation Rates by Line Width, 2007-2011



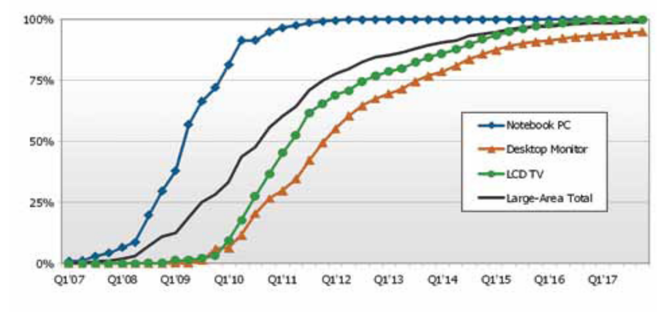
Source: SIA

Technological progress should enable the semiconductor industry to continue benefiting consumers and businesses around the world. Light emitting diodes (LEDs) and TVs utilizing LED technologies as well as Smart Cities are growing markets in which these products are key elements with strong future market potential.

Until 2010, the LED industry grew through development of multiple applications including automotive, mobile phone backlights and keypad lights, and notebook PC display backlighting, as well as indicators, signage and illumination. With the rapid adoption of LED backlights in LCD and monitors, the industry is undergoing a boom in investment, and new companies are entering the market. The LED industry entered into a new phase in 2010, as the market for LED backlights in large-area liquid crystal displays (LCDs) took off.

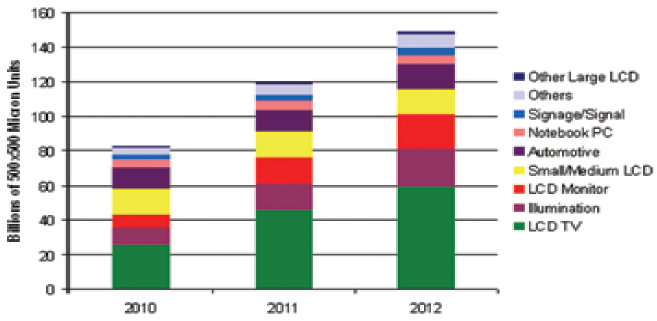
Developments in manufacturing, materials and packaging have all contributed to the increased output and falling prices for LED devices. The increased scale of manufacturing is driving additional improvements in LEDs, and ongoing materials and process development will likely further performance. This should open up the ultimate market for LEDs, general illumination. LED lamps and street lights are regarded as key lighting markets for LEDs. Demand growth for the LEDs industry is expected at 50% for 2011 and 25% for 2012.

Figure 138. LED backlights are used in more than half of all large-area TFT LCD panels



Source: SIA

Figure 139. Total LED demand will pass 100 billion chips in 2011



Source: SIA

In the longer run Organic LED (OLED) revenues are expected to grow to about $8bn in 2017, up from $0.8bn in 2009, with 33% CAGR. Mobile phone main displays had strong growth recently, and should continue to lead revenues to around $4bn in 2017. TV is expected to become the second largest revenue-producing application, at around $3bn in 2017.

Production and Distribution

- Technology choice depends on volume, purity, temperature and demand pattern.
- Cryogenic separation, for high purity and large volumes, accounts for 95% of worldwide production.
- Non-cryogenic separation, for lower purities and smaller volumes, includes PSA, VPSA and membranes, and offers large cost savings.
- Access to raw materials is important for speciality gases.

Production

Cryogenic gases can be produced by cryogenic distillation and non-cryogenic air separation, but the former is most prevalent.

Using air as its raw material, companies produce oxygen, nitrogen, argon, helium, neon, krypton and xenon through several air separation processes of which cryogenic air separation is the most prevalent.

- Oxygen is produced in large quantities and at high purity as a gas or liquid by cryogenic distillation and as a lower purity gas (typically about 93%) by adsorption technologies.
- Nitrogen is produced in large volumes in both gas and liquid form by cryogenic distillation; smaller volumes may be produced as a gas by PSA or diffusion separation processes. Cryogenic processes can produce very pure nitrogen. Adsorption and diffusion processes are typically used to make lower purity product in small amounts.

Praxair led the development and commercialisation of non-cryogenic air separation technologies for the production of cryogenic gases. These technologies optimise production capacity for the company by lowering the cost of supplying industrial gases. These technologies include pressure swing adoption (PSA), proprietary vacuum pressure swing adoption (VPSA) and membrane separation to produce gaseous oxygen and nitrogen, respectively.

PSA – The pressure swing adsorption (PSA) process selectively produces oxygen or nitrogen by passing compressed air through an adsorbing medium. The choice of adsorbent and process cycle design determines which gas will be produced, even though the adsorption isotherms of the two gases are almost identical; depending on the type of adsorbent used, an oxygen-rich or nitrogen-rich gas passes more rapidly through the adsorbent and is collected. The respective nitrogen-rich or oxygen-rich waste product remaining in the adsorbent pores is desorbed at lower pressures to regenerate the adsorbent. PSA units are typically portable; they are used at on-site locations and may be quickly started up or shut down.

VPSA – Each VPSA system includes a rotary-lobe feed air blower, vacuum blower (two bed systems only), one or two adsorbent vessels, an oxygen surge tank, switching valves and computer controls. In the single-bed system, the blower draws in air, compresses it and sends it to the adsorbent vessel to remove impurities, leaving 90-94% pure oxygen as the product. The adsorbent is then regenerated as the blower removes gas by reducing the pressure inside the vessel. The waste gas (nitrogen, water and carbon dioxide) is then discharged into the air. Since oxygen is not produced during regeneration, the system includes a low-pressure surge tank to allow for continuous oxygen supply. The two-bed system uses a similar adsorption process cycle that relies on swings in pressure- from above one atmosphere to below atmospheric pressure (vacuum) – to cycle each bed sequentially from adsorption to desorption. One bed is always adsorbing impurities to separate oxygen from air, while the other bed regenerates. Thus, the beds alternately produce oxygen into a surge tank which ensures that product is available continuously at a consistent pressure and purity.

Process gases are produced by methods other than air separation.

Process gases, including carbon dioxide, hydrogen, carbon monoxide and acetylene are produced by methods other than air separation.

- Most carbon dioxide is purchased from by-product sources, including chemical plants, refineries and industrial processes and is recovered from carbon dioxide wells.
- Hydrogen and carbon monoxide are produced by either steam methane reforming of natural gas or by purifying by-product sources obtained from the chemical and petrochemical industries.
- Acetylene is typically produced from calcium carbide and water or purchased as a chemical by-product.

Typical savings from an oxygen VPSA system range from 20 to 50%.

For large-volume liquid oxygen users, typical savings from an oxygen VPSA system range from 20 to 50% due to reduced distribution and energy costs.

Membranes are often the most cost-effective and flexible way to produce a continuous supply of gases for a variety of applications.

Membrane Technology – Membranes employ the principle of selective permeation to separate gases. Each gas has a characteristic permeation rate that is a function of its ability to dissolve in and diffuse through a membrane. Today's commercial gas separation membranes are typically polymeric hollow fibres. Thousands of these fibres are bundled together in a membrane module.

The more permeable gases such as oxygen, water vapour and carbon dioxide are concentrated in one stream, while nitrogen and argon are retained and collected in a separate stream. With a nitrogen membrane, the stream carrying oxygen, water vapour and carbon dioxide is vented. Praxair's nitrogen producing membranes are the most advanced air separation systems commercially available, producing 300 to more than 120,000 scf per hour of nitrogen at 95 to 99.999% purity.

For bulk liquid users, typical savings from a nitrogen-producing membrane system can be as much as 50%. For cylinder users, these membrane systems can increase productivity by eliminating cylinder changing, cylinder handling and storage. And both bulk liquid and cylinder users benefit from reduced distribution and order processing costs. And as the requirements change, the membrane system can be easily adapted to meet them.

The membranes separate nitrogen from air by selective permeation.

The key of nitrogen production is the advanced hollow-fibre membrane cartridge. The membranes separate nitrogen from air by selective permeation. When air is supplied to the membrane cartridge, oxygen, carbon dioxide and water vapour permeate rapidly through the membrane fibre and return to the atmosphere. Nitrogen, which does not readily permeate the membrane, goes directly into the distribution system and is supplied at the customer's flow rate, pressure and purity requirements.

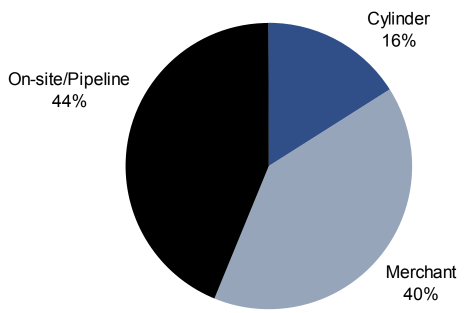
Membrane based nitrogen applications include oil and gas drilling, controlled atmosphere, maritime transport, inerting, beverage dispensing, tire inflation, and laboratory gas supply. Hydrogen membranes are used in refineries and petrochemical plants for hydrogen recovery, hydrogen/carbon monoxide ratio adjustment and olefin recovery. Carbon dioxide removal membranes process natural gas (sweetening), biogas/landfill gas and synthetic natural gas to enhance the value of the feed gas.

Distribution

Distribution methods for industrial gases include pipeline/on-site, merchant liquid and packaged distribution lines.

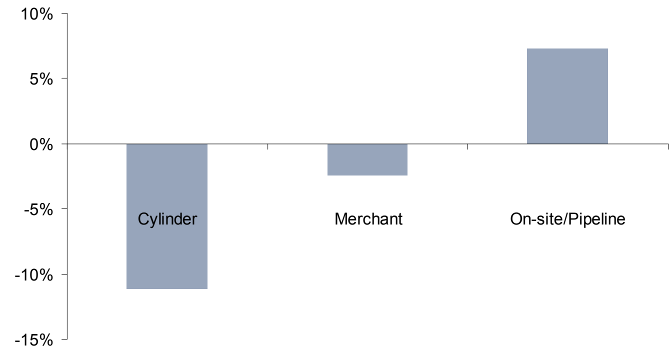
There are three basic distribution methods for industrial gases: pipeline/on-site or tonnage, merchant liquid, and packaged or cylinder gases. These distribution methods are often integrated, with products from all three supply modes coming from the same plant. The method of supply is generally determined by the lowest cost means of meeting the customer's needs, depending upon factors such as volume requirements, purity, pattern of usage, and the form in which the product is used (as a gas or as a cryogenic liquid). Whether intended for industry or healthcare, gases are distributed in gaseous form through a pipeline, in liquid form in cryogenic trailers, and in gaseous form in cylinders for small quantities or specialty gases.

Figure 140. Air Liquide's Distribution by Distribution Line, 2010



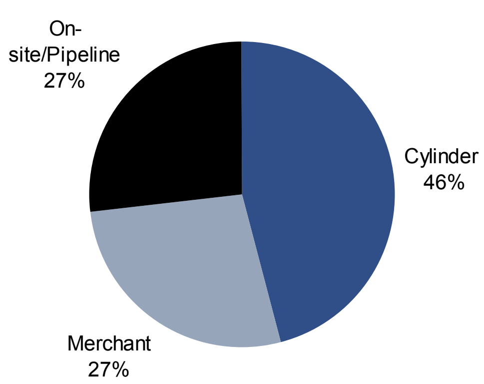
Source: Company Reports

Figure 141. Air Liquide's Distribution Line Growth Rates, 2010



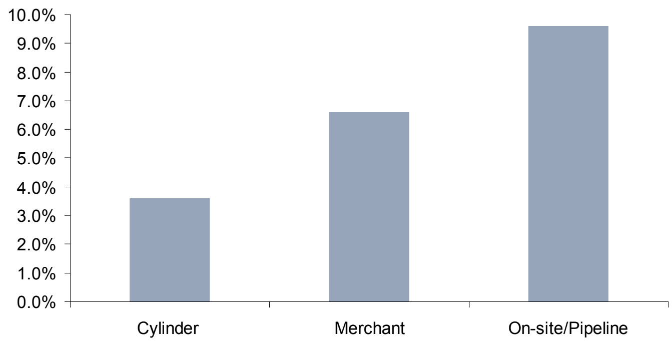
Source: Company Reports

Figure 142. Linde's Distribution by Distribution Line



Source: Company Reports

Figure 143. Linde's Distribution Line Growth Rates



Source: Company Reports

Customers who have a relatively constant demand pattern are supplied gas on-site or by pipeline.

On-site – Customers that require the largest volumes of product (typically oxygen, nitrogen and hydrogen) and that have a relatively constant demand pattern are supplied by cryogenic and process gas on-site plants. Companies construct plants on or adjacent to their customers' sites and supply the product directly to customers by pipeline. On-site product supply contracts generally are total requirement contracts with terms typically 15 years and containing minimum purchase requirements and price escalation provisions. In effect, the contract is designed to deliver about a 12% post tax return on investment for the gas supplier with the capital written off over 15 years and the operating costs, as they occur, passed through to the customer.

Advanced air separation processes allow on-site delivery to customers with smaller volume requirements. Customers using these systems usually enter into requirement contracts with terms typically ranging from 5-15 years. On-site cryogenic systems are efficient, reliable and cost-effective if large volumes of high purity liquid or gaseous nitrogen, argon or oxygen are required. This business line provides oxygen, nitrogen, and hydrogen, to the metal, chemical, energy conversion and oil and gas sectors through a network of plants and pipelines. Air Liquide's network includes 287 large air separation units producing nitrogen, oxygen and argon, 39 hydrogen and carbon monoxide units and 17 co-generation plants producing energy and steam around the world. In North America, Praxair operates eleven pipeline complexes that supply our customers with more than 390 million cubic feet of hydrogen each day. Praxair operates gas pipelines in locations across the US to transport oxygen, nitrogen, hydrogen, argon and helium. Sources for these pipelines include pressure swing adoption (PSA), membrane gas separation, steam methane reformers, and partial oxidation gasification.

Pipeline – This is basically the same as tonnage but the industrial gas provider owns a pipeline infrastructure in an industrial basin and when the new contract is secured this pipeline is extended to the new site. It may also generally require additional capacity which will be constructed adjoining the pipeline system. Air Liquide has substantial pipeline infrastructure in Benelux, the Ruhr, Rhone valley and Texas. It is building pipelines in China.

Bulk liquid delivery by tanker trucks supplies customers with distributable liquid oxygen, nitrogen, argon, carbon dioxide, hydrogen and helium.

Merchant (Bulk Liquid Delivery) – The merchant business is generally associated with distributable liquid oxygen, nitrogen, argon, carbon dioxide, hydrogen and helium. The deliveries generally are made from producers' plants by tanker trucks to storage containers at the customer's site. Due to distribution costs, merchant oxygen and nitrogen generally have a relatively small distribution radius from the plants at which they are produced. Merchant argon, hydrogen and helium can be shipped much longer distances. The agreements used in the merchant business are usually three to five-year requirement contracts. This business line allows a wide range of different gases and associated services to industries of all sizes requiring variable quantities, to be distributed in bulk (liquid form) or in cylinders for small quantities.

Customers requiring small volumes are supplied products in metal containers called cylinders, under medium to high pressure.

Packaged Gases – Customers requiring small volumes are supplied products in cylinders under high pressure. Packaged gases include atmospheric gases, carbon dioxide, hydrogen, helium and acetylene. Cylinders may be delivered to the customer's site or picked up by the customer at a packaging facility or retail store. When gas volume requirements are small, individual gas cylinders of argon, helium, carbon dioxide, oxygen, nitrogen, acetylene, or blends of gases can be used directly in the welding or cutting operation. Packaged gases are generally sold by purchase orders. Air Products operates packaged gas businesses in Europe, Asia and Brazil. In the United States, Air Products' current packaged gas business sells products only for the electronics and magnetic resonance imaging (principally helium industries). Praxair Microbulk is the most cost-effective cylinder alternative for argon, nitrogen, oxygen and carbon dioxide supply. The Praxair Microbulk gas delivery system has revolutionized traditional distribution by efficiently introducing on-site filling technology which replaces cylinders.

Healthcare products – and services are provided to patients in their homes, primarily in Europe. Customers receive respiratory therapies, home medical equipment and infusion services. Air Products has leading market positions in Spain, Portugal and the United Kingdom. Air Liquide has a €1bn Healthcare business and is the leading provider of these products and services outside the US. Linde is also relatively well placed.

Linde AG

Company description

Linde has 21% of the global gases market and is one of the two leaders in Europe. Its takeover of BOC has given it a strong position. The company is well placed in the key growth drivers of emerging markets and healthcare.

Investment strategy

We have a Buy recommendation on Linde. The main driver for the share price is the steady earnings stream underpinned by long-term contracts and steady growth in the gases and engineering divisions. Shares have outperformed the sector recently due to the market shifting to less risky assets. We believe this will be part of an ongoing trend driven by its superior mid-term growth potential.

Valuation

We use DCF and peer group analysis to reach our target price. Our DCF analysis is based on a WACC of 7.1% (previously 7.5%), growth rate of 4% and average ROCE over the sustainable advantage period of 35 years. This gives a value of €143 per share. For conservatism, we set our target price of €140 at a slight discount to our DCF valuation, to reflect the uncertainties inherent in long-term forecasting.

Risks

We would highlight the following risks to our valuation and target price: The earnings are defensive. Should global growth actually prove stronger than expected, Linde's steady growth may be perceived as more pedestrian. Engineering is at a peak in margins and this will likely come off. Linde has leadership in emerging regions where political risk is higher than in developed markets. It has a significant European cylinder business that will likely be somewhat impacted by the European recession.

L'Air Liquide SA

Company description

Air Liquide is the world's largest industrial gas company, and following its €7bn acquisition of Messer in the US and Europe, has a market share of about 23%. It has an outstanding track record of delivering consistent growth. The main gases sold are oxygen, nitrogen, argon, hydrogen and carbon dioxide. 93% of its operating profits come from the industrial gases and services division. It is well placed to develop its tonnage business, healthcare and hydrogen operations and is accelerating growth via its services businesses.

Investment strategy

We have a Neutral recommendation on Air Liquide. Air Liquide has one of the most outstanding earnings growth records in the chemicals industry. We expect its earnings momentum to be sustained over the next four years at more than 10% with the development of hydrogen markets (as legislation demands cleaner, desulphurised fuels) and cyclical demand for its low capital-intensive service offerings. Key growth markets are petrochemicals and refinery schemes in Asia and the Middle East, modernisation of steel in emerging regions, and coal to chemicals. These drivers and the potential for EPS growth we believe are now reasonably fully accounted in the share price and therefore we rate Air Liquide Neutral.

Valuation

Our DCF analysis, assuming long-term growth of about 4% and a WACC of 7.1% (previously 7.5%), implies a fair value for the shares of €110. The benefits of tonnage contracts secured mean that the ROCE should rise by about 1% over the next three years. Remaining conservative, we apply a discount to our DCF to arrive at a target price of €100.

Risks

We would highlight the following risks to our valuation and target price: Sales growth is reasonably visible for the next three years, underpinned by newly installed capacity and environmental legislation (leading to increased demand for hydrogen in oil refineries) that is already in place. The main risk factors: 1) customers cancelling projects or delaying them; 2) price pressures proving worse than expected in merchant and cylinder markets, 3) cost pressures rising more strongly than it is possible to pass them on, 4) forex movements. There is a high correlation between capex and growth so delays to projects will be the main factor reducing the growth potential and hence affecting sentiment towards the shares.

Air Products and Chemicals Inc

Valuation

Our price target of $99 is derived using an average of our forward P/E and FV/EBITDA valuations.

Price/Earnings: We apply a 17x multiple to our 2012 earnings estimate of $6.16 to get a $105 target price. This multiple is below the multiple we assign to its main competitor Praxair, which delivers higher margins and higher returns on capital. Air Products has historically traded in a range of 9.5x-25x forward earnings, with an average of 17x.

EV/EBITDA: Our second valuation methodology is an EV/EBITDA multiple, which derives a target price of $93. We use an EV/EBITDA multiple of 9x, which is within its historical range of 6x-12x. Air Products' historical EV/EBITDA multiple average is 9x. After applying the 9x multiple to our 2012 EBITDA estimate of $2.67 billion, we then deduct net debt of $4.1 billion to derive a price target of $93.

Risks

We see the following risks to the stock achieving our target price:

A double-dip recession could negatively impact the company's volumes. We believe the risks associated with a potential double-dip in economic activity are partially offset by the company’s solid project backlog and long-term growth prospects. Also, the industrial gas industry has consolidated from roughly 10 major global players in the early 90s to 4 major gas companies today, providing a favorable competitive environment.

APD is exposed to natural gas and energy costs, which could increase in the near-term. The chemicals business uses natural gas-based feedstocks, though APD’s earnings are not highly sensitive to changes in natural gas prices. The gas business also uses natural gas, but there is a contractual pass-through of natural gas prices built into hydrogen pricing that partially protects the business.

The electronics franchise operates in a volatile, high growth industry. The company's primary exposure is to semiconductors and LCDs, which are high growth businesses with tough pricing environments. The key in electronics is for volume growth to outpace pricing declines.

Air Products' industrial gas business is also highly leveraged to US manufacturing. Lower end market demand and lower-than-anticipated growth rates for some of the company's businesses could have a negative impact.

Praxair Inc

Valuation

Our target price of $118 is an average of the prices derived from our two valuation methodologies: price/earnings and enterprise value/EBITDA.

Price/Earnings: We have derived a target price of $123 by applying a 20x price/earnings multiple on our 2012 EPS estimate of $6.13. This multiple is above the one we apply to Praxair's principal US competitor, Air Products, as Praxair has higher margins and higher ROC. We find that Praxair's forward price/earnings multiple has historically (past 10 years) ranged between 10x-26x, with an average normalized level of 17.5x.

Enterprise Value/EBITDA: Additionally, we value Praxair using an EV/Forward EBITDA multiple, as it has shown a consistent trading range over the cycle. We derive a target price of $113 by applying an EV/EBITDA multiple of 10.5x to our 2012 EBITDA estimate of $3.88 billion, and subtracting net debt of $6.185 billion. We note that Praxair has historically (past 10 years) traded at an EV/EBITDA range of 6x-14x. This multiple is above the one we apply to Praxair's principal US competitor, Air Products, as Praxair has higher margins and higher ROC.

Risks

We see the following risks to the stock achieving our target price:

A double-dip recession could negatively impact Praxair's volumes. We believe the risks associated with a potential slowing of economic conditions are partially offset by the company's strong project backlog and the structure of its long-term contracts, which smoothes margin volatility over time.

Praxair is a co-defendant in lawsuits by roughly 1,800 claimants alleging neurological damage (Parkinson's disease) caused by fumes from manganese welding rods. Praxair was a distributor of manganese welding rods, but never a producer. In July 2005, a federal judge ruled that each case would be considered individually. To date, Praxair has either been dismissed from the cases with no payment or has settled a few cases for nominal amounts.

The company's current net debt to capital ratio is roughly 48% - higher than some other industrial gas companies. Should interest rates increase, or Praxair need to borrow more to fund its increasing growth initiatives, it could result in higher interest expense. In addition, higher borrowing could potentially lead to a lower bond rating, thus increasing the cost of borrowing.

Praxair's industrial gas business is highly leveraged to the US manufacturing industry and the company has noted some sluggishness in this end market. Should economic growth slow materially, it could hinder end market demand and result in lower-than-anticipated growth for many of Praxair's businesses.

Notes

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Appendix A-1

Analyst Certification

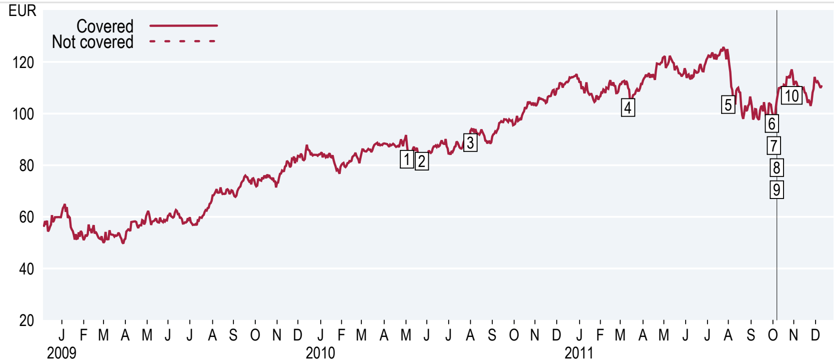
The research analyst(s) primarily responsible for the preparation and content of this research report are named in bold text in the author block at the front of the product except for those sections where an analyst's name appears in bold alongside content which is attributable to that analyst. Each of these analyst(s) certify, with respect to the section(s) of the report for which they are responsible, that the views expressed therein accurately reflect their personal views about each issuer and security referenced and were prepared in an independent manner, including with respect to Citigroup Global Markets Inc and its affiliates. No part of the research analyst's compensation was, is, or will be, directly or indirectly, related to the specific recommendation(s) or view(s) expressed by that research analyst in this report.

IMPORTANT DISCLOSURES

Linde AG (LING.DE)

Ratings and Target Price History
Fundamental Research

Analyst: Andrew Benson



	Date	Rating	Target Price	Closing Price
1	4-May-10	1M	*105.00	87.65
2	25-May-10	*2M	*90.00	81.55
3	2-Aug-10	2M	*95.00	93.32
4	11-Mar-11	2M	*115.00	109.90

	Date	Rating	Target Price	Closing Price
5	1-Aug-11	2M	*130.00	122.45
6	30-Sep-11	2M	*110.00	100.75
7	4-Oct-11	2M	*105.00	96.16
8	7-Oct-11	Stock rating system changed		

	Date	Rating	Target Price	Closing Price
9	7-Oct-11	*2	105.00	105.45
10	28-Oct-11	2	*120.00	117.10

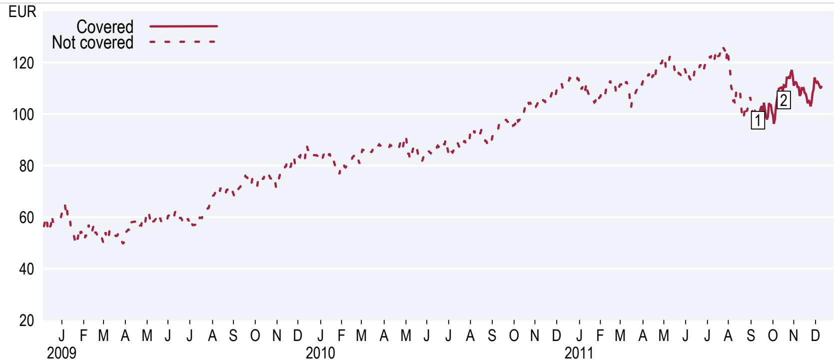
* Indicates change

Rating/target price changes above reflect Eastern Standard Time

Linde AG (LING.DE)

Ratings and Target Price History
Best Ideas Research
Relative Call (3 Month)

Analyst: Andrew Benson



	Date	Rating	Target Price	Closing Price
1	12-Sep-11	*ADD LP	-	97.98

	Date	Rating	Target Price	Closing Price
2	18-Oct-11	*REM LP	-	111.20

* Indicates change

Rating/target price changes above reflect Eastern Standard Time

L'Air Liquide SA (AIRP.PA)

Ratings and Target Price History
Fundamental Research

Analyst: Andrew Benson

	Date	Rating	Target Price	Closing Price
1	28-Jan-10	*2L	79.69	70.71
2	7-Jul-10	2L	*80.00	82.49
3	2-Aug-10	2L	*85.00	89.33
4	14-Dec-10	2L	*100.00	96.57
5	11-Aug-11	2L	*97.00	86.28
6	4-Oct-11	2L	*95.00	85.76
7	7-Oct-11	Stock rating system changed		
8	7-Oct-11	*2	95.00	89.18

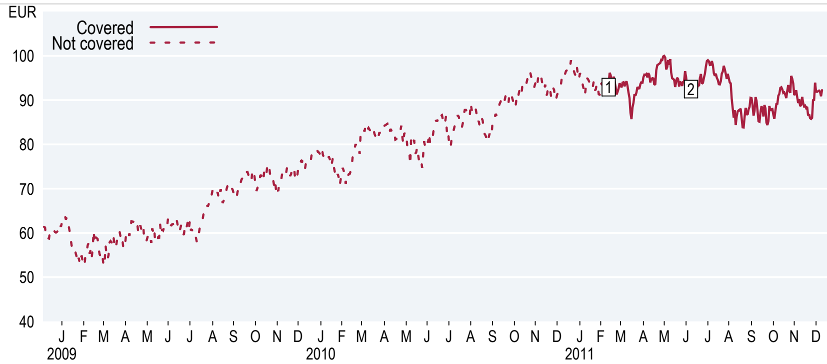
* Indicates change

Rating/target price changes above reflect Eastern Standard Time

L'Air Liquide SA (AIRP.PA)

Ratings and Target Price History
Best Ideas Research
Relative Call (3 Month)

Analyst: Andrew Benson



	Date	Rating	Target Price	Closing Price
1	11-Feb-11	*ADD LP	-	93.91
2	8-Jun-11	*REM LP	-	92.50

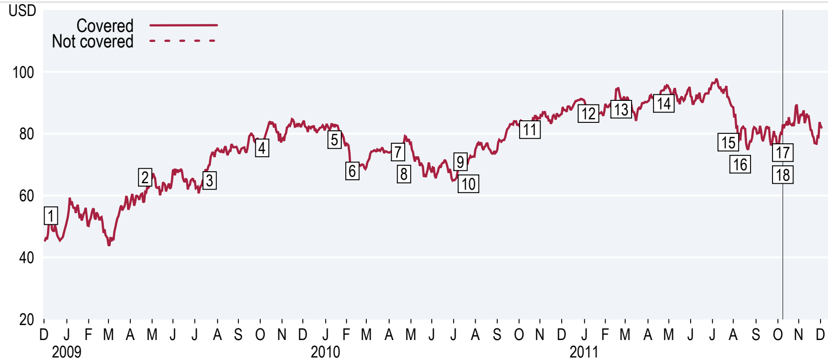
* Indicates change

Rating/target price changes above reflect Eastern Standard Time

Air Products and Chemicals Inc (APD)

Ratings and Target Price History
Fundamental Research

Analyst: P.J. Juvekar



	Date	Rating	Target Price	Closing Price
1	10-Dec-08	2M	*55.00	53.49
2	22-Apr-09	*1M	*70.00	61.19
3	22-Jul-09	1M	*82.00	69.88
4	4-Oct-09	1M	*89.00	75.53
5	14-Jan-10	1M	*96.00	82.07
6	9-Feb-10	*2M	*73.00	67.95
7	14-Apr-10	2M	*74.00	76.01
8	22-Apr-10	2M	*82.00	77.32
9	12-Jul-10	2M	*74.00	69.17
10	22-Jul-10	2M	*75.00	71.60
11	18-Oct-10	2M	*86.00	82.95
12	7-Jan-11	2M	*94.00	88.50
13	23-Feb-11	*1M	*107.00	90.89
14	25-Apr-11	1M	*108.00	94.03
15	25-Jul-11	1M	*109.00	91.80
16	10-Aug-11	1M	*99.00	77.82
17	8-Oct-11	Stock rating system changed		
18	8-Oct-11	*1	99.00	80.03

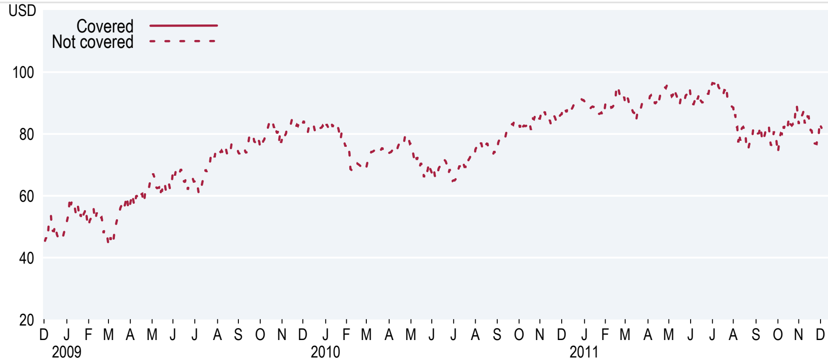
* Indicates change

Rating/target price changes above reflect Eastern Standard Time

Air Products and Chemicals Inc (APD)

Ratings and Target Price History
Best Ideas Research
Relative Call (3 Month)

Analyst: P.J. Juvekar



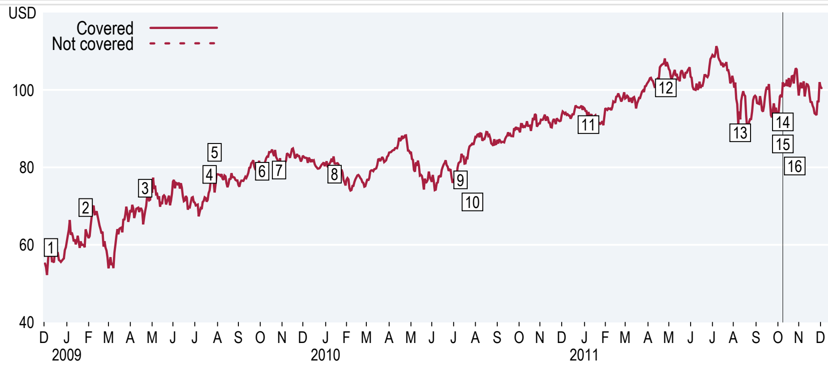
* Indicates change

Rating/target price changes above reflect Eastern Standard Time

Praxair Inc (PX)

Ratings and Target Price History
Fundamental Research

Analyst: P.J. Juvekar



	Date	Rating	Target Price	Closing Price
1	10-Dec-08	2M	*60.00	58.59
2	28-Jan-09	2M	*63.00	64.00
3	22-Apr-09	*1M	*79.00	68.74
4	22-Jul-09	1M	*87.00	74.06
5	29-Jul-09	1M	*83.00	73.51
6	4-Oct-09	1M	*93.00	79.21
7	28-Oct-09	1M	*92.00	79.89
8	14-Jan-10	1M	*99.00	81.01
9	12-Jul-10	1M	*94.00	81.50
10	28-Jul-10	1M	*99.00	86.28
11	7-Jan-11	1M	*112.00	94.29
12	27-Apr-11	1M	*120.00	106.10
13	10-Aug-11	1M	*111.00	92.38
14	8-Oct-11	Stock rating system changed		
15	8-Oct-11	*1	111.00	98.09
16	26-Oct-11	1	*118.00	104.32

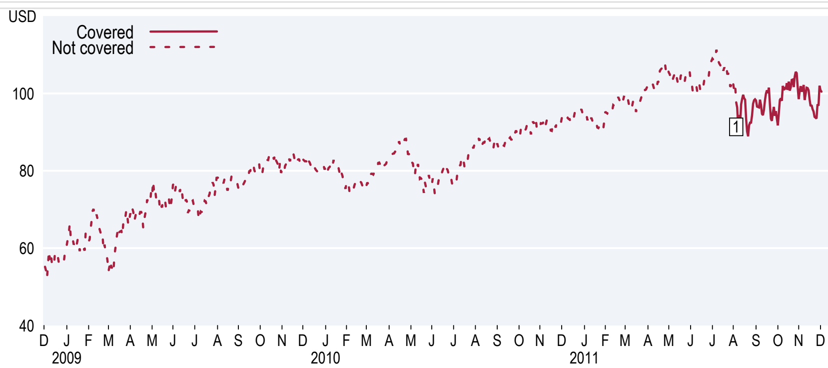
* Indicates change

Rating/target price changes above reflect Eastern Standard Time

Praxair Inc (PX)

Ratings and Target Price History
Best Ideas Research
Relative Call (3 Month)

Analyst: P.J. Juvekar



	Date	Rating	Target Price	Closing Price
1	4-Aug-11	*ADD MP	-	97.70

* Indicates change

Rating/target price changes above reflect Eastern Standard Time

Within the past 12 months, Citigroup Global Markets Inc. or its affiliates has acted as manager or co-manager of an offering of securities of Praxair Inc.

Citigroup Global Markets Inc. or its affiliates has received compensation for investment banking services provided within the past 12 months from Linde AG, L'Air Liquide SA, Praxair Inc.

Citigroup Global Markets Inc. or an affiliate received compensation for products and services other than investment banking services from Air Products and Chemicals Inc, Praxair Inc, Linde AG, L'Air Liquide SA in the past 12 months.

Citigroup Global Markets Inc. currently has, or had within the past 12 months, the following as investment banking client(s): Linde AG, Praxair Inc, L'Air Liquide SA.

Citigroup Global Markets Inc. currently has, or had within the past 12 months, the following as clients, and the services provided were non-investment-banking, securities-related: Air Products and Chemicals Inc, Praxair Inc, Linde AG, L'Air Liquide SA.

Citigroup Global Markets Inc. currently has, or had within the past 12 months, the following as clients, and the services provided were non-investment-banking, non-securities-related: Air Products and Chemicals Inc, Praxair Inc, Linde AG, L'Air Liquide SA.

Citigroup Global Markets Inc. or an affiliate received compensation in the past 12 months from Air Products and Chemicals Inc, Praxair Inc.

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The Firm is a market maker in the publicly traded equity securities of L'Air Liquide SA.

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Citi Investment Research & Analysis Ratings Distribution

	12 Month Rating			***Relative Rating***		
Data current as of 10 Oct 2011	**Buy**	**Hold**	**Sell**	**Buy**	**Hold**	**Sell**
Citi Investment Research & Analysis Global Fundamental Coverage	59%	34%	7%	10%	79%	10%
% of companies in each rating category that are investment banking clients	45%	42%	37%	50%	43%	46%

Guide to Citi Investment Research & Analysis (CIRA) Fundamental Research Investment Ratings:
CIRA's stock recommendations include an investment rating and an optional risk rating to highlight high risk stocks.
Risk rating takes into account both price volatility and fundamental criteria. Stocks will either have no risk rating or a High risk rating assigned.
Investment Ratings: CIRA's investment ratings are Buy, Neutral and Sell. Our ratings are a function of analyst expectations of expected total return ("ETR") and risk. ETR is the sum of the forecast price appreciation (or depreciation) plus the dividend yield for a stock within the next 12 months. The Investment rating definitions are: Buy (1) ETR of 15% or more or 25% or more for High risk stocks; and Sell (3) for negative ETR. Any covered stock not assigned a Buy or a Sell is a Neutral (2). For stocks rated Neutral (2), if an analyst believes that there are insufficient valuation drivers and/or investment catalysts to derive a positive or negative investment view, they may elect with the approval of CIRA management not to assign a target price and, thus, not derive an ETR. Analysts may place covered stocks "Under Review" in response to exceptional circumstances (e.g. lack of information critical to the analyst's thesis) affecting the company and / or trading in the company's securities (e.g. trading suspension). As soon as practically possible, the analyst will publish a note re-establishing a rating and investment thesis. To satisfy regulatory requirements, we correspond Under Review and Neutral to Hold in our ratings distribution table for our 12-month fundamental rating system. However, we reiterate that we do not consider Under Review to be a recommendation.
Relative three-month ratings: CIRA may also assign a three-month relative call (or rating) to a stock to highlight expected out-performance (most preferred) or under-performance (least preferred) versus the geographic and industry sector over a 3 month period. The relative call may highlight a specific near-term catalyst or event impacting the company or the market that is anticipated to have a short-term price impact on the equity securities of the company. Absent any specific catalyst the analyst(s) will indicate the most and least preferred stocks in the universe of stocks under consideration, explaining the basis for this short-term view. This three-month view may be different from and does not affect a stock's fundamental equity rating, which reflects a longer-term total absolute return expectation. For purposes of NASD/NYSE ratings-distribution-disclosure rules, most preferred calls correspond to a buy recommendation and least preferred calls correspond to a sell recommendation. Any stock not assigned to a most preferred or least preferred call is considered non-relative-rated (NRR). For purposes of NASD/NYSE ratings-distribution-disclosure rules we correspond NRR to Hold in our ratings distribution table for our 3-month relative rating system. However, we reiterate that we do not consider NRR to be a recommendation.

Prior to October 8, 2011, the firm's stock recommendation system included a risk rating and an investment rating. **Risk ratings,** which took into account both price volatility and fundamental criteria, were: Low (L), Medium (M), High (H), and Speculative (S). **Investment Ratings** of Buy, Hold and Sell were a function of CIRA's expectation of total return (forecast price appreciation and dividend yield within the next 12 months) and risk rating. Additionally, analysts could have placed covered stocks "Under Review" in response to exceptional circumstances (e.g. lack of information critical to the analyst's thesis) affecting the company and/or trading in the company's securities (e.g. trading suspension). Stocks placed "Under Review" were monitored daily by management and as practically possible, the analyst published a note re-establishing a rating and investment thesis. For securities in developed markets (US, UK, Europe, Japan, and Australia/New Zealand), investment ratings were:Buy (1) (expected total return of 10% or more for Low-Risk stocks, 15% or more for Medium-Risk stocks, 20% or more for High-Risk stocks, and 35% or more for Speculative stocks); Hold (2) (0%-10% for Low-Risk stocks, 0%-15% for Medium-Risk stocks, 0%-20% for High-Risk stocks, and 0%-35% for Speculative stocks); and Sell (3) (negative total return). For securities in emerging markets (Asia Pacific, Emerging Europe/Middle East/Africa, and Latin America), investment ratings were:Buy (1) (expected total return of 15% or more for Low-Risk stocks, 20% or more for Medium-Risk stocks, 30% or more for High-Risk stocks, and 40% or more for Speculative stocks); Hold (2) (5%-15% for Low-Risk stocks, 10%-20% for Medium-Risk stocks, 15%-30% for High-Risk stocks, and 20%-40% for Speculative stocks); and Sell (3) (5% or less for Low-Risk stocks, 10% or less for Medium-Risk stocks, 15% or less for High-Risk stocks, and 20% or less for Speculative stocks).

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