

The Chemical Industry in the Netherlands: World leading today and in 2030–2050



Preface

A catalyst to a better future

The chemical industry in the Netherlands forms part of one of the strongest chemical clusters in the world, the interconnected Antwerp-Rotterdam-Rhine-Ruhr Area (ARRRA). This cluster is responsible for a huge array of products that supply the competitive European manufacturing industry for both domestic and export markets. Clearly, the assets of this cluster extend far beyond its impressive physical production facilities. While the population of the Netherlands represents a mere 0.2 percent of the global total, the chemical industry is responsible for a full 2 percent of global output. In view of the importance of chemicals, the new government of the Netherlands selected the industry as one of nine national growth sectors (“top sectors”), with the aim of putting into place a tailored industrial policy. In June 2011, a high-profile taskforce published the acclaimed “New Earth, New Chemistry: Actieagenda TopSector Chemie” report.

In the coming decades, megatrends — forces such as population growth and aging, urbanization, resource scarcity, shifting economic power, and climate change — will reshape global demand in virtually every sector. The chemical industry is already undergoing fundamental changes in response to these megatrends. As one example, bio-based feedstocks have been introduced into the value chain, enabling technologies and end markets to converge. As another, investments in new production capacity have increasingly been shifting to the Middle East and Asia. In the Netherlands, industry watchers are asking what needs to be done to adjust to the emerging realities. Some of the answers lie in this study. Commissioned by the Vereniging van de Nederlandse Chemische Industrie (VNCI), the national chemical industry association, the following pages include insights from over 100 industry specialists at multinational companies such as AkzoNobel, Dow, DSM, ExxonMobil, SABIC, and Shell and in universities, research institutes, and government.

The VNCI and Deloitte Netherlands expect significant changes to affect the growth and vibrancy of the Netherlands chemical industry. Global gross domestic product (GDP) will rise fourfold in the next 40 years, new feedstocks will become attractive, and new technologies will transform the industry. Almost unanimously, the specialists interviewed for this report confirmed that these changes offer tremendous opportunities for Europe to build on its current cluster strengths, and that the role played by the Netherlands will be vital. These opportunities will be incorporated into the ongoing stakeholder dialogue to position the chemical industry in the Netherlands for the decades ahead.

VNCI management and Deloitte Netherlands would like to thank all the individuals interviewed for this report, as well as the workshop participants, for their involvement and commitment. The VNCI and Deloitte Netherlands are confident that the release of this report into the market will stimulate a continued discussion between the chemical industry and its stakeholders.

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Part one: The vision

The Chemical Industry in the Netherlands: World leading today and in 2030–2050

Over the past decade, economic momentum has shifted from the developed world to the Asia-Pacific region, and in the last few years Europe has struggled with financial issues. The chemical industry is not immune to the general economic pessimism, and in the process of researching this paper, the VNCI and Deloitte Netherlands teams heard several gloomy outlooks, some even suggesting that chemicals might be a sunset industry. The research does not support this view. Substantial global economic growth over the long run, combined with the industry's strong starting position, offers ample growth opportunities.

This section outlines the outcomes of this study: the VNCI vision for the chemical industry in the Netherlands between 2030 and 2050. Subsequent sections focus on the project background, the current position of the industry, global market trends, future scenarios, and the industry's response.

The key takeaway for 2030–2050

The northwest European region will increase its strength in innovation, cooperation, and specialization. It will be active in production across the value chain and in end markets that include fossil and bio-based feedstock. This trend will enable the chemical industry to continue as a leading sector in generating wealth and jobs in the Netherlands.

Although the world may take various turns at critical junctures in the future, the Netherlands chemical industry will be able to adapt to economic, demographic, and technological trends through to 2050.

A world-leading cluster in 2030–2050

Four divergent scenarios for 2030–2050 all expect the Netherlands to remain a world leader in the chemical industry. The country's industry will be a key part of the large and highly integrated cluster in the Antwerp-Rotterdam-Rhine-Ruhr Area (ARRRA), one of a few leading chemical clusters in the world. In 2030–2050 the ARRRA will be Europe's regional hub for feedstock, production, research, and development. This cluster will compete and interact with similar areas in the United States, China, India, the Middle East, and Brazil.

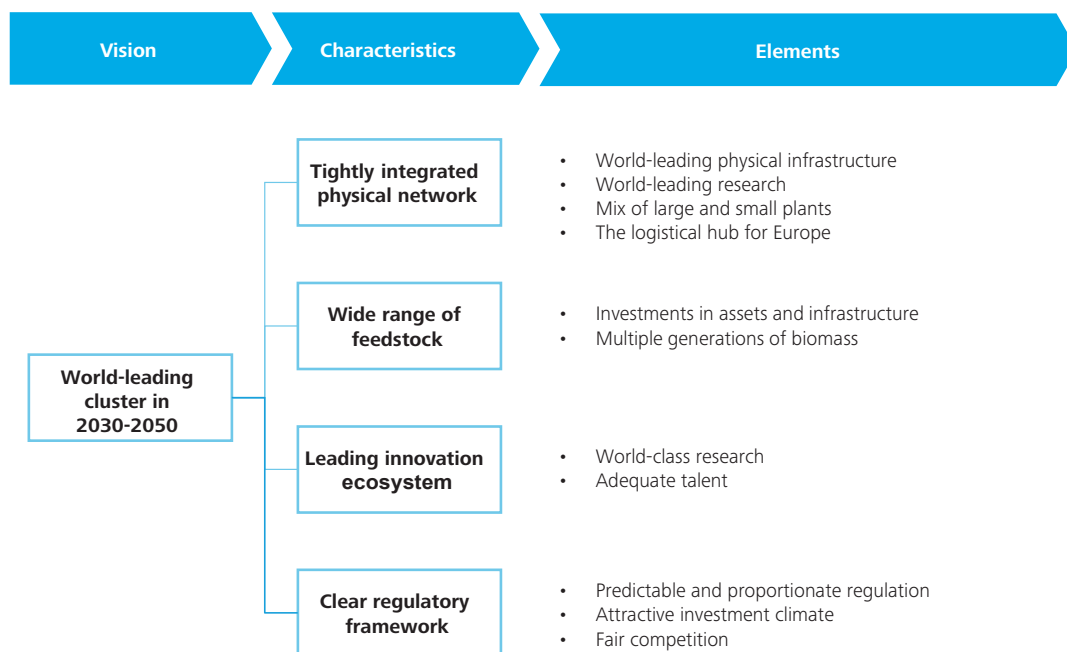
In 2030–2050 the ARRRA cluster will concentrate on delivering a mix of base chemicals and high value-added products and services, with a much lower health and

environmental impact than today. Companies in the cluster will be active throughout the entire chemical value chain, from base chemicals to customer-specific solutions. Where possible, they will be connected to end users' sites in order to strengthen not only their own competitive position but also that of their customers. For example, innovations developed in the chemical industry will help the European automotive industry, while innovations in the automotive industry will, in turn, push the chemical industry forward.

Despite lower global market shares, revenues in the ARRRA cluster and the Netherlands will remain high. Global demand will have grown substantially, and positions in selected end markets will have strengthened. As a result, the chemical industry will remain an important employer in the Netherlands, with higher added value per employee.



Figure 1: The Netherlands chemical industry in 2030-2050



Source: Deloitte Netherlands analysis

In the VNCI vision for 2030–2050, the chemical industry of the Netherlands has four key characteristics (see Figure 1):

1. A tightly integrated network of large and small plants, pipelines, suppliers, and end users across northwest Europe.
2. The flexibility to use a wide range of feedstock.
3. The cornerstone position in a leading innovation ecosystem.
4. A clear regulatory framework.

To realize this potential, the industry must build and expand on its current strengths.

Tightly integrated network

The current ARRRR network will evolve into a large, integrated petrochemical complex of sustainable companies in Northwest Europe by 2030–2050. This cluster will be much stronger due to factors such as world-leading physical infrastructure, a mix of large and small plants, and its role as the logistical hub for Europe.

World-leading physical infrastructure

In 2030–2050 the cluster will be more physically integrated than it is today. Tighter integration across the ARRRR will have improved efficiency, and regions within the cluster will have become specialized. For example, Rotterdam will

function as the center for base chemicals, while Limburg specializes in life sciences.

Chemical companies will be physically linked with their customers and suppliers, enabling more customer-specific products. And with much of the oil and gas coming from remote locations or from deep water, large flows of crude oil and natural gas will still be refined and processed in end markets. Europe will therefore continue to operate significant base chemicals plants in the ARRRR.

Examples of (physical) integration

The Huntsman site in Botlek is an example of physical integration. The company produces polyurethane with the aid of steam and electricity. The water released in the process is sent to Lucite to manufacture acrylics, which generates steam that is sent back to Huntsman. Huntsman also supplies water, steam, and electricity to Invista for the production of polymers. In total, 25 companies are part of the cluster around Huntsman.

The Chemelot site in Geleen houses 70 different chemical and life sciences companies. The site fosters open innovation with mini-plants and labs. Furthermore, on-site suppliers and producers can cooperate for smarter research, development, and production.

Increased exchange of raw, semi-finished, and residual products and energy within the cluster will have driven down production and environmental costs even further. Additionally, utility infrastructure and refineries will be co-sited with chemical plants, creating tightly knit areas within which chemical, power, water, waste, and refining plants share infrastructure. This will enable the exchange of resources and excess energy. Improved recycling, re-use, and life-cycle management will further augment efficiency. To that end, the industry will have intensified its cooperation with the agro and waste management sectors (see “Examples of (physical) integration”).

World-leading maintenance capabilities will keep physical assets in good condition as de-bottlenecking and constant process improvements enhance productivity. A continuing drive for efficiency and sustainability will help the cluster to lead in resource efficiency, operational excellence, safety, and quality.

Mix of large and small plants

Within the cluster, large production facilities will co-exist with a plethora of innovative small companies that operate container-sized plants. These small and medium-sized enterprises (SMEs) are now pivotal in building a diverse and innovative chemical industry because larger players will rely to a greater extent on collaboration and partnerships with SMEs for innovation and supplies. SMEs will co-reside with larger companies to help reduce capital expenditure and to take advantage of scale and access to energy, among other benefits.

In 2030–2050 the chemical industry in the Netherlands will also support SMEs by reducing their administrative regulatory burden. Provision of permits for total sites, including SMEs located onsite with larger companies, is a good example. Furthermore, favorable tax conditions for innovative SMEs will facilitate access to public–private partnerships (PPPs).

The logistical hub for Europe

The combination of the ports in Rotterdam, Amsterdam, and Delfzijl and the national logistics systems will allow companies in the Netherlands to retain a strong position in the global chemical industry in 2030–2050. This will require continuous investments in road, rail, and water infrastructure. The chemical industry in the Netherlands will stimulate this development by committing itself to Northwest European production facilities.

In addition to state-of-the-art plants, public investments

will need to be made in advanced ports and (additional) pipeline systems, roads, rail track, and waterways across the region. End users’ sites will be able to connect wherever possible.

Wide range of feedstock

By 2030 the industry is expected to have begun to



reduce its dependence on hydrocarbons by increasing the use of secondary (waste) and bio-based feedstock. Hydrocarbons will still form the predominant feedstock, and their consumption will even grow in absolute terms, but bio-based alternatives will represent as much as 15–20 percent of inputs next to shale gas, which will also become more important. This development enabled by the flexibility to diversify inputs will help to make the ARRRR cluster a leader in sustainability. The chemical industry in the Netherlands will enjoy wide social acceptance and be perceived as innovative, clean, and safe.

Investments in assets and infrastructure

By 2030–2050 the Northwest European cluster will make the changes to its asset base needed to accommodate new feedstock for both bulk and specialty chemicals. These changes will reduce the risk of raw material shortages and increase sustainability in the process. The industry will also be able to offer more diverse products with new functionalities to support a wide range of new end markets, including health, food, and agro.

Most waste will be sourced from Western Europe itself. Biomass, on the other hand, will come from around the world. Some countries, such as Brazil, will be able to process most of their material domestically. Others, such as Ukraine and West African countries, will not have the large, sophisticated chemical clusters required to process biomass economically. Biomass from these countries will go through only simple processing steps at the source before being shipped to end markets for further processing.

The ports of Rotterdam and Antwerp will become European hubs for bio-based feedstock and waste, in addition to oil and gas.

Multiple generations of biomass

By 2030 the industry will employ multiple sustainable sources of bio-based feedstock. These sources are different from today's first-generation biomass, which competes with food. Second-generation biomass includes non-edible source material like straw, whole plants, and wood which contains polymers of plant cell walls. Its use will become standard practice. Third-generation biomass currently under consideration includes industrial-scale production of algae that have been biologically engineered to replace existing naphtha-based products but with fewer processing steps, or to provide altogether new functions.

Leading innovation ecosystem

By successfully combining know-how in chemicals, life sciences, synthetic biology, biotechnology, logistics, and information technology, the Netherlands can become a leader in material and life sciences in 2030–2050. This will reinforce Europe's position as a premier exporter of high value-added products that address global megatrends. Reaching this goal requires world-leading research and talent.

World-leading research

In a development that has already begun as a result of active industry involvement in research, by 2030–2050 the Netherlands chemical cluster will have become closely linked with universities, research institutes, venture capitalists, SMEs, and a host of suppliers. There will be strong collaboration and mutual intellectual entrepreneurial stimulus among all players.

Netherlands universities will become world leading at the intersection of agriculture, biology, life sciences, and chemistry. Scientific research will also support the transition to new feedstocks and higher resource efficiency.

The chemical industry will establish shared priorities with both universities and government over areas of critical research and infrastructure. Selected world-leading research groups will be funded in the Netherlands and managed to the highest standards. As well as these financial benefits, measures will be developed to enhance excellence. Rigorous admission standards for students and researchers, global recruiting, intensive cooperation among

leading research institutes, "up-or-out" promotion policies, facilities for innovative thinking, and a high-performance culture are all examples. A choice group of departments will be able to attract top students and professors from all over the world.

The industry will also support chemical science parks near universities and chemical production sites. These parks will include innovation labs to help start-up companies and research facilities to support innovation in its earliest stages. Centers for open chemical innovation will accelerate pioneering thinking. Shared pilot production facilities will help to make commercialization easier.

Large players will contribute venture capital funding with pre-seed and seed financing for SMEs. This will be accomplished through corporate venturing (as DSM, for example, is already doing¹), investments via third-party funds, and PPPs with central and local governments. One model is the U.S. National Science Foundation's Small Business Innovation Research program², developed to help finance high-risk/high-payoff projects.

In addition to the hard sciences, the research ecosystem will include social scientists and economists who contribute to social innovation and to finding new, more dynamic, flexible approaches. A culture of strong social innovation will help to develop opportunities where research fields intersect.

The right talent

In 2030–2050 the chemical industry in the Netherlands will be aligned with academia and policy makers with respect to skill development. Programs such as the Human Capital Agenda will attract more students into technical and chemical disciplines at all educational levels.³ The chemical industry will encourage life-long learning within the ever-changing sector by providing ongoing updates. In addition, it will continue to promote the sector to students, teachers, and the wider public by demonstrating its catalytic role in making the world a better place. All in all, the sector will offer good career prospects, either within the industry or in related academic fields.

¹ DSM, www.dsm.com/nl_NL/html/venturing/home.htm

² National Science Foundation, www.nsf.gov/eng/iip/sbir/

³ Regiegroep Chemie, *Projectplan HCC*

The sector in the Netherlands will benefit from an international perspective by attracting talent from other European and overseas countries. For many scientists and engineers from Eastern Europe and the Asia-Pacific region, the Netherlands is an attractive place to live and work. Chemical research entities in the country will be even more tightly connected to leading research institutes worldwide, enabling them to tap into remote resources and share ideas globally.

Clear regulatory framework

A clear regulatory framework that stimulates investment and safeguards a level playing field is crucial for achieving the vision for the industry. Predictable and proportionate regulation, an attractive investment climate, and fair competition rules are key elements. Regulatory conditions on the road to 2030–2050 are an important factor and are highlighted in the sections describing the different scenarios for the future.

Predictable and proportionate regulation

A vibrant chemical and manufacturing industry will be supported by a proportionate and effective regulatory framework. Regulation and legislation will protect the environment and ensure health and safety for employees and the general public without unnecessarily impeding industry growth.

The chemical industry in the Netherlands will be involved early in the regulatory development process. To foster innovation, it favors goal-oriented regulations instead of prescriptive requirements. The chemical industry will aim for consistent regulatory enforcement across the European Union (EU), which it considers key to a level playing field.

Attractive investment climate

To retain existing players and attract new ones to Europe, a strong investment climate will be promoted. This climate will be influenced by factors such as tax policies, the availability of skilled talent, infrastructure, business sites, and market conditions.

A favorable fiscal climate will have attracted both foreign direct investment and business headquarters to the Netherlands. Additional favourable conditions will be swift decision-making processes and the capacity to issue environmental permits for a number of companies simultaneously.

Fair competition rules

Global free trade is fundamental to building strong

chemical and manufacturing industries in Europe, and open markets are essential to the competitiveness of the European chemical industry. They provide access to feedstock and end markets across the globe. A level playing field within Europe, and for Europe within the rest of the world, will therefore be nurtured. To provide access to the so-called emerging markets such as China, India, Brazil, Russia, and Southeast Asia, the chemical industry will promote fair reciprocal commitments to the rule-based trading system.

Growth in all four potential futures

The future of the cluster will, of course, very much depend on the state of the world in 2030–2050. The Netherlands has a very strong starting position. Internal benchmarking by multiple global companies today finds that their Netherlands plants are among the best performing in the world.⁴ The country benefits from a highly skilled workforce, an integrated network of plants, and excellent transportation infrastructure. As shown in Figure 2, its chemical industry represented 9.6 percent of European production in 2010, 4 percentage points above its share of European GDP. The EU represented 21 percent of global chemical production, in line with its 20 percent share of global industrial GDP. Worldwide, the chemical industry represents 4.9 percent of global GDP, which translates into €2.4 trillion in sales.⁵ As “the industry of industries,” a strong European chemical sector positively affects the manufacturing industry of the entire continent.

It is fair to assume that global chemical demand will grow substantially toward 2050. The World Bank expects the global economy to grow by 4.1 percent per annum through to 2030, driven mainly by the rise of Asian and South American countries. Large countries like China, India, and Brazil are very likely to become middle- to high-income nations. Most economists project a decrease in the EU’s share of world GDP from 26 percent today to less than 20 percent by 2030.⁶ They also believe that two-thirds of the increase in global GDP by 2050 will come from per capita GDP, against just one-third from population growth.⁷ This forecast translates into a growing middle class in the developing world: a whole new class of

⁴ CMAI, interviews

⁵ Cefic Chemdata International

⁶ Carnegie Endowment for International Peace, *The World Order in 2050*

⁷ Carnegie Endowment for International Peace, *The World Order in 2050*; United Nations, *United Nations World Populations Prospects 2009*; The World Bank, *World Development Indicators & Global Development Finance 2011*

Figure 2: The potential futures: The four scenarios quantified

		2010 Actual	2030 Scenarios			
			Fragmentation	Green Transition	Abundant Energy	High-Tech World
World	GDP growth rate (20 years trailing)	5.6%	2.5%	3%	5%	4.5%
	GDP (€ trillion)	47.6	80	89	133	120
	Chemical production/GDP	4.9%	4.5%	4.5%	5%	5%
	Chemical production (€ billion)	2.353	3.600	4.000	6.600	6.000
EU	Share of global GDP	26%	19%	18%	16%	17%
	Share of global industrial GDP	20%	16%	14%	10%	11%
	Share of global chemical production	21%	17%	16%	12%	15%
	Chemical production (€ billion)	491	620	640	790	900
Netherlands	Share of EU GDP	5%	5%	5%	5%	5%
	Share of EU chemical production	10%	12%	12%	13%	13%
	Chemical production (€ billion)	47	74	77	103	117
	Global chemical market share	2.0%	2.1%	1.9%	1.6%	2.0%
	Chemical sales (Index 2010=100)	100	157	163	219	249

Key-upside driver Key-downside driver

Source: Cefic, Cefic Facts and Figures 2011, www.cefic.org; The World Bank, *World Development Indicators and Global Development Finance*, 27 September 2011; Carnegie Endowment for International Peace, *The World Order in 2050*, April 2010

consumers who will use their collective buying power to acquire goods in great quantities — energy-efficient and affordable automobiles and homes, smart electronics for communication and entertainment, healthy nutrition and cosmetics to name just a few — all of which will require advanced materials and solutions supplied by the chemical industry.

Less certain is how the world will react to this demand explosion. Therefore, this report develops four potential futures (or scenarios) for 2030–2050 according to the possible evolution of technology and government policies. Although the scenarios are fundamentally different, applying any of them to the VNCI vision for 2030–2050 reveals a substantially larger chemical industry in the Netherlands. Indeed, production levels rise by 2030 in all scenarios, from 50 percent to more than 200 percent.

Scenario One: Fragmentation

One potential reaction to the increase in demand is global fragmentation. In this, the most pessimistic scenario, innovation is limited and regional trading blocs scramble to secure resources. Global economic growth is a mere 2.5 percent annually and even lower in Europe, far below both the World Bank's estimates and the historical average of

5.6 percent annually over the last 20 years.⁸

In the Fragmentation scenario, the industry is centered on a limited number of chemical champions in each economic bloc. China and India have their own regional champions, but trade restrictions limit their impact on the European market. Similarly, European companies face ownership restrictions in other regions. In response, companies focus on optimizing their plants in domestic chemical clusters and offer a fairly wide range of base and specialty chemicals to their home markets. Further downstream, many smaller companies continue to exist.

In this bleak scenario, Europe produces primarily for itself, and its share of global chemical production drops to just above 16 percent of world industrial production. The Netherlands benefits from its strong position vis-à-vis other European countries, however, enabling it to capture up to 12 percent of market share within Europe. Revenues expand to more than 50 percent above 2010 levels, although annual growth is a paltry 2 percent (including inflation).

⁸ The World Bank, *World Development Indicators & Global Development Finance 2011*

Scenario Two: Green Transition

The second scenario calls for a global green transition wherein large percentages of feedstock originate from biomass and chemistry is integrated with biotechnology. Triggers for this scenario are the on-going greening of the consumer and the corresponding marketing strategies of consumer business companies like Unilever, Nestle, and Coca-Cola Company and many niche players.⁹ In the Green Transition scenario, 15 to 20 percent of global feedstock includes biomass by 2030. Meanwhile, the global economic growth rate is only moderately higher than in the Fragmentation scenario.

Because the economics of bio-based and naphtha plants are similar, changes in the cost structure of the industry are minor. Integrated sites remain crucial, and major players have gradually converted a part of their capacity to bio-feedstock. While naphtha is still important, the industry tends to fragment more instead of consolidate and integrations with cellulose-based industries are a possibility. Players from oil-producing regions coexist with new entrants from countries that fully exploit their bio-feedstock advantage, such as Brazil. New multinational companies from China and India compete globally with leading U.S. and European companies.

The success of Europe in this scenario depends on its ability to satisfy the green customer and effectively integrate new feedstock into the cluster. Here, the Netherlands is relatively well positioned both on a global level and within Europe. Its advantages include:

- A major world port plus an advanced network of hinterland connections and logistical expertise. Because not only tropical countries but also Ukraine and France could play a prominent role in the production of biomass, Rotterdam is uniquely positioned to become a hub for oil, gas, and bio-based feedstock. If new feedstock flows through Rotterdam, the ARRRR is a logical processing site.
- World leadership in waste management and recycling (together with Germany).
- A head start in environmental awareness, including issues related to climate change.

In the Green Transition scenario, the Netherlands has gained market share within a relatively declining Europe,

with revenues climbing to around two-thirds higher than today.

Scenario Three: Abundant Energy

A third scenario is a world of abundant energy. This assumes large availability of energy sources with only limited greenhouse gas impact, mainly because of technological breakthroughs in solar technology. With cheap solar energy, demand for oil collapses and naphtha-based intermediates and chemicals in general become significantly less expensive. Economic growth is unprecedented, especially in the Asia-Pacific region. Global GDP grows by 5 percent per annum in this scenario, and the chemical industry benefits substantially from larger end markets.

With low oil prices, naphtha-based chemical production is dominant. Chemical production in Western Europe remains cost competitive in a solar world because feedstock price advantages are so small that they become irrelevant. Cost curves flatten and create a much more level playing field in the Abundant Energy scenario than is the case today. Process efficiency is the leading competitive differentiator.

Alternatively, gas becomes widely available. With transportation shifting to electric vehicles fuelled by gas-fired power plants, naphtha demand drops. In this shale gas world, the United States and China benefit more than Europe does because of their proximity to feedstock. Europe therefore concentrates on products from naphtha that are produced with economic advantages.

Incumbents use their scale advantages to grow, and an oligopoly of mega chemical companies dominates the industry. Some of these have European or American roots, others Chinese or Indian. The very largest companies are products of mergers between leaders from the West and the East. Because the number of players is limited, all have fairly wide product ranges. Smaller downstream players also exist, but these focus on niches with lower minimum scales. Oil- and gas-based chemical products are complemented by bio-based chemical production, which can benefit from low energy prices and add new functionality to the range of chemical products.

The Netherlands and the ARRRR are well positioned for the Abundant Energy scenario because operational excellence in naphtha-based processing is a crucial success factor. Chemical output in the Netherlands grows more than twofold, driven by strong end-market sales and a higher European, though lower global, share of production.

⁹ Biorefining magazine, *Coca-Cola partners with three biotech firms to develop bio-PET*, 16 December 2011

Scenario Four: High-Tech World

The fourth scenario is a much more technologically sophisticated world. In the High-Tech World scenario, there is an explosion in the number of scientists and engineers, as well as in the quality of information technologies. The number of patents has grown by 4 percent annually since World War II. In line with this rate, the scenario posits scientific output 5.5 times higher in 2050 than in 2011, bringing unprecedented possibilities for innovation and resource efficiency.

At 5 percent per annum, global economic growth is strong and is supported by free trade. Revenues for the global chemical industry have increased as innovation has brought new applications that further displace traditional materials like wood and metal.

In this environment, the global chemical industry looks similar to today's information technology (IT) sector: it consists of a small number of very large players, some Western, some Chinese and Indian. These companies own large, integrated chemical complexes and have strong distribution networks. Also like IT, there are many start-ups and smaller players, each catering to a different niche. Some remain independent; others are bought by the larger players as their potential market expands. Venture capital funding and close relations with universities have become more important. By breaking down traditional silos along the value chain, the chemical industry captures the added value from new technical developments, playing the crucial role of integrator.

Multiple Silicon Valley-style chemical clusters exist around the world. Each is unique, depending on the composition and skills of the players in the cluster. The result is further specialization, intense global trade, and broad diversity, even among the industry leaders.

In this scenario, by 2030–2050 the Netherlands and the ARRR cluster have carved out multiple niches based on strengths in the current cluster and adjacent industries. Concentration on nutrition, health, and personal care allows the cluster to leverage the position of the Netherlands in agriculture and life sciences. The High-Tech World has a positive outcome for the country because of its

- Strong collaborative culture focused on multidisciplinary problem solving
- Leading research position in areas such as material sciences, nanotechnology, chemical engineering, and complex systems
- Strong position in agro, food (chemistry), health, and logistics

By 2030 the Netherlands' production is more than double today's levels, a projection based on a global chemical industry growing at a 5 percent compound annual growth rate (CAGR) and a constant global market share of 2 percent.

Main conclusions from the report

Economic, demographic, technological, and societal megatrends through 2050 will lead to resource management challenges and yet unmet needs in the end markets. These also constitute opportunities for the Netherlands chemical industry to remain a leading generator of sustainable wealth and jobs. In any one of the examined very different possible future scenarios, the chemical industry will be able to shape and strengthen its own important role by leveraging the present skills of the highly integrated and connected chemical cluster in Western Europe that covers the Netherlands, Belgium, and Germany and stretches from Rotterdam to Ludwigshafen. Key elements of the vision for 2030–2050 are an open innovation eco-system, focus on end market needs and close collaboration in the relevant value chains, tightly knit network of world-leading assets with intra-sector and cross-sector synergies, high operational resource efficiency and safety standards, and efficient use of diverse feedstocks ranging from biomass to naphtha and gas while operating in a level playing field. In 2050, the chemical industry will be producing and selling solutions for other sectors, rather than liquids and solids. The "industry of industries" will benefit from a net brain gain and enjoy and deserve the image of an attractive, clean, safe, sustainable, and innovative top sector.

Part two: Developing the vision

The why and how of the new vision

The outlook for the chemical industry in the Netherlands is mixed. In the course of researching this paper, the VNCI and Deloitte Netherlands found that even some inside the industry are pessimistic about its future. Some outside stakeholders go as far as regarding chemicals as a sunset industry, with little or no prospects for growth. And yet the government of the Netherlands seems to disagree, having identified chemicals as one of nine industries it expects to drive future economic prosperity.

Which of these opposing views is right? To find out, the VNCI developed the idea of Vision 2030–2050. The VNCI is the national chemical industry association of the Netherlands. It represents one of the major industries in the country, with €47 billion in combined revenues, 64,000 employees in 2010, and a wide range of supplier and customer industries. The VNCI promotes the collective interests of the chemical industry and aims to create optimal conditions to advance growth, innovation, and operational excellence.

The 2030–2050 time horizon of this report ensures a long-term perspective going beyond the current asset base and specific sector issues. It also avoids company-specific issues. Most of the insights presented are valid for the 2030–2050 period, with quantification limited to 2030.

An inside-out visioning process

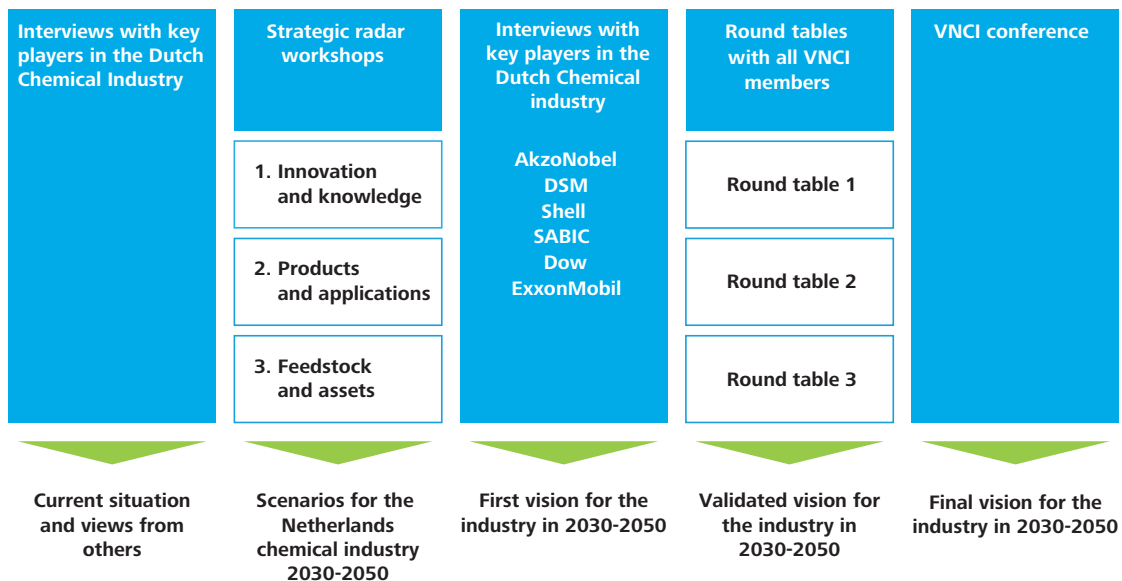
The Vision 2030–2050, documented in this report, was developed over seven months from April to October 2011 and involved the participation of over 100 specialists from inside and outside the chemical industry.

The development process had five steps (see Figure 3):

1. Extensive desk research was conducted on both the current state of the industry and long-term trends, using interviews with thought leaders (Appendix B) and numerous secondary sources (Appendix E).
2. Long-term trends were identified and discussed in three thematic specialist workshops with thought leaders (Appendix C). The meetings focused on the following themes: innovation and knowledge, products and applications, and feedstock and assets. They followed an outside-in approach (Figure 4). The resulting list of base trends and key uncertainties for the industry in 2030–2050 was used to develop the four industry scenarios described in Part one of this report.
3. In three round-table sessions, the scenarios were presented to representatives of VNCI member companies ranging from SMEs to multinationals (Appendix D). After validating the scenarios, the participants developed a first view on the industry in 2030–2050.
4. Similar discussions were held during interviews of executive board members of AkzoNobel, Dow Chemical EMEA, DSM, ExxonMobil Benelux, SABIC, and Shell (Appendix B).
5. A draft report was approved by key participants in the process. After processing their feedback, the final document was prepared.

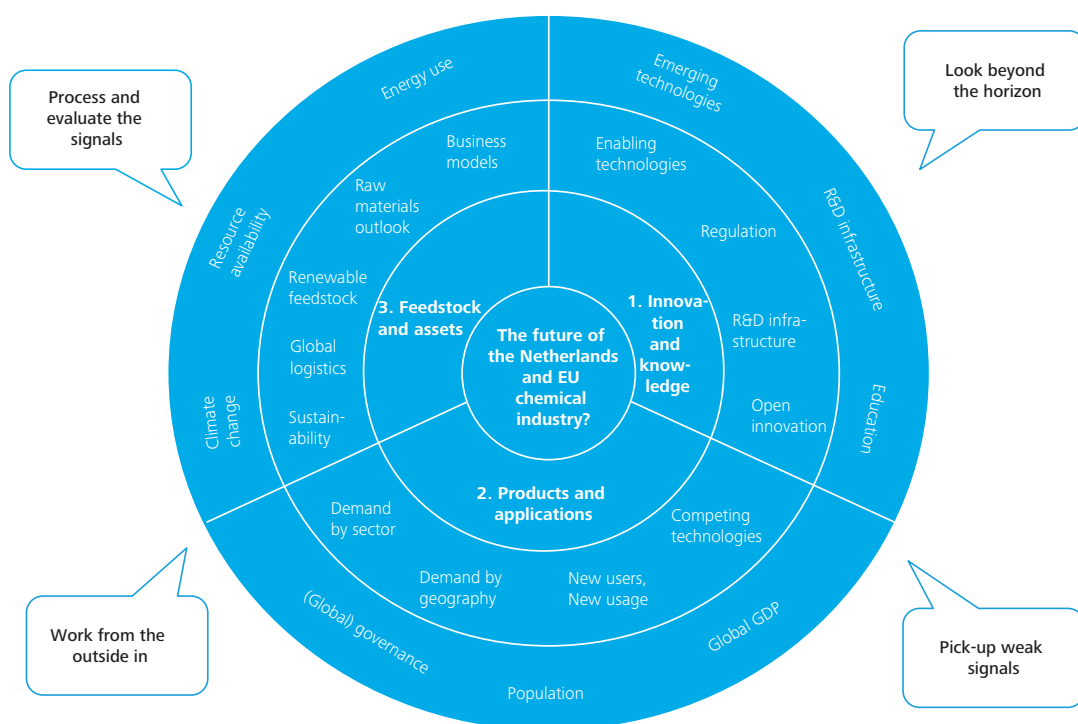
The process was supervised by a steering group composed of Colette Alma (VNCI), Nelo Emerencia (VNCI), Peter Nieuwenhuizen (AkzoNobel), Ruud Derks (DSM), and Vincent Oomes and Willem Vaessen (both Deloitte Netherlands).

Figure 3: Project approach



Source: Deloitte Netherlands analysis

Figure 4: Strategic radar process to spot long-term trends



Source: Deloitte Netherlands analysis

Starting from a great position

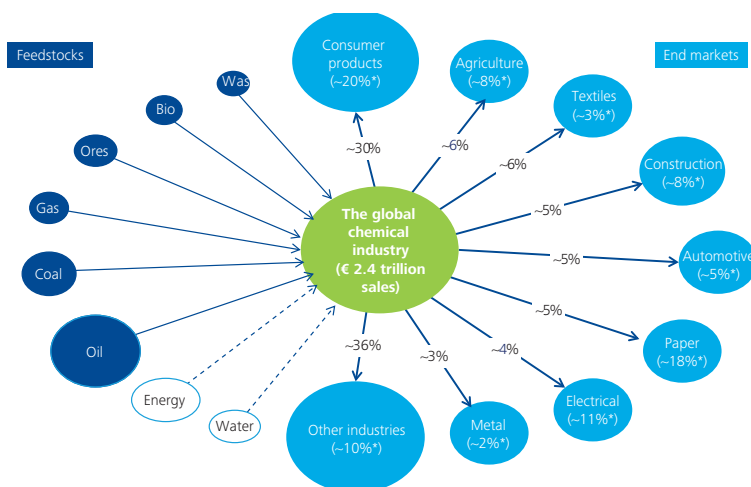
The following section offers a description of the current situation in the global chemical industry and specifically the position of Europe and the Netherlands. It analyzes global macroeconomic and demographic developments heading toward 2050 and suggests substantial economic growth potential through the trends discussed. It also delves into the question of whether the world will have enough natural resources to meet its growing needs.

The chemical industry is the “industry of industries”

Worldwide, the chemical industry was a €2.4 trillion business in 2010. Long considered the “industry of industries,” it supplies raw materials to manufacturers everywhere. The customer base is diverse: in Europe, for example, 30 percent of chemicals sold are used in consumer products, 6 percent in agriculture, 6 percent in textiles and clothing, 5 percent in building materials, 5 percent in automotive products, 5 percent in paper and printing products, 4 percent in electrical goods, 3 percent in metal products, and 36 percent in all other manufacturing industries.

With such a wide application footprint, it is not surprising that chemical revenues are closely correlated to world GDP (see Figure 5). From 1991 to 2010 global sales increased 4.8 percent annually, versus a 4.3 percent growth rate for world GDP. The 0.5 percentage point difference suggests

Figure 5: The industry of industries

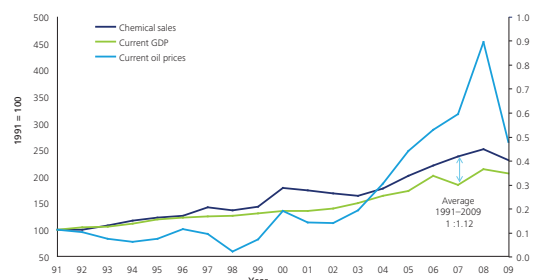


* Share of chemicals in end market value

Source: Cefic, Cefic Chemdata International, May 2011; Deloitte Touche Tohmatsu Limited Global Manufacturing Industry group, *End market alchemy: Expanding perspectives to drive growth in the global chemical industry*, 19 October 2011, www.deloitte.com/endmarketalchemy

that the industry, driven by technological innovation, is taking a modest GDP share from producers of other raw materials such as steel and wood.

Figure 6: Global chemical sales versus global GDP



Source: Cefic, Cefic Chemdata International, May 2011; International Monetary Fund, Data and Statistics, May 2011; Inflation data, May 2011, www.inflationdata.com

Dutch cluster is highly competitive

Traditionally, the EU has been a strong player in the global chemical industry. It produces over 21 percent of world sales, in line with its 20 percent of global industrial GDP and 11 percent of world population (see Figure 6).¹⁰ The Dutch industry in the Netherlands punches above its weight with 2 percent of world production and only 0.2 percent of population.¹¹ This makes the chemical industry a crucial sector for the economy of the Netherlands: after food, it is the country's second-largest industry. The chemical industry generated almost 3 percent of added value to the Dutch economy and represented approximately 20 percent of Dutch exports in 2010. As a share of Dutch manufacturing, the chemical industry is still growing, although manufacturing represents a declining share of the total economy due to the shift to services.

¹⁰ Cefic Chemdata International; The World Bank, World development indicators database; The World Bank, Global development finance 2011; United Nations, World population prospects 2009

¹¹ Cefic Chemdata International; United Nations, World population prospects 2009

As their relatively high production shares imply, Europe and the Netherlands are net exporters of chemical products. Indeed, contrary to popular belief, both the continent and the country have been able to increase chemical trade balances substantially over the last 20 years (see Figure 7).

The power of the cluster

A cluster is a geographic concentration of interconnected businesses, suppliers, and associated institutions in a particular field. Clusters are successful not only because of benign factors such as skilled labor and physical location but also because of highly demanding customers, intense rivalry among companies in the cluster itself, and powerful related industries. Clusters increase the productivity of individual companies, drive innovation in the field, and stimulate new businesses.

This trade balance success has developed because of various factors, including a highly skilled European labor force, large and modern port facilities, and a dense network of plants and pipelines operated at relatively low costs. Nowhere is this better demonstrated than in the ARRRR, which is one of the most important chemical industry clusters in the world. The assets in this network are state-of-the-art due to regular maintenance, de-bottlenecking, and continuous process improvement. As a result, the Netherlands is well positioned within Europe. Moreover, internal benchmarking at multiple global companies reveals that the highly skilled workforce makes their plants in the Netherlands among the best performing in the world.

The European chemical industry benefits from its proximity to large and highly demanding customers. Many world-leading manufacturers of consumer products, building materials, automotive products, and agricultural products are headquartered in Europe, and many have significant research and development (R&D) and production sites there as well. And of these, many are located in or close to

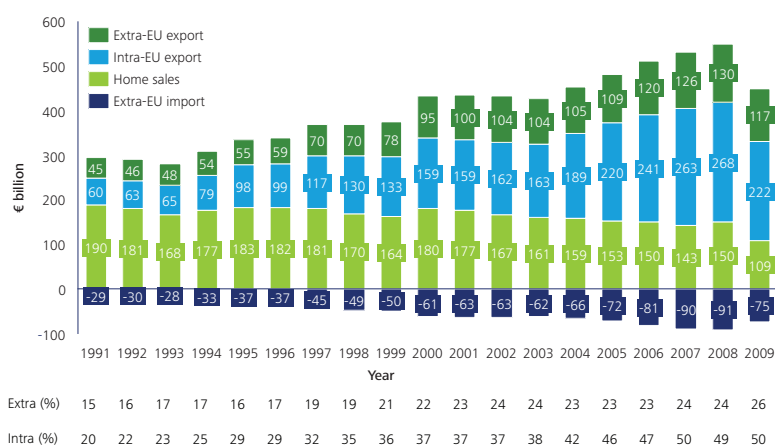
Dutch chemical cluster strengths

- Integration with refineries and pipeline systems
- Transportation infrastructure
- Mix of large and small plants with a wide range of products and grades
- Proximity to world-class end users
- Presence of global players
- Skilled workforce
- Strong universities
- Culture of cooperation
- Maintenance culture

Dutch chemical cluster weaknesses

- Cost of labor
- Distance of feedstock (less important with integrated refineries and chemical production)
- Limited supply of engineers
- Limited number of start-ups

Figure 7: EU chemical trade balance



* EU
Source: Cefic, Cefic Facts and Figures 2010, www.cefic.org

the ARRR cluster. These customers constantly challenge chemical companies to perform better. Their physical proximity also facilitates the joint development of new products and applications.

With 20 of the 50 largest chemical companies headquartered in Europe and four in the Netherlands (AkzoNobel, DSM, Lyondell Basell, and Shell Chemicals), plus a large number of SMEs, competition is intense. Almost all leading U.S. and European chemical companies are active in the ARRR cluster. Dow Chemical, Dupont de Nemours, ExxonMobil, and SABIC all have significant operations in the Netherlands.

Finally, the ARRR cluster is home to a number of powerful related industries. Examples include the agriculture and food businesses, with such companies as Unilever and Friesland Food Campina. These export-oriented process industries share many characteristics with the chemical industry and also benefit it. For example, the animal feed industry in Rotterdam could provide biomass volume to the chemical industry.

Of course, Europe's positive trade balance is also a consequence of relative weaknesses in other regions. Thanks to its historical strengths, Europe has been able to import oil from overseas, process it, and then export finished products, including chemicals. This expensive detour is gradually being eliminated as export markets become more developed and are increasingly able to process feedstock themselves. Figure 8 reveals the following trends:

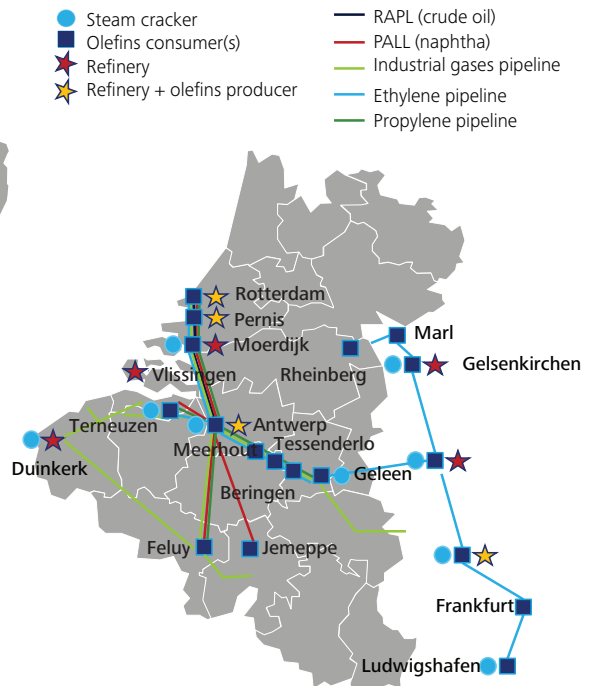
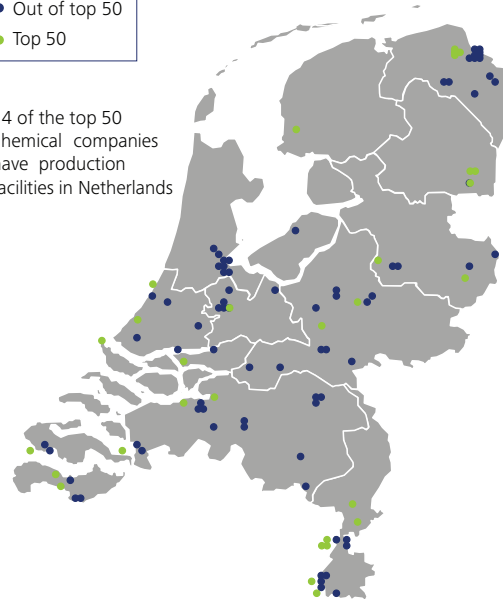
- Since 2005 the European trade surplus with Asia, the Middle East, and Brazil has shrunk by 10–20 percent depending on the region (although the balance is still positive). Trade with China is already at a deficit: European imports from China exceed exports by 10 percent. The trade balance with the United States and Russia is positive, however, with a 20 percent surplus that grew by 3–10 percent annually from 2005 to 2010.
- On a product basis, trade surpluses are declining for petrochemicals and base chemicals as these are increasingly being produced at their source. However, surpluses of polymers and consumer chemicals are still growing.

Figure 8: The Dutch chemical cluster

Chemical and petro production facilities

- Out of top 50
- Top 50

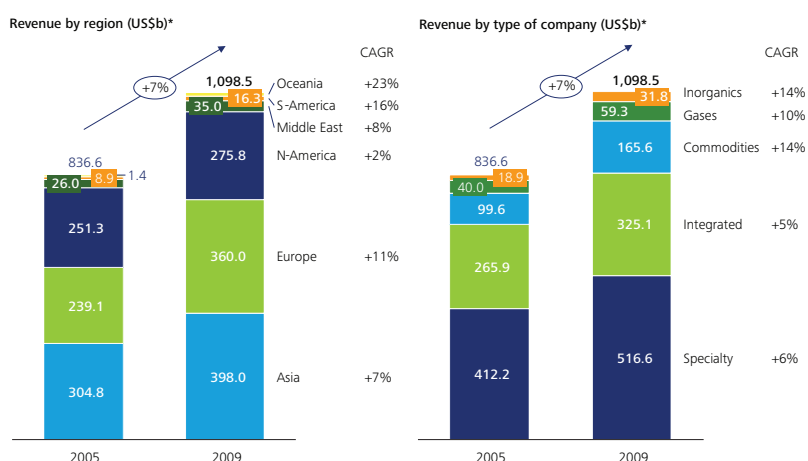
14 of the top 50 chemical companies have production facilities in Netherlands



Source: VNCI, Internal data, 2011; Port of Rotterdam, www.portofrotterdam.com/nl/Over-de-haven/haven-algemeen/Pages/achterlandverbindingen.aspx; Port of Antwerp, *Europe's World Scale Chemical Cluster, 2005*

European and Dutch companies outgrowing the market

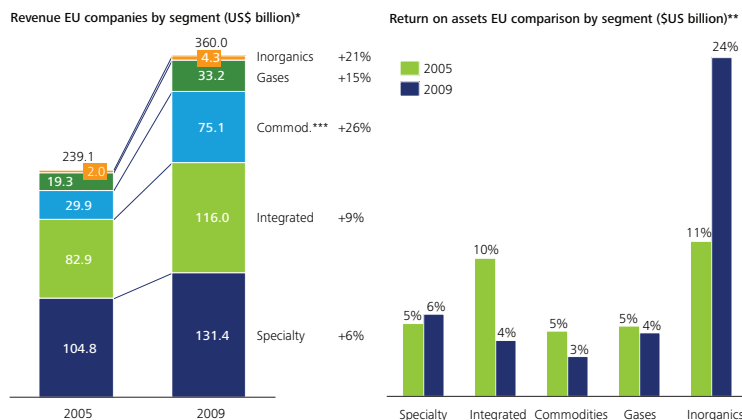
Figure 9: Revenues of the 225 largest chemical companies



* Based on 225 of 232 publically traded companies in the world
 Source: Deloitte Touche Tohmatsu Limited Global Manufacturing Industry group, *The decade ahead: Preparing for an unpredictable future in the global chemical industry*, 17 December 2009, www.deloitte.com/thedecadeahead

With their strong home base and firm commitment to the industry, European multinationals have been growing faster than any other regional group (see Figure 9). From 2005 to 2009 revenues of this group grew 11 percent per year versus 7 percent for all multinationals. Growth of U.S.-based multinationals was the lowest, at only 2 percent. European multinationals have benefited more from globalization than have their American counterparts, due to faster global expansion and greater specialization.

Figure 10: Financial performance of European chemical companies



* Based on 49 of 50 European companies ** Based on 43 of 50 European companies
 *** Change in commodities mainly due to Lyondell Basell acquisition
 Source: Deloitte Touche Tohmatsu Limited Global Manufacturing Industry group, *The decade ahead: Preparing for an unpredictable future in the global chemical industry*, 17 December 2009, www.deloitte.com/thedecadeaheadSpecialty

Despite strong growth, the margins of the European multinationals have declined. Returns on assets of integrated companies dropped from 10 percent in 2005 to 4 percent in 2009. For commodity chemical companies the decline was less dramatic, from 5 percent to 3 percent, while margins for gas companies declined from 5 percent to 4 percent (see Figure 10). Only specialty and inorganic producers were able to increase returns.

These low returns, which were well below the cost of capital, explain the challenges of stock market performance for most companies despite the strong growth. Of course, the story is not the same for all companies. Some large VNCI members report that their Dutch plants are extremely profitable, earning returns on assets that far exceed the cost of capital.



End markets will have increasing importance to the way the chemical industry makes and distributes its products. The industry will be the channel master in the value network and thereby strengthen its financial returns.¹²

¹² For a more detailed discussion on end markets, please see the Deloitte Touche Tohmatsu Limited Global Manufacturing Industry group, *End market alchemy: Expanding perspectives to drive growth in the global chemical industry*, 19 October 2011, www.deloitte.com/

Base technology is mature, applications still proliferate

One of the main reasons for low returns in the global chemical industry is that its base technology appears to be mature. Few new molecules have been developed in recent years. The chemical industry had big breakthroughs with polyvinyl chloride (PVC) in the 1920s, low-density polyethylene (LDPE) and polyurethane (PUR) in the 1930s, polyethylene terephthalate (PET) in the 1940s, high-density polyethylene (HDPE) and polypropylene (PP) in the 1950s, and linear low-density polyethylene (LLDPE), the most recent blockbuster, in the late 1970s. Over the same period, however, the number of applications for these plastics has proliferated, enabling the growth of tailor-made polymers.

Europe, the United States, and Japan have traditionally been the leading regions for innovation and R&D in the chemical industry. The United States leads in terms of patents¹³ because scale has been an important driver of innovation. The number of patents in chemicals is primarily a function of chemical sales rather than of academic performance. That is, the bigger a company or region is, the more chemical patents it will produce.

The ARRR is relatively strong in environmental technology, chemical engineering, nanotechnology, materials, and food chemistry. The World Economic Forum calls the Netherlands the eighth most innovative country in the world, with top-10 scores for innovation capacity, quality of scientific research institutions, and higher education and training.¹⁴ Its scientists are highly productive, with approximately 0.7 publications per researcher per year, second only to Switzerland and more than twice the global and U.S. averages.

And though global top-10 rankings of universities are dominated by universities in the United States (other than Oxford, Cambridge, ETH Zürich, and Tokyo), 11 Dutch universities are among the top 200 in the QS World University Rankings. This is substantially more per capita than the United Kingdom (30 in the top 200), Germany (12 in the top 200), France (5 in the top 200), or Italy (2 in the top 200). In chemistry, physics, and biological and environmental sciences, all major universities in the Netherlands are ranked in the top 100.

endmarketalchemy

¹³ World Intellectual Property Organization, *World intellectual property indicators 2010*

¹⁴ World Economic Forum, *Global competitiveness report 2010–2011*

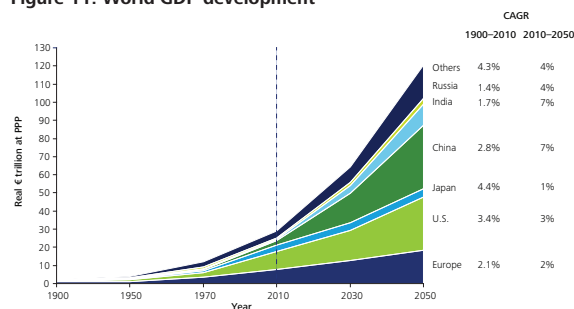
Worldwide growth in demand for chemical products

The competitive environment in the Netherlands will remain intact even in a world undergoing profound changes through 2050. Wealth will proliferate as the middle classes in the Asia-Pacific region and South America vastly increase, resulting in an explosion of demand for physical goods and a much larger market for chemical products.

A proliferation of wealth

In the next 40 years, China, India, Brazil, and many other emerging economies will join Europe, the United States, Japan, and Korea as high-income countries with vast middle classes and corresponding consumption patterns. As these countries become richer, G20 GDP is expected to increase more than fourfold, from €28 trillion in 2009 to €120 trillion in 2050 in constant prices (see Figure 11). The distribution of global wealth will begin to reflect the pattern it had before the Industrial Revolution, when the Chinese economy was as big as Europe's. The rest of the world will be catching up with the West, strengthening the global economy in the process.

Figure 11: World GDP development



Source: United Nations, *United Nations World Populations Prospects*, 2009; The World Bank, *World Development Indicators and Global Development Finance*, 27 September 2011; Carnegie Endowment for International Peace, *The World Order in 2050*, April 2010; Rijksuniversiteit Groningen, *Maddison Historical Statistics*

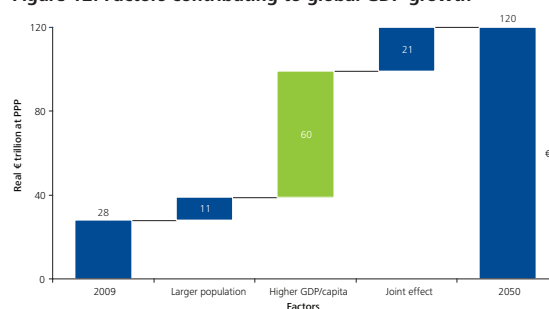
As seen in Figure 11, the presence not of *more* people but of *more relatively wealthy* people — meaning a vastly larger middle class — will distinguish 2050 from 2011. Higher GDP per capita will account for two-thirds of the increase in global GDP through 2050, with population growth accounting for only one-third. Most of the population increase will be in low-income countries such as those in Africa, whereas China, with its one-child policy, will have a rapidly aging society over the next 40 years.

Europe and Japan are the first regions to face the challenge of caring for an aging population. This will require fast technological advancements to support the elderly, address

employee shortages, and stimulate innovation inside and outside the chemical industry.

Although Europe's share of global GDP will decline from 26 percent in 2010 to 15 percent in 2050, its absolute GDP is still expected to grow by 140 percent to €17 trillion over the period (see Figure 12). This implies an economy that is 2.2 times larger than today, spread across roughly the same population.

Figure 12: Factors contributing to global GDP growth



Source: United Nations, *United Nations World Populations Prospects*, 2009; The World Bank, *World Development Indicators and Global Development Finance*, 27 September 2011; Carnegie Endowment for International Peace, *The World Order in 2050*, April 2010; Deloitte Netherlands analysis
Note: G20 excluding EU

One effect of a vastly larger middle class globally is that more people will be able to pursue tertiary education. The worldwide number of university graduates is expected to grow to 1.4 billion in 2050, from 0.5 billion today. Not surprisingly, most of this growth will be in the Asia-Pacific region. This will pose a challenge for Europe. With its stagnant population, Europe's home-grown graduates will have fallen from 20 percent of the world's total to 12 percent by 2050.

Moreover, fewer will graduate as engineers or scientists. In 2008, only 14 percent of Dutch university graduates received a degree in these fields. Europe and the Netherlands may have to implement policies to attract overseas scientists and engineers. But no level of immigration will be able to offset the decline in their share of engineers and scientists. Strengthening global cooperation will therefore be key differentiating countries and regions.

An explosion in demand

Increased wealth will intensify demand for mobility, buildings, equipment, and food, all of which require materials supplied by the chemical industry. Much of this demand will be in traditional applications. Middle-class households in India will purchase furniture, for example, which requires chemical coatings.

Growth opportunities will emerge beyond these traditional applications, however, via the introduction of new products. For example, chemical companies can develop smart materials for better building insulation, stronger plastics to replace steel, or materials that inhibit the growth of bacteria and reduce the risk of epidemics in densely populated areas. The industry can supply new packaging material that is lighter and easier for an aging population to use or develop products to help increase life expectancy, such as diagnostic tools to detect diseases at early stages and enable more effective prevention and treatment. Such product innovations are more likely to occur in a cluster that is strongly integrated across the value chain because innovation will take place at the intersection of disciplines and end markets.

Not a zero-sum game

With high-growth economies like China and India graduating to the developed world, the production of chemicals will continue to increase in these markets. Today, major European chemical companies are building facilities in China, one of which is larger than the biggest chemical complex in Europe. Ultimately, China and India will have the largest integrated chemical systems in the world.

More production in the Asia-Pacific region will be accompanied by more R&D. In the last decade, Asia-Pacific chemical R&D spending has grown so significantly that differences between regions have almost disappeared. In the coming years, R&D centers will be located in regions with the strongest outlooks for growth. Asia's increasing share of engineers, combined with access to intellectual property via open innovation models, will put pressure on Europe's position as a leader in innovation and R&D.

With a large share of production and R&D in the Asia-Pacific region, new chemical multinationals from developing markets will emerge. Depending on regulatory constraints, these will be either regional champions or truly global players that may eventually acquire Western competitors. This is already happening in the steel industry, as Indian companies such as Mittal and Tata take their place among the global giants. In the chemical industry, companies like Sinopec, Reliance, and Formosa Plastics have already hinted at global ambitions, and furthermore enjoy the support of their governments.

The availability of feedstock will drive the production of base chemicals to the Middle East and the United States. Currently the global chemical industry depends heavily on

naphtha-based feedstock, with oil products accounting for almost 95 percent of the total input in Organisation for Economic Co-operation and Development (OECD) countries. Specifically, the following developments are likely:

- Instead of shipping oil to Europe, processing it there, and transporting products back to the Asia-Pacific region, it will become more economical to process oil at the source. The need to create employment opportunities for a young and growing population and the availability of capital in the Middle East will further accelerate this trend.
- Shale gas found in the United States will help American chemical production rebound and reduce its imports from Europe. Environmental concern about European shale gas production due to its denser population will contribute to the decline of its share of global production.

For Europe, this shift does not necessarily have to be negative. Although it may lose a significant piece of overseas exports and also parts of its base chemicals production to the Middle East and the United States, the region will remain competitive in other areas. The conversion of gas produces fewer aromatics and more olefins, and Europe can remain a strong contender in aromatics-based products like benzene, toluene, and xylene when its refining process is integrated with chemical production. This trend will be complemented by stimulation of a strong European manufacturing base.

More important, with worldwide demand increasing fourfold and new technologies emerging, ample opportunities exist to develop new products that can be sold to the global markets. And the disadvantages of this overall picture for the Netherlands are even lower. As discussed earlier, the ARRRRA cluster is the most cost efficient in Europe. Any rationalization due to increased global competition will therefore hit other European clusters first.

In summary, although they will be marked by challenges, the next 40 years can certainly produce a mutually beneficial situation for all players, in which the Dutch chemical industry prospers alongside other global chemical producers.

The resource challenge

As the world becomes richer, consumption and waste levels will rise correspondingly, as follows:

- Total energy consumption is expected to almost double between 2005 and 2035.¹⁵ If current practices continue, CO₂ and greenhouse gas emissions will rise accordingly.
- Water will become increasingly scarce. Water supplies are already constrained in the Middle East, which has depleted 40 per cent of its naturally available water. By 2015 the Indian subcontinent and Southern Africa will also reach high depletion rates. Depletion rates in China and the United States will double to more than 20 per cent over the same period.¹⁶
- Supplies of metals like indium, silver, and antimony may be exhausted within 30 years.¹⁷ The availability of copper is expected to end in 2055, iron ore in 2065, and phosphate in 2085.

Increased scarcity will be accompanied by a constant struggle to meet demand, leading to rising and highly volatile prices.

Growing volumes of waste could, however, provide a solution to resource scarcity. Advanced recycling and reuse will become an important part of the solution for waste management and mitigate the exhaustion of resources.



¹⁵ U.S. Energy Information Administration, *International energy outlook 2010*

¹⁶ United Nations Environment Programme, *Vital water graphics, 2002*

¹⁷ International Organizing Committee for the World Mining Congresses, *World mining data 2010*

Four scenarios to meet growing demand

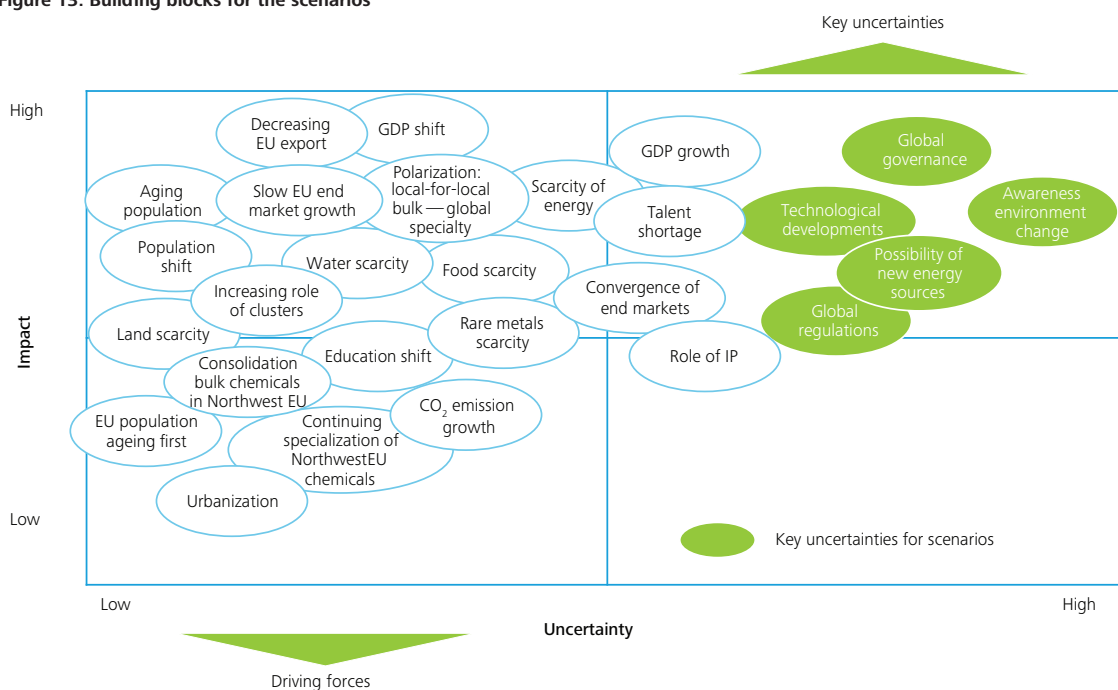
When it comes to meeting expected demand, the chemical industry faces several possibilities. Solutions may be found in additional feedstocks, new sources of energy, and technological breakthroughs. Alternatively, the industry may have to struggle to meet higher demand with dwindling resources at a time when governments could be either accelerating or slowing down implementation processes to resolve gaps between supply and demand.

In order to assess the impact of the possible ways to meet growing demand, it is useful to return to the four scenarios briefly discussed in Part one.

Protectionism becomes the dominant paradigm. It limits free trade and therefore slows economic growth. Energy and commodity prices rise in a distorted market. Concerns about climate change and pollution arise locally in wealthy regions that have limited access to energy and other resources. Innovation and R&D focus on solving local issues, and technological solutions are guarded at a regional level.

As a consequence, local-for-local markets dominate the chemical industry. For Europe this implies limited market growth, since exports are limited and domestic end-market growth slows due to weak economic growth

Figure 13: Building blocks for the scenarios



Source: Deloitte Netherlands analysis

Scenario One: Fragmentation

The Fragmentation scenario has few technological breakthroughs. Nations and regional blocs seek self-sufficiency to counter the effects of resource scarcity.

The mid-21st century sees a multipolar world with unstable relations. Europe and the Americas, China, India, and Russia form economic blocs and each scrambles for resources and imposes trade barriers to protect its interests. In the darkest variations of this scenario, the economic situation leads to military conflict between the superpowers.

and a stagnant population. Fortunately, competition from overseas is also limited.

Europe's dependence on imported feedstock stimulates diversification. Use of second- and third-generation biomass and recycling/reusing is stimulated by local governments, though not with full success.

Fragmentation also presents opportunities for the chemical industry, which could play a vital role in limiting dependence on other regions. Under such a scenario, the industry delivers new methods for growing crops and increasing yields by using plastic beds instead of arable



land for farming. It develops smart packaging to increase the shelf life of perishable food and improves desalination techniques for water.

The chemical industry in 2050 also provides solutions that reduce energy use and promote alternative energy sources. Examples include lightweight materials for the automotive industry and better batteries for electric vehicles, which will be in greater demand in this scenario. The demand for energy efficiency in the construction sector is met by better insulation and reflective paints that reduce energy use and decrease energy storage loss. As fossil fuels become scarcer, the chemical industry provides products to make extraction more efficient, such as polymers that improve oil viscosity.

Industry impact

In a fragmented world, the industry is centered on a small group of chemical champions in each economic bloc. China and India have their own regional champions, but trade restrictions limit their impact on the European market. Similarly, European companies face ownership restrictions in other regions. In response, they focus on optimizing their plants in domestic chemical clusters and offering a fairly wide range of base and specialty chemicals to customers in their home markets. Further downstream, many smaller companies continue to exist.

In this environment, higher operational efficiency and prompt response to new customer needs will be essential. Because it is stronger than any other region in Europe, the ARRA cluster will take market share away from other European sites.

Scenario Two: Green Transition

In the Green Transition scenario, scientific evidence linking climate change to variations in rainfall, weather patterns, sea levels, and disease outbreaks has made the environment the dominant issue. Demand for sustainability successfully drives technological and scientific developments toward clean, energy-efficient, and sustainable products, processes, and feedstock.

Companies follow the lead of Pepsi, Coca-Cola, and Toyota, which in 2011 began to use bio-plastics for most of their products to save costs, support a green image, and create consumer pull for green products. Quality brands introduce sustainable products. More emphasis on sustainability is also incorporated into regulations such as REACH (registration, evaluation, authorization, and restriction of chemicals).

New forms of bio-based feedstock are embraced. These are different from today's first-generation biomass, which competes with food. Use of second-generation biomass becomes standard practice; this includes non-edible source material like straw, whole plant, and wood, which contains polymers of plant cell walls. Third-generation biomass under consideration includes algae that has been biologically engineered to offer the same functionalities as naphtha-based products but with fewer processing steps, or altogether new functionalities. Algae are used as a base element for molecules, using functional molecules instead of building blocks to synthesize molecules.

In this scenario, 15–20 percent of global feedstock is bio-based by 2030–2050, still well below the 90 percent that academic studies suggest is feasible for plastics¹⁸ but significantly above today's 1–2 percent (a figure that corresponds to just 0.02 percent of all available material, the balance going to food and energy).

Demand for sustainable products also stimulates the reuse and recycling of disposed materials (a practice sometimes referred to as urban mining). This involves collecting, separating, and processing plastics. Furthermore, emitted CO₂ is used as a feedstock to produce hydrocarbons (a process called artificial photosynthesis). And through pyrolysis, liquid fuels with similar characteristics to those based on naphtha are produced from biomass. The chemical industry value chain incorporates new concepts such as cradle-to-cradle design, which uses recycled chemicals and metals as feedstock. This development allows players from the agro-food and waste sectors to enter the value chain.

Economic growth in this scenario is relatively low because of the requirement to comply with strict regulations and associated costs. Regulatory measures focused on improving sustainability are coordinated at a global level, using a system of greenhouse gas emission taxes. In order to guarantee a level playing field for the chemical industry, sustainability trade agreements are signed. These pacts cover issues such as the costs of CO₂ emissions and sustainability criteria in pricing structures.

Industry impact

Because bio-based and naphtha plants are similar, major changes in the economics of the industry are unlikely. Integrated sites remain crucial, and major players gradually convert parts of their plants to bio-feedstock. Because naphtha remains important, the industry fragments rather than consolidates (and converges with other cellulose-based industries). Players from oil-producing regions coexist with new entrants from countries that fully exploit their bio-feedstock advantage, such as Brazil. New multinationals from China and India compete globally with leading United States and European companies.

The success of Europe in this scenario depends on its ability to meet the green customer demand and integrate new feedstock into the cluster. The Netherlands is relatively well positioned for the following reasons:

- It boasts a major world port plus an advanced network of hinterland connections and logistical expertise. In addition to tropical countries, Ukraine and France could play a prominent role in the production of biomass, and Rotterdam is uniquely positioned to become a hub for oil, gas, and bio-based feedstock. If new feedstock flows through Rotterdam, the ARRRR is a logical processing site.
- Together with Germany, the Netherlands is a world leader in waste management and recycling.
- As in most wealthy and densely populated areas within Europe, social awareness about climate change and the environment is developing faster in the Netherlands than in the United States and Asia.

Scenario Three: Abundant Energy

In the Abundant Energy scenario, new sources of energy make concerns about climate change and continuity of energy supplies merely a bad dream. The new sources may be traditional, such as natural gas, but with added technology that limits their greenhouse gas impact. There may also be technical breakthroughs like geothermal energy or inexpensive and powerful solar energy. For example, with high-performance and ultra-low-cost photovoltaic panels, companies and households would be able to produce their own electricity. Chemical plants would also be able to generate most of their own energy needs.

In this scenario, demand for oil, gas, and other traditional energy sources drops dramatically, thereby reducing overhead costs for chemical companies and eliminating the need to seek alternative feedstock. Chemicals and other products become cheaper, creating endless possibilities for developing new applications to displace existing products, such as plastic houses. The significant decrease in transportation costs stimulates global trade and strong economic growth.

The availability of low-cost energy creates opportunities for technologies that currently require great quantities of energy. Additionally, strong economic growth stimulates further technological developments in areas such as molecular selection, molecular modelling, and process intensification.

¹⁸ Shen, Haufe, Patel (Utrecht University), *Product overview and market projection of emerging bio-based plastics*, 2009

Enabled by healthy profits, environmental solutions focus on mitigating the effects of toxins rather than on energy efficiency. Consumers are concerned about the effects of toxins on humans and the environment, and debate the ethics of biotechnology, nanotechnology, and genetically modified products.

Industry impact

With the advance of solar technologies, hydrocarbons are cheap and widely available, so oil- and gas-based chemical production remains dominant. Chemical production in Western Europe remains cost competitive because feedstock price advantages are effectively irrelevant. Most cost curves are flat, creating a level playing field in which process efficiency is the leading competitive differentiator.

In response, incumbents use their scale advantages to grow even more. An oligopoly of mega chemical companies dominates the industry. Some of these have European or American roots, while others are based in China or India. The largest companies are products of mergers between leaders from the West and the East. Because the number of players is limited, all of them offer a wide range of products. Smaller downstream players focus on niches with lower minimum efficient scale.

Oil- and gas-based chemical products are complemented by bio-based chemical production, which also benefits from low energy prices and is able to add new functionality to the range of chemical products.

The Netherlands and the ARRA are positioned beautifully in this scenario because operational excellence is the key factor in success.

Scenario Four: High-Tech World

The High-Tech World scenario assumes a technology revolution with multiple breakthroughs:

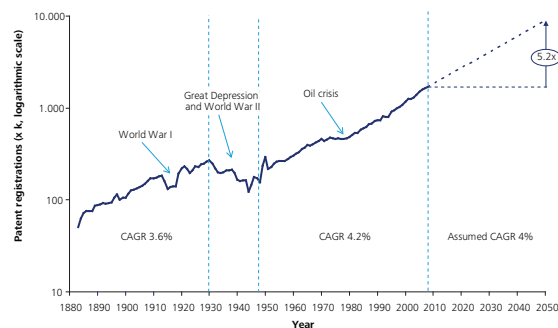
- New technologies provide fresh opportunities in molecular design and supra-molecular chemistry. Bio-engineers are able to select and model molecules in ways that were never before possible, creating new applications and revenues for the global chemical industry. These molecules can be produced via integrated, low-cost processes.

- Processes are intensified, facilitating asset-light strategies and decentralization in the form of small-scale plants alongside large, integrated complexes. Energy efficiency in the chemical industry and elsewhere improves significantly. Safety standards increase as plants get smaller and simpler to operate.
- A new catalytic system, possibly nanocatalysis, is available to convert CO₂ to CH₄, making CO₂ a feedstock for the chemical industry.

A key assumption in this scenario is a dramatic rise in successful scientific output. This is likely because that output has grown at a fairly constant rate of about 4 percent per year since 1883 (except during the world wars and the Great Depression, as seen in Figure 14). At this pace, five times the number of inventions will appear in 2050 as occur today.

The enhanced output is also driven by an explosion in the numbers of engineers, as China and India bring higher education to the masses and technology improves. Furthermore, output per scientist increases as computing power advances. A dramatic decrease in the cost per unit of computing power, transmission bandwidth, and storage capacity results in more powerful computing and even better user interfaces. Enhanced connectivity stimulates open models of innovation wherein scientists share information in real time.

Figure 14: World scientific output



Source: WIPO, *World Intellectual Property Indicators 2010*

The traditional inductive model of research — in which companies develop intellectual property (IP) on their own, hoping it will result in innovation — have disappeared. This linear model could be replaced by an extrapolation model, whereby ideation is collaborative or crowd sourced, followed by traditional in-company R&D. Another possibility is a collaborative extrapolation model, where both ideation and development are shared by multiple participants. This model already exists today as “open source” in the software industry. In either case, IP is more difficult to protect, as more participants are involved in the R&D process.

Dramatically higher research output will yield new technologies in the next 40 years, such as those shown in Figure 15. These technologies are the result of converging technologies and science fields. Nanotechnology, for example, combines biology, chemistry, physics, and engineering.

- Supramolecular chemistry goes beyond individual molecules and focuses on chemical systems consisting of multiple assembled molecular subunits, or components. Whereas traditional chemistry usually uses strong spatial molecular organizations, supramolecular chemistry focuses on weak organizations of molecules. Self-organizing molecules are capable of self-assembly and also of signalling and reacting to triggers. Self-organizing molecules make possible new products such as medicines that direct themselves to certain parts of the human body.

All these new technologies will lead to new chemical processes and products. As shown in Figure 16, the list of conceivable products is long and includes many expected breakthroughs. These products transform the chemical industry and reinstate it as an innovative, high-tech industry.

Figure 15: Trends in enabling technologies

<p>Small world</p> <p>Nanotechnology will enable innovations and new capabilities in materials and medicine, combining several fundamental research areas and leading to developments in interdisciplinary science.</p>	<p>Intentional biology</p> <p>The ability to re-engineer and manipulate biology will strongly influence future applications.</p>	<p>Mathematical world</p> <p>The ability to process, manipulate, and understand patterns in data will increase. Massive computation will make simulation widespread.</p>
<p>Lightweight infrastructure</p> <p>New materials will enable new infrastructure designs that incorporate smaller, smarter, and more independent components.</p>	<p>Extended self</p> <p>Biotechnology, brain science, information technology, and robotics will enable mental and physical adjustments.</p>	<p>Sensory transformation</p> <p>Development of computational devices that can sense, understand, and act upon their environment will coincide with major breakthroughs in understanding of the brain.</p>

Source: Institute for the Future, *Science and Technology Outlook 2005-2055*, 2006

On a molecular level, two major developments lead to new applications for chemical products in this scenario:

- Synthetic biology combines knowledge from biology, chemistry, and engineering in order to design and construct biological functions and systems that are not found in nature. This allows the chemical industry to master the design, selection, and modelling of molecules, creating molecules with specific characteristics on demand.

New technologies also have an impact on how chemical products are made. “Designer molecules” are made to specification in small, container-sized plants. As the minimum scale of efficiency decreases, the industry fragments, changing the dynamics of the current cluster structure.

Industry impact

Global economic growth in the High-Tech World scenario is strong, supported by free trade. Positive economic conditions and global cooperation provide a predictable and stable long-term policy basis for technological innovation and investment. Customers are fast adopters of these new technologies.

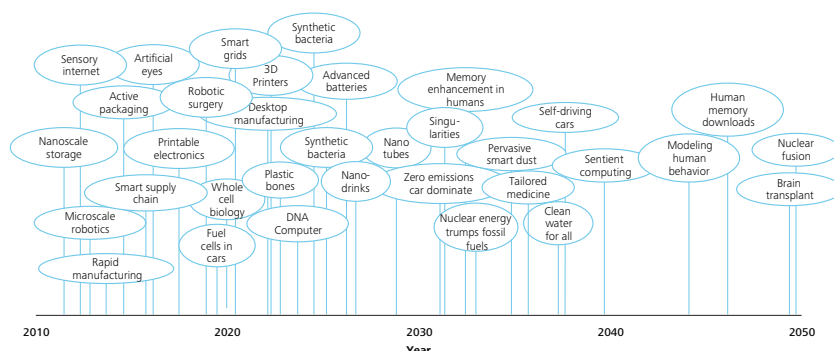
Revenues for the chemical industry increase substantially as innovation produces new applications and displaces traditional materials like wood and metal. In this environment, the chemical industry looks much more like today's IT sector. Like IT, it consists of a small number of very large players — some Western, some Chinese or Indian — that

concentrate on nutrition, health, and personal care, leveraging the Dutch position in agriculture and life sciences.

A High-Tech World could be a positive outcome for the Netherlands because the country currently has:

- A culture of collaboration focused on multidisciplinary problem solving.
- A leading position in research areas such as material sciences, nanotechnology, chemical engineering, and complex systems.
- A strong position in the agro, food (chemistry), health, and logistics industries.

Figure 16: Possible future products



Source: Horizon Scanning Centre, *Technology and Innovation Futures Technology Annex*, 2010; Now and Next, *Trends and Technology Timeline 2010+*, June 2011; Now and Next, *Innovation timeline 1900-2050*, June 2011; Institute for the Future, *A Map for the Programmable World*, 2009.

own large, integrated chemical complexes and have strong distribution networks. As with IT, there are many start-ups and smaller players, each catering to a niche. Some remain independent, while others are bought by larger players as their potential markets expand. Venture capital funding and close relations with universities become more important. The chemical industry captures the added value from new technical developments in the crucial role of integrator, breaking down traditional silos along the value chain.

Nonetheless, it will have to attract more scientists and chemical engineers, stimulate world-class research in selected domains, collaborate with international top scientists, and attract venture capital to the chemical industry.

Multiple Silicon Valley-style clusters exist around the world. Each is different, depending on the composition and skills of the actors within the cluster. The result is further specialization, intense global trade, and broad diversity, even among the industry leaders.

To succeed in this scenario, the Netherlands and the ARRRRA cluster will have to build on pockets of strength in the current cluster and adjacent industries. A logical step is to

A world-class cluster, ready for the future

By combining what is currently known about the chemical industry with the four scenarios, we can see various possible futures for the chemical industry in the Netherlands. This vision contains several core elements that apply to all scenarios, though to differing degrees.

Each scenario requires a different response, but whatever the future brings the following characteristics will make the northwest European chemical industry one of the leading clusters in the world:

- A highly integrated, state-of-the-art network of big and small plants, pipelines, and end users on a northwest European scale.
- The flexibility to use a wide range of feedstock.
- A leading innovation ecosystem.
- A clear regulatory framework.

The ARRRRA cluster will remain a major player in the chemical industry in 2030–2050, delivering high value-added products while minimizing health and environmental impacts. It will be active throughout the entire chemical value chain, from base chemicals to customer-specific solutions. Where possible, it will be connected to end users' sites. Its global market share will be lower than it is today, but this will be offset by substantially larger global end markets and a stronger position in selected market segments. And by becoming more diverse, the northwest European chemical cluster can fully exploit its strengths while simultaneously responding to environmental and technical trends.

In 2030–2050 the chemical industry will be an important employer in the Netherlands with rising added value per employee. In the High-Tech World scenario, employment is higher than today, though skewed more toward smaller companies. In all other scenarios the number of employees is high as well. In the Fragmentation scenario, economic growth is low but competition from overseas is weak. In the Green Transition scenario, the Netherlands is a significant player. And in the Abundant Energy scenario, economic growth is so high that loss of global market share is only moderately relevant.

Large, state-of-the-art cluster

The diversity, scale, and innovative strength of the current northwest European chemical and industrial clusters offer great opportunity for further integration. Improvements to connections between the Rotterdam, Antwerp, and Ruhr areas will create opportunities for highly efficient

production. Enhanced exchange of raw, semi-finished, and residual products and heat through co-siting will drive costs down. Close cooperation between end-market companies, government, and university and research institutes will further stimulate innovation.

By 2030 one large, world-class petrochemical complex will exist in northwest Europe, and integrated, sustainable chemical industries will be based on biomass, bio-fuel, and reused feedstock. Some plants will run purely on bio-based feedstock, and petrochemical plants will mix in bio-based feedstock. The complex will include both traditional production facilities and innovative container-sized facilities. The network will be tightly integrated with leading customers across the value chain, from R&D to production, distribution, and service. The northwest European petrochemical complex will keep modernizing and acquire market share from other petrochemical assets across Europe. World-class maintenance capability will keep the assets in good running condition.

By 2030–2050 the ARRRRA chemical cluster will have used its emphasis on efficiency and sustainability to become the leader in resource efficiency and operational excellence (in particular with respect to safety and quality). Current experience provides the basis for this approach. Standardized life-cycle assessments will be used as the criterion for resource efficiency. Integration, co-siting within the cluster, and the exchange of resource and (excess) energy will improve efficiency throughout northwest Europe. Recycling, reusing, and improving the life-cycle management of chemical products will make the use of chemicals even more efficient. The cluster will also build an effective synergy with the waste from the agro and energy sectors.

By focusing on best-in-class energy and resource efficiency, operational excellence, and use of a broader range of feedstock, the European industrial cluster will have a smaller ecological footprint than any other industry worldwide. Both efficiency and feedstock diversification will make the cluster the undisputed leader in sustainability. Consequently, social acceptance of the industry will ride high: the chemical industry in the Netherlands will be perceived as innovative, clean, and safe. It will supply smart products that minimize health and environmental impacts. The industry will attract talent from both at home and abroad.

A strong, cost-effective cluster is crucial in all scenarios. In the Green Transition, Abundant Energy, and High-Tech World scenarios, the Netherlands competes head on with global players and other clusters. In the Fragmentation scenario, it has to take market share from other European production sites.

Wide range of feedstock

By 2030–2050 the industry will have reduced its dependence on naphtha by increasing its use of secondary (waste) and bio-based feedstock. Naphtha will still be the major feedstock, however, and its use will have grown in absolute terms. The balance between bio-based and traditional feedstock depends on which scenario gets the upper hand. By 2030–2050 the northwest European cluster will have made the changes to its asset base needed to process different sorts of feedstock for both bulk and specialty chemicals. By doing so, the industry will minimize its exposure to the risk of raw material supply while simultaneously becoming more sustainable. With these changes, the industry will also offer a more diverse product output that supports a wide span of end markets, including health, food, and agro.

In combination with the ports of Rotterdam and Antwerp, the northwest European chemical cluster will be Europe's hub not only for oil and gas but also for bio-based feedstock and waste. Energy and feedstock will be imported from all over the world, and the ARRRR is the natural access point. Several conclusions can be drawn:

- With much oil and gas coming from remote locations and from deep water, large flows of crude oil and natural gas will still have to be refined and processed in end markets. All large consumer markets — China, India, the Americas, and Europe — will therefore operate significant base chemical plants in large clusters in 2030–2050.
- The chemical industry will embrace second- and third-generation biomass as feedstock or as semi-finished products well before 2050. Increasing variety in biomass will ensure that its sources are geographically dispersed. By 2050 some countries, like Brazil, will process these flows themselves. Others, such as West African countries and Ukraine, will not have large, sophisticated chemical clusters that can economically process biomass but will also rely on the ARRRR cluster for their European sales. Biomass from these countries will go through simple processing steps at the source and then ship to end markets for further processing.

- With strong positions in oil, gas, and biomass, Rotterdam will also be the leading European hub for waste flows used as feedstock in the chemical and energy industries.

Raw material diversification is particularly relevant in the Green Transition scenario. Even though limited progress in bio-based technologies is assumed in the Fragmentation and High-Tech World scenarios, they nonetheless require feedstock diversification because resources remain scarce in both. Diversification is less important in the Abundant Energy scenario.

Leading innovation ecosystem

Innovation facilitated by the chemical industry is the catalyst for new products, processes, and business models. The Dutch sector has successfully combined its know-how in chemicals, life sciences, synthetic biology, biotechnology, logistics, and information technology. Innovation in the chemical industry is crucial to strengthening Europe's position as a premier exporter of high value-added products that address challenges such as the aging population, resource constraints, and environmental issues.



The chemical cluster in the Netherlands in 2030-2050 will extend to universities, research institutes, venture capitalists, SME chemical companies, and a host of suppliers. Dutch universities will have chosen their battles by 2030-2050, concentrating on being world class at the intersection of agriculture, biology, life sciences, and chemistry. A small number of very strong departments will attract the best students and professors from all over the world. And thanks to its high level of innovation, the chemical industry will attract the interest of domestic and international students alike. Venture capital firms will form specialized units for chemicals, moving their offices away from financial centres to be closer to the cluster. In addition to citizens of the Netherlands, they will recruit highly qualified international specialists for their portfolio companies.

The strength of this innovation ecosystem is a key success factor in all four scenarios. In the Fragmentation scenario it will focus on developing solutions for scarcity-related problems. In Green Transition, breakthroughs in bio- and process technology are needed. In the Abundant Energy scenario, process innovation is essential because the most efficient plants will be the winners. And innovation is, of course, the key theme in the High-Tech World scenario.

A clear regulatory framework

In 2030–2050 a vibrant chemical and manufacturing industry will be supported by a proportionate and effective regulatory framework that stimulates investments and safeguards a level playing field. Regulation and legislation protect the environment and ensure health and safety for employees and the general public without penalizing the industry unnecessarily.

The chemical industry in the Netherlands will be involved early in the regulatory development process. It favors goal-oriented regulation instead of prescriptive requirements to foster innovation. The chemical industry aims for consistent enforcement across the EU, which it considers key for a level playing field.

In order to retain existing players and attract new ones to Europe, a strong investment climate will have been pursued. This climate is influenced by factors such as tax policies, availability of skilled talent, infrastructure, business sites, and market conditions. A favorable fiscal climate, with a speedy decision-making process, will benefit the chemical cluster.

Foreign direct investment and a favorable fiscal climate will attract corporate headquarters to the Netherlands. Additional favorable conditions include simultaneous swift decision-making processes and the ability to issue environmental permits for a number of companies.

The level playing field will be nurtured both for the Netherlands within Europe and for Europe in world markets. To provide access to markets such as China, India, Brazil, Russia, and Southeast Asia, the chemical industry will promote fair reciprocal commitments to the rule-based trading system.

This regulatory framework strengthens the industry in all scenarios. Its impact is lowest in the Fragmentation scenario, which is the least dependent on international trade and innovation.

Contingent strategies

The vision provides a broad basis for strategic choices that will strengthen the Northwest European chemical cluster in all possible futures. Each scenario, however, emphasizes different elements of the vision:

- In the Fragmentation scenario, the northwest European chemical industry needs to put more emphasis on feedstock diversification and resource efficiency.
- In the Green Transition scenario, the industry needs to focus specifically on feedstock diversification and resource efficiency, supported by broad innovation.
- In the Abundant Energy scenario, operational excellence and the innovation ecosystem are the key elements, and feedstock diversification becomes irrelevant.
- In the High-Tech World scenario, great emphasis is placed on developing the leading innovation ecosystem, focusing on selected research fields.

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Appendices

- A. Scenario overview
- B. Interviewees
- C. Strategic radar workshop participants
- D. Round-table participants
- E. Reference material

Scenario overview

	Fragmentation	Green Transition	Abundant Energy	High-Tech World
Description	Fragmentation to ensure self-sufficiency	Bio- and waste-based feedstocks, responding to the need for sustainability	Inexpensive energy, widely available feedstock	Rapid technological developments
Economy	Low growth rates, decoupling Europe from global growth	Low to average growth rates	Above-average growth rates through increased globalized demand due to lower transportation costs	Above-average growth rates coupled with increased globalized demand
GDP growth rate (20 years)	2.5%	3.0%	5.0%	4.5%
Government policies and regulation	Trend toward local production to meet local market needs, prompting strict regulations on supply self-sufficiency	Sustainability-driven compliance based on protectionism	Free trade stimulated by lower transportation costs	Dominance of free trade, negotiated and strict regulations
Energy and commodity prices	High commodity prices due to distorted global markets	High energy costs due to increased compliance costs, high commodity prices due to protectionism	Low energy and feedstock prices as a result of technical breakthroughs	High process efficiency, resulting in soaring energy and commodity prices
Climate and environment	Sustainability on the agenda of relatively wealthy and resource-dependent countries	Market shift toward more awareness of climate and environmental changes, prompted by scientific evidence	Focus on mitigating the effects of toxins, facilitated by decent profits	Concerns about energy consumption, climate change, and pollution, prompted by industrialization and urbanization
Ethics, culture, and (customer) behavior	Strong local focus of social values, enabling acceptance of the chemical industry	Social values that place greater emphasis on environmentally sustainable products	Economic growth that creates demand for sustainable, non-toxic products and production	Fast acceptance of new technologies
Science and technology	Nationally regulated development of technologies related to local needs	Relatively fast innovation and R&D with a strict focus on sustainability	Development of environmentally sustainable products with non-toxic focus	Rapid technological breakthroughs and innovations in a converged, IP-free world
Feedstock mix	90–95% hydrocarbon 5–10% bio-based	80–85% hydrocarbon 15–20% bio-based	95–100% hydrocarbon 0–5% bio-based	85–90% hydrocarbon 10–15% bio-based
Industry structure	Limited number of regional champions with broad product ranges	Multiple global companies with focused portfolios, often from emerging markets	Oligopoly of mega companies with broad product ranges	Diverse mix of focused multinationals and many mid-sized companies

Interviews

Chemical company executives

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Thomas Deman (ExxonMobil)
Henry Egberink (SABIC Europe)
Gerard van Harten (Dow Chemicals)
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Strategic radar workshop

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Paul Oude Lenferink (Tanatex)
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