ENTERPRISE UNDER RESTRAINT

“A transition perspective for Dutch refineries towards 2030”

Pre study MEE
Enterprise under restraint

“A TRANSITION PERSPECTIVE FOR DUTCH REFINERIES TOWARDS 2030”

Pre study MEE

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Preface

The Dutch petroleum refining industry has a special position amongst European refineries because it is predominantly an export industry. Its capacity far exceeds the domestic needs for transport fuel and chemical feedstock. 65% of its production is exported. This unique position has been created thanks to the strategic position of Dutch geographical infrastructure, well-educated personnel and a stable political and economic climate.

The Dutch refining industry is amongst the most energy efficient in the world today. It is also highly integrated with the downstream petrochemicals sector. This provides a competitive advantage compared to stand alone refining or petrochemical manufacturing. The infrastructure and the density of process industries gives The Netherlands an advantage, thus providing a platform for future development.

Energy transition will pose an unprecedented challenge to the sector. The ultimate objective of transition is to reach the phasing out of petroleum products in Europe forty years from now. However, the route to achieve this goal is highly uncertain, both in terms of technology and timing. Looking forward, every credible prediction shows that, while oil as an energy source will decline slowly in the Atlantic basin, fossil fuels will continue to be needed at a constant demand level during the next decades.

It is the ambition of the Dutch refining industry to secure supply of this critical commodity under all scenarios. The Netherlands must maintain its position as the favored and most efficient processing and supply location. The market for oil related products is global. If products cannot be made here, they can and will be made elsewhere. Most likely in less efficient installations. They will have to be imported into Europe and will increase dependence on foreign sources for strategic products. Such a development is undesirable.

The Dutch refining industry seeks to continue the steady
development in efficiency and processing innovation which has led to its present position. It must come out as top performer in the capacity restructuring which is currently ongoing in Europe. Thus the sector will be an enabler of sustainable transition.

In this pre-study the members of the Dutch petroleum industry have investigated the possibilities to achieve these goals. Substantial effort and investment will be needed for the restructuring of installations. More stringent product specifications in the future may conflict with the desire to become more energy efficient. The environmental requirements of a densely populated area may be at odds with the need for the industry to be flexible and to process a variety of crudes. These issues will need to be resolved in an environment lacking the benefit of an expanding market. Uncertainties about the transition pathway and a long term payback are critical hurdles in obtaining capital to make these investments.

The sector believes that being an enabler of sustainable transition is possible but that it should not be taken for granted that it will be able to fulfill this role. The margins in the industry are narrow. Nationalistic tendencies amongst the surrounding European countries may prove to be profound, and present a barrier towards efficient and sustainable restructuring not only in Europe but globally. The sector and governmental authorities must work together to ensure that a fiscal and regulatory environment will exist which allows the Dutch sector to continue to compete with the rest of the world. The platform for such discussion is currently very weak.

It is the industry’s firm belief that in thirty years ‘time the refining and petrochemical manufacturing will look very different from today but also that it will certainly still exist. It is our ambition that it remains healthy, vibrant and profitable in the Netherlands, as the best location for this industry in Europe.

Margeret Hill, VNPI
The Hague, October 2011
Management summary

Preliminary study
This preliminary study for the refinery sector was commissioned by AgentschapNL in the context of the Long-Term Agreement on Energy Efficiency for ETS Enterprises (MEE) and was carried out in collaboration with the Netherlands Petroleum Industry Association (VNPI).

This study explores the potential for improving energy efficiency and reducing the Dutch refinery industry CO₂ emissions and presents a vision of the Dutch refinery industry in 2030.

Developments towards 2030
Many worldwide developments have an impact on the Dutch refinery sector. The challenge up to 2030 and beyond for refineries, being part of the entire chain of energy production, is to secure affordable energy in a sustainable way. Developments like changing demands (including increasing demand for biofuels), changing product specifications, stability of oil supply, new technology developments and the ageing population will require adaption of the refinery industry.

The Dutch refinery industry has to continue improving its competitive advantages in this changing and highly competitive landscape. Permit restrictions and legislation, like ETS III (CO₂¹) and regulation on bunker fuel specifications, trigger innovation as well as high investment, while the market is slightly declining.

In the SWOT presented below, the most important developments influencing the Dutch refinery are summarized.

¹ CO₂ included CO₂ equivalents
**Strengths**
- Good performing refineries (energy-efficiency, Solomon benchmark first quartile), sufficient production scale and flexible
- Well located and many integration advantages in VARA area (Vlissingen-Antwerp-Rotterdam-Amsterdam)
- Qualitative good labour force

**Weaknesses 2011**
- Not as many energy efficiency options in comparison to new built installations in the Middle East and Asia
- Permit restrictions and legislation not taken into account in global business environment
- Product mix (gasoline surplus) and export heavily dependent on demand from Germany and Belgium
- High labour costs
- No sustainable image and closed character of the sector

**Opportunities 2030**
- Continuous investment in energy-efficiency and other process innovations
- New energy saving options like heat exchange with neighbours (co-siting) or carbon reduction options like CCS and CCU
- Options for role in bio based economy (biomass co-processing and biofuels)
- Integration with gas supply chain (LNG)
- More export outside EU
- Improved image through realising sustainability ambitions and communication about achievements
- Adapt to long term developments beyond 2030

**Threats 2030**
- Investment decline due to demand growth outside Europe
- No level playing field increased costs without benefits (e.g. ETS III and compliance with Dutch legislation over and above EU requirements)
- High investments due to bunker fuel desulphurisation and demand for more middle distillates (like diesel, which is driven by tax regime)
- Substitutes like electric or biogas vehicles
- Shortage of well-educated future employees
- Continued negative image

**Future of Dutch refineries depends heavily on permits and legislation**
As refineries act in a global business environment, the competitiveness of refineries might decline sharply due to permit restrictions and legislation. The result will be increasing pressure on margins (which are already low), in the end leading to closures of refineries.

Although many solutions for improving the competitiveness of the Dutch refineries are in line with more sustainability, improving energy-efficiency in particular will lead to a lower cost price and lower carbon emissions (which are discussed in the next chapter); the future of the refinery industry in the Netherlands and Europe depends heavily on regulations and other actions from policy bodies.
Based on the previous insights, 2 scenarios for the Dutch refinery sector can be proposed (see table below). Scenario 1 (*Sustainable Progress*) shows a favourable future for the Dutch refineries in which cooperation between the sector and (local) government can lead to a competitive and energy efficient sector; and scenario 2 (*Regression*) shows how stringent legislation and permit restriction can lead to a decrease of the Dutch refinery sector.

<table>
<thead>
<tr>
<th>Scenario 1 (Sustainable Progress)</th>
<th>Scenario 2 (Regression)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• New cooperation between refinery industry and (local) government, balancing environmental issues and economic aspects (long term holistic Planet and Profit approach)</td>
<td>• Stringent legislation and permit restrictions lead to higher costs (without benefits)</td>
</tr>
<tr>
<td>• Competitive Dutch refinery industry with a level playing field. Legislation and permit restrictions lead to innovations and therefore world class refining technology</td>
<td>• Slowly declining market demand</td>
</tr>
<tr>
<td>• Stable market demand (due to closures of inefficient refineries in EU), and energy efficient production</td>
<td>• Competitiveness of Dutch refinery industry declining</td>
</tr>
<tr>
<td>• Shift to higher volumes of product in upgraded quality segments.</td>
<td>• Leading to lower margins and capacity reduction</td>
</tr>
<tr>
<td>• Leading to economic benefits for the Netherlands and environmental benefits worldwide</td>
<td>• Leading to higher imports of refined products and decrease in (in)direct jobs, added value, knowledge</td>
</tr>
<tr>
<td>• Geographic advantages will allow Netherlands refineries to come out as winners in EU capacity rationalization.</td>
<td>• Investors are unwilling to provide funds for needed technical rejuvenilation</td>
</tr>
<tr>
<td></td>
<td>• Netherlands will bear its share of EU capacity rationalization.</td>
</tr>
<tr>
<td></td>
<td>• Substantial CO₂ emission reduction as a consequence of, relocation to foreign areas.</td>
</tr>
</tbody>
</table>

**Improving energy efficiency and reducing the Dutch refinery industry CO₂ emissions**

The Dutch refinery industry has an impressive track record on energy efficiency (2nd quartile of the KBC energy-efficiency benchmark) and lowering of emission (SO₂: -55%; NOx: -41%; VOC: -53%; fine particles: -86% in the last decade). Still, the
Dutch refineries can improve their energy efficiency and reduce CO$_2$ emissions, although most of the ‘low hanging fruit has already been picked’. In the table below an overview of 6 options for reducing energy and CO$_2$ is presented, as well as the cost effective and technical potential of the 6 options. Also Organizational (O), Market (M) and Technical (T) risks are presented.

<table>
<thead>
<tr>
<th>Theme</th>
<th>Scope</th>
<th>O</th>
<th>M</th>
<th>T</th>
<th>CO$_2$ (kton/year)</th>
<th>CO$_2$ (kton/year)</th>
<th>E(TJ/yr)</th>
<th>E(TJ/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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<td></td>
<td>Cost effective</td>
<td>Technical potential</td>
<td>Cost effective</td>
<td>Technical potential</td>
</tr>
<tr>
<td>1a. energy efficiency</td>
<td>Harbour/plant</td>
<td>M</td>
<td>M</td>
<td>S</td>
<td>822</td>
<td>NYQ</td>
<td>12500</td>
<td>NYQ</td>
</tr>
<tr>
<td>1b. Novel technology</td>
<td>Plant</td>
<td>M</td>
<td>M</td>
<td>L</td>
<td>0</td>
<td>133</td>
<td>0</td>
<td>2400</td>
</tr>
<tr>
<td>2. Regional efficiency</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>a. cogeneration</td>
<td>Plant</td>
<td>M</td>
<td>L</td>
<td>S</td>
<td>33-38</td>
<td>78-411</td>
<td>600-1600</td>
<td>1400-7400</td>
</tr>
<tr>
<td>b. Heat transport</td>
<td>Regional</td>
<td>L</td>
<td>L</td>
<td>S</td>
<td>100</td>
<td>900</td>
<td>2000</td>
<td>23000</td>
</tr>
<tr>
<td>3. CCS and CCU</td>
<td>Regional</td>
<td>XL</td>
<td>XL</td>
<td>M</td>
<td>350</td>
<td>NYQ</td>
<td>6200</td>
<td>NYQ</td>
</tr>
<tr>
<td>4. Renewable energy</td>
<td>Plant</td>
<td>M</td>
<td>L</td>
<td>S</td>
<td>55</td>
<td>97</td>
<td>1000</td>
<td>1750</td>
</tr>
<tr>
<td>5. Bio-based feedstock</td>
<td>Plant</td>
<td>M</td>
<td>M</td>
<td>L</td>
<td>120</td>
<td>170</td>
<td>2600</td>
<td>4300</td>
</tr>
<tr>
<td>6. Plant to wheel</td>
<td></td>
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<tr>
<td>a. Distribution</td>
<td>Chain</td>
<td>S</td>
<td>L</td>
<td>M</td>
<td>43</td>
<td>70</td>
<td>782</td>
<td>1264</td>
</tr>
<tr>
<td>b. End-user</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>b.1. Energy efficient fuels</td>
<td>Chain</td>
<td>S</td>
<td>M</td>
<td>M</td>
<td>834</td>
<td></td>
<td>15000</td>
<td></td>
</tr>
<tr>
<td>b.2. Biofuels</td>
<td>Chain</td>
<td>S</td>
<td>M</td>
<td>M</td>
<td>834-1388</td>
<td></td>
<td>15000-2500</td>
<td></td>
</tr>
<tr>
<td>b.3. Mix diesels/gasoline</td>
<td>Chain</td>
<td>M</td>
<td>L</td>
<td>L</td>
<td>NYQ</td>
<td>NYQ</td>
<td></td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
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<td></td>
<td></td>
<td><strong>26700</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Calculated by 1TJ = 0,05555 kton CO$_2$  
NYQ = not yet quantified  
italic is calculated. Abbreviations see page 76
In this pre-study a total volume of cost effective energy saving potential equivalent to 27PJ per annum was identified. This amounts to approximately 18% of the energy consumption of the sector.

The VNPI is of the opinion that the follow-up of these technical projects is at the discretion of the individual refiners. In the contact of the convenant MEE, the refineries will periodically prepare Energy Efficiency Plans. This will be the forum in which it is possible to discuss individual choices and opportunities per company.

In addition there is the need for a discussion with government about the strategic role that refineries will have to play in the Netherlands in the process of energy transition in the long term. This entails a discussion about the conditions that need to be fulfilled in order for the optimum climate for the scenario: Sustainable progress to materialize. It will be about the dilemma of an industry, which is on the one hand urged to disappear in the long term, but on the other hand is equally urged to make large scale investments in process improvements, product refocus, emission abatement and energy reduction on the short and medium term.

The responsibility for ensuring security of supply during the transition period and the ambition of the Netherlands to maintain its economic position calls for a far broader forum than the predominantly technical setting of the Convenant MEE. The members of the VNPI intend to attempt to define these criteria and seek a vital dialogue.
1. Introduction

1.1 PRE STUDY MEE
This preliminary study for the refinery sector was commissioned by AgentschapNL in the context of the Long-Term Agreement on Energy Efficiency for ETS Enterprises (MEE) and was carried out in collaboration with the Netherlands Petroleum Industry Association (VNPI).

This study explores the potential for improving energy efficiency and reducing the Dutch refinery industry CO₂ emissions. All five Dutch refineries fall under MEE, which includes the obligation to strive for best performance as concerns energy efficiency improvement, encompassing options of energy efficiency in cooperation with others in the chain. This study presents a vision of the Dutch refinery industry in 2030 within the global context, and proposes solutions that will make the sector more sustainable. A so-called roadmap, a strategic plan detailing the specific measures to achieve up to 50% energy-efficiency improvement by 2030, can be used as the study follow up.

1.2 PRE STUDY PROCESS
The creation of the pre study consists of three parts: a document analysis; 6 interviews with members of the VNPI; and a session with representatives of the refinery sector and other relevant parties (see Annex 3 for participants and documents used).
This process resulted in the concept version of the pre study. Said version was discussed with the VNPI CO₂ and Energy Efficiency task group and the improved version was validated by the refinery committee, thereby assuring the commitment of the entire sector.

1.3 IMPORTANCE OF DUTCH REFINERY INDUSTRY
The Dutch refinery industry is part of a global market. The entire chain includes both the exploration, production and transport of crude oil (upstream) and the refining, distribution and marketing of petroleum products (downstream). VNPI members are only active in the downstream segment. In view of the scope of the MEE Covenant, this study has been confined to the downstream segment.

With a total capacity of 5 refineries producing 1.2 Mbb/d, the Dutch refinery industry has a 1.4% share of the world-wide capacity and has the 5th largest installed capacity in Europe, where a total of 15.5 Mbb/d is produced by 104 refineries[1].

The Dutch refinery industry makes a significant economic contribution. First, the Dutch refineries are important because of their added value (contribution to the GDP). The annual added value of the Dutch industry varies between € 1 - 4 billion, which is 2%-5% of the total added value of the Dutch industry (see Figure 1). The added value is derived from total sales of € 25-30 billion[2].
FIGURE 1  *Added Value of Dutch refinery industry in comparison to rest of industry*

Source: CBS, Berenschot analysis
The refinery industry is also important to the Dutch balance of trade. As opposed to all other major EU countries, which produce primarily for the home market, the Dutch refinery industry is focused principally on exports. Most of the produced products (63%) are exported directly, chiefly to Germany and Belgium via the RAP and RRP pipelines. Another 12% is exported by the chemical industry (see Figure 2). With the Rotterdam harbour, where 4 of the 5 refineries are located, the Dutch refinery industry is an important hub for Northwest Europe. Although exports have an important economic effect, the export dependency also makes the Dutch refinery industry more “footloose” and open to cost competitiveness from imports outside the EU.
FIGURE 2 Material flows for domestic use and exports

Source: Roland Berger, 2008
The Dutch refinery industry is also an important provider of direct and indirect jobs. The number of direct jobs is over 4,000. But indirect jobs like services (maintenance and facility service) and additional suppliers (engineering and materials, port, labs, logistics) that are directly dependent on the refinery industry presumably number between 32,000-36,000 jobs[3].

Furthermore, the interconnection with the chemical industry increases the competitiveness of both sectors.

Without the refinery sector, the Dutch economy would not only lose its direct and indirect economic advantages, but would also be more dependent on other countries to fulfil the demand of the Dutch and other customers for the refined products it is now supplying. As a consequence, more energy and CO₂ might be produced, since many refineries in the rest of the world are not as energy-efficient as the Dutch refineries. In addition, the refinery industry plays an important role in the overall production chain of many industries. It is a vital part of the knowledge intensive industry, the basis of the Dutch knowledge economy.

1.4 STRUCTURE OF THIS REPORT
The next chapter (Chapter 2) describes the projection for the Dutch refinery industry towards 2030. Chapter 3 concerns the options for energy and emission reduction. Possible subsequent steps are discussed in Chapter 4.
2. Projection for Dutch refinery industry towards 2030

Many worldwide developments have an impact on the Dutch refinery sector. The challenge up to 2030 and beyond for refineries, being part of the entire chain of energy production, is to secure affordable energy in a sustainable way. Developments like changing demands, changing product specifications, stability of oil supply, new technology developments and the ageing population will require adaption of the refinery industry. Sustainability developments such as ETS III (CO₂), regulation on bunker fuel specifications, growth of biofuels and demand for sustainable products intensify this demand even further. These developments are described in this chapter.

2.1 DEMAND DEVELOPMENT TO 2030

Refineries process crude oil into different kinds of products. Most products are used for transportation (63.6% in EU), but chemical products (14.7% in EU) and heating and power products (21.7% in EU) are also produced (see Annex I, Figure 1 for further information).

The anticipated demand for refined products in Europe is expected to gradually decrease on the run up to 2030 (see Figure 3), although there is a differentiation between the various refined products. The reason for this trend is the increasing energy efficiency of vehicles and vessels in the EU, stabilisation of population growth and an ageing population.
FIGURE 3  EU refined product demand

Source: Europia, 2010, Historical data: IEA and Local Sources, Forecast: PFC Energy
This development could lead to (increasing) overcapacity and low(er) margins, and margins for refineries are already relatively low (see Annex I, Figures 8-10 for more information), which could actually lead to closing refineries in the EU. A few refineries have already been (temporarily) shut down recently and several European refineries are on sale due to decreasing margins (see Annex I, Figures 8, 9 and 12). How the Dutch refineries will be influenced by this trend depends on their competitiveness in comparison to the other European refineries (see Section 2.4).

Looking at last year’s utilisation, the impact of the financial and economic crisis is apparent, as it led to utilisation rates of the EU based refineries of 79% in 2009 and 76% in 2010, in comparison to 85% in 2008[4]. Another downside is that lower utilisation usually leads to less energy efficient, and therefore, more expensive production runs.

### 2.1.1 Changing demand in refinery products

When looking at changes in demand for different refinery products in more depth, the demand for the so called middle distillates, such as jet fuel, kerosene and gasoil (including diesels and marine gasoil), is expected to grow for a few more years in contrast to the overall demand. The relative share of jet fuels and kerosene increased between 1990 and 2008 from 5.5% to 9.4%. Gasoil (including diesel but excluding heating oil) increased from 17.7% to 31% in the same period[5]. Nevertheless, the demand will most probably peak in the period 2015-2020 and decline after 2020 to 2030, similarly to the total EU market[6] (see also Annex I, Figure 2). Gasoline demand in the EU is widely expected to fall further from now on (by 20.7% according to PRIMES scenario).

One evident important trend is the shift that has been made from gasoline to gasoil/diesel (see Figure 4). The diesel/gasoline ratio was above 2.10 in 2010 and is expected to grow even more (though probably not as much as in the last ten years). Currently the increased demand for diesel is stimulated by tax incentives for diesels. The expected growth might therefore decrease if the tax stimulus is no longer provided. Since (hybrid) gasoline engines are expected to become more energy efficient in comparison to diesel engines, tax incentives for diesel could decrease in future.
FIGURE 4  Evolution of product demand in the EU

The impact of the changing demand on the Dutch refineries is that more investments in e.g. hydrocrackers and hydrogen plants are needed in order to adjust to the market demand and to produce a relatively larger quantity of diesel and other middle distillates. The gasoline surplus is now primarily exported to the US (see also Section 2.1.3), but more competition is expected in this market due to capacity expansion in Asia, the Middle East and the US itself.

2.1.2 Worldwide energy demand

In contrast to the European market for refined products, the worldwide demand for primary energy, including oil and refined products, is expected to grow (see Annex 1, Figure 5).

Figure 5 shows that as the primary market for refinery products is transportation, growth is being driven by growing demand from the Asia Pacific region and not from Europe (as was stated above) or North America.
FIGURE 5  Transportation demand by region (and sort)

millions of oil-equivalent barrels per day

North America

Europe

Asia Pacific

Light duty vehicle demand will decline by about 20 percent in North America and one-third in Europe.

In Asia Pacific, transportation demand will nearly double from 2005 to 2030.

Source: ExxonMobil, 2010
For the Dutch refineries, being global players, this implies that most investments will be made in the Asia Pacific region where the demand is increasing. Investments needed for Dutch refineries to produce more middle distillates and to adapt to legislation on desulphurisation and carbon emissions (ETS) (see Section 2.4) might therefore be jeopardised.

The basic ingredient for refineries, oil, is one of the most important sources of primary energy. In order to produce all needed energy, all energy sources including oil (products) are expected to continue to grow until 2030 and beyond. However, when considering the sources of the total primary energy, the share of oil will be relatively lower, as can be seen in Figure 6.
**FIGURE 6** Shares of world primary energy and contributions to growth

* includes biofuels

**Source:** BP, 2011
Oil, coal and gas are expected to continue to comprise the largest shares of the total world primary energy till 2030 (70-80%). The largest growth in shares of world primary energy in the period 2010-2030 is expected to be for gas, coal and renewables (including biofuels). The growth in coal is a result of increased consumption in Non-OECD countries (especially China), whereas growth in gas use is also expected in OECD countries. Gas is used chiefly for electricity production and heating, but gas-to-liquid as a transportation fuel is also expected to grow.

A big challenge for the coming decennia is to produce enough energy for the growing demand in an affordable way. All sources of energy are expected to grow until 2030 in order to fulfil the ever growing energy demand. This is a big challenge because most new fossil sources are ‘difficult’ due to their locations (deep water sources) and the crude quality that needs more processing steps (tar sands). The alternatives, such as renewable sources, are by and large more expensive than fossil sources. Therefore, innovation in all sources, both fossil and others, is needed.

2.1.3 EU and Netherlands imports and exports of refined products

The two most important refinery products in the EU in terms of import/export volume are gasoline and gasoil/diesel (include heating oil). Gasoil/diesel is the main product being imported into the EU, chiefly from Russia, though also from North America, and gasoline is the main product being exported, chiefly to North America and Africa (see Figure 7). Recently, demand from the US declined, leading to more exports of gasoline, with lower margins, to Africa. The EU is also very import-dependent on jet fuel and kerosene, primarily from Middle Eastern countries[7].
FIGURE 7  Trade flows of two most imported/exported refinery products

Gasoline/gasoil trade flows to/from Europe 2009
net flows in million tonnes

Source: Europia, 2010
Increasing competition is expected. New refineries (incorporating the latest energy-efficiency insights) are being installed in the Middle East and in Asia (China and India). Russia is now starting to deliver gasoline and diesel to EU specifications: they are installing hydro treating, hydrocrackers and alkylation units, and are buying EU based refinery capacities. However, for the most part the refined products from Russia are not produced as energy efficiently as those from Europe.

In order to contain or reduce these trade deficits, the EU refining industry would have to invest significantly in additional refinery conversion capacity to produce more middle distillates, and it would have to reduce gasoline-focused refinery capacity[8], unless diesel demand were to decrease due to fewer tax incentives.

2.2 MACRO DEVELOPMENTS
Changes in demand are not the only factors that will have an impact on the Dutch refinery sector. Other macro developments will require adaptation from the sector, as will be described in this section.

2.2.1 Demographic and economic development
Figure 8 shows the expected development of the worldwide population, use of primary energy and the GDP. All three parameters will grow, especially in Non-OECD countries. Both the use of primary energy and GDP are expected to grow more than 100% in Non-OECD countries.
FIGURE 8 Population, primary energy and GDP development in OECD and Non-OECD countries

Source: BP, 2011
Note that GDP growth in OECD countries will expand much faster than primary energy use. The explanation for the difference with Non-OECD countries is that most of the GDP growth in OECD countries will come primarily from services, which are not energy intensive. Also increased energy efficiency will be achieved (for all countries) in industry, power sector, transport sector and residential energy use.

These macro developments underpin the trend described above: that almost all of the growth in (oil) demand will come from Non-OECD countries, chiefly from Asia.

2.2.2 Stability of oil supply
Oil (crudes) are the main input for the refineries, and therefore a stable supply of oil is crucial for refineries. Europe produces only a small part of the total supply of liquids (primarily oil) from North Sea wells. Supply, and especially growth in supply, will be dominated by OPEC countries until 2030 and will culminate in over 45% of worldwide oil production. Other major oil suppliers are Russia and North America (as shown in Figure 9).
FIGURE 9 Liquids (primarily oil) supply by region and type

LIQUIDS SUPPLY BY REGION

LIQUIDS SUPPLY BY TYPE

Source: BP, 2011
Europe is heavily dependent on import of (crude) oil to fulfil its energy demands (this is also applicable to gas). The Netherlands is also heavily dependent on import of crude oil. More than 98% of the oil used in the Netherlands is imported (chiefly from Russia, Norway, the UK, Saudi Arabia, Iran, Nigeria, Kuwait and Iraq), of which between 40-45% is directly exported (see Figure 10).
FIGURE 10 Oil imports (98% of total oil used) in the Netherlands and their purpose

Source: CBS, Berenschot analysis
As long as there is demand for refined products in Europe and the Netherlands, a stable supply of oil is crucial.

2.2.3 **Technology development and substitutes**

Many governments are intensively stimulating development of renewable energy sources. The reasons for this stimulation often concern sustainability issues such as climate change. But renewable energy is also being stimulated so the country will be less import dependent on oil (and gas).

The two most important developments for the future of refineries are the electrification of transport vehicles (starting with hybrid and electric cars) and the use of biofuels.

Electrification of transport vehicles can be seen as a substitute for refineries, because most electricity will not be generated from oil (products). Although making predictions about breakthroughs for electric and hydrogen vehicles is difficult, it is expected that in 2030 electric and hydrogen vehicles will only be interesting in niche markets due to high costs (e.g. for new grids) and the limited range and battery capacity of electric cars. The energy density of oil is higher than the electrical energy (Wh/kg and Wh/L see TNO figure below). This implies that unless battery capacity increases enormously and battery cost decreases, electric cars will still be expensive and inefficient. The investments in new electrical grids could also be a barrier. Hybrid cars are competitive and sales therefore are expected to increase till 2030.

Biofuel refineries can be seen as substitutes for Dutch (oil based) refineries, as many biofuel refineries are built in proximity to biomass sources, most of which are located outside the EU. The total demand for transport biofuels in Europe is
expected to grow from 30 to 45 Mt/a till 2030 from a 2010 level of approximately 15 Mt/a (see Figure 10). Biofuels are expected to still be a small percentage (5% - 7.5%) of the total product demand for transport purposes of 600 Mt/a (excluding refinery fuel and loss). However, as biofuels are currently being stimulated by taxation or legislation, the expected increase is dependent on stability of regulators. Biofuels will chiefly be imported from Brazil and America, the dominant producers of biofuels, and will be mixed with EU refined products (see Annex 1).
FIGURE 11 Scenarios of total EU27 transport biofuels demand Mt/a

Source, CONCAWE, 2010
There are many sustainability issues that need to be resolved in the current production of biofuels, as will be further elaborated upon in Chapter 3. Development of 2nd and 3rd generation biofuels, e.g. production by algae, is a more sustainable option, but still requires further research. Adding biomass as feedstock in addition to crude oil (co-processing) might be a future possibility, but requires further research, as will be discussed in Chapter 3.

In contrast to electrification of vehicles and biofuels, renewable energy sources such as wind, solar, biomass (and nuclear) only (directly) substitute for oil that is used for heating and power. As most oil in Europe is used for transport fuels and chemical products, only 21.7% of the oil used for generation of heating and power can be replaced (directly) by (new) renewable energy sources. Although the development of renewable energy sources is being stimulated, it is not expected to be a dominant source of energy, as stated in the previous section. Normally new energy technologies require thirty years of double digit (26% p/a) growth to become 1-2% of the energy system[9]. Figure 12 shows the expected technology deployment of energy sources.
**FIGURE 12 Energy-Technology Deployment**

*Historic data: Energy Balances of OECD Countries (IEA, 2009), Energy Balances of Non-OECD Countries (IEA, 2009); Projections: Shell International*

**Source:** Shell, 2011
Of course, in the time frame 2011-2030 unexpected breakthroughs, e.g. in the field of energy storage or atomic fusion, could reshape the world in ways no one has predicted.

### 2.2.4 Ageing population

In OECD countries, as well as in Asian countries such as China and Japan, larger percentages of the population will be above retirement age. In the Netherlands it is expected that in the period 2011-2015 the number of people above retirement age (65) will increase by half a million and will grow further by another 1.5 million in the period 2016 to 2040[10]. The potential labour force (all persons between the ages of 20 and 65) is now 10.8 million, but will decrease by 0.8 million by 2040 unless the retirement age is raised. Currently, the number of people older than 65 is 26% of the potential labour force, but will increase up to 49% by 2040. As a consequence, pension and health expenses will grow, but the largest impact on the refinery industry might be not having enough well-educated employees available. The need for well-educated technical personal on all levels, especially operator-level is therefore a top priority.

### 2.3 SUSTAINABILITY DEVELOPMENTS

The most important sustainability developments, as well as their influence on the Dutch refinery industry, are described in this section.

#### 2.3.1 Greenhouse gasses and CO₂

The greenhouse gas (GHG) that is primarily emitted by the refinery industry is CO₂ (almost 100%)[11]. GHG emissions are held responsible for global warming and climate change. Although still under discussion, a well-known limit for the amount of CO₂ that is acceptable is 450 ppm of greenhouse gases, which would cause a maximum rise of temperature of 2°C. Some experts even advocate 350 ppm, a level below the current figure[12]. The broad consensus for the need to stay below the level of 450 ppm implies that global emissions need to fall by at least half by 2050, since increased worldwide energy use (especially in Non-OECD countries as indicated in Section 2.1) will lead to higher CO₂ emissions.

The total CO₂ emissions of the refinery industry in Europe are circa 140 Mton CO₂. The Dutch refinery industry emitted 10.8 Mton CO₂ in 2009, which is 6.2% of the total CO₂
emitted in the Netherlands (see Figure 13). Note that the ‘percentage of the total’ line shows a downward trend, meaning that the amount of CO₂ emitted by the refinery industry is decreasing in comparison to the rest of CO₂ emitters.
**FIGURE 13** CO$_2$ emissions of refinery industry in comparison to rest of total CO$_2$ emissions in the Netherlands

Source: CBS, Environmental accounts (IPCC-regulations), Berenschot analysis
2.3.2 EU decarbonisation ambition

The European Union has an enormous ambition as far as reducing GHG emissions[13] is concerned. GHG emissions should be reduced by 80-95% by 2050 compared to the 1990 level (see Figure 14).
FIGURE 14 *EU GHG emissions towards an 80% domestic reduction (100% = 1990)*

Source: European Commissions, 2010
In order to achieve this ambition, all industry sectors, including the EU and Dutch refinery sector, must make an enormous effort to reduce CO₂ emissions.

Although the ambition of the EU is commendable, if other countries outside the EU do not take similar actions, the impact on a worldwide scale will be limited. The EU, with little more than 10% of global emissions, will not be able to tackle climate change on its own[14], especially when the enormous (growth in) CO₂ emissions in other regions becomes reality as expected (see Annex 1, Figure 13).

Note that 8-10% of the total GHG emissions in the value chain of refined products is emitted by refineries. The highest percentage of GHG emissions is emitted during the combustion of fuel use in vehicles (the tank to wheel phase), which pertains to the transport sector (see Figure 15).
FIGURE 15  GHG emissions of the total chain

Crude oil production 1-4%  Refining 8-10%  Distribution 1%  Combustion of unit of energy 85%

→ Covered by ETS in Europe → Well to tank 15% (production) → Well to wheel 85% (consumption)

Source: Europia, 2010
2.3.3 EU decarbonisation ambition for transport sector

In order to achieve the ambition of 80-85% reduction of GHG emissions, the ambition for the transport sector is a 95% reduction of said emissions. This ambition has been investigated and labelled very challenging[15]. The analyses included technical developments such as hybrid, plug-in hybrid, electric and fuel cell cars, energy efficiency of vehicles, biofuels (36% GHG transport reduction on 1990 levels). In addition, non-technical options, including improved spatial planning, speed enforcement, lower motorway speeds and more fuel efficient driving were included. Economic instruments such as taxation, regulation and subsidy of innovation were also studied. The conclusion was that the ambitious target could be reached if all options were implemented (see Figure 16) and many technical and economic issues were resolved (the scenarios are further explained in Annex I, Figure 14).
FIGURE 16 Potential reduction in transport GHG emissions

Source: European Commission, 2010
If the decarbonisation of the transport sector is achieved, the demand for gasoline will probably decrease faster than predicted by the demand scenarios in Section 2.1.

2.3.4 Cost effectiveness of CO$_2$ reduction
The cost effectiveness of decarbonisation of the transport sector varies for the different solutions (see Figure 17).
FIGURE 17 Cost effectiveness of CO₂ reduction options

Source: Europia, 2010, IEA
End-use efficiency (in light and heavy duty vehicles, ships and aviation) is the most cost effective way to reduce CO₂ emissions; it might even be profitable. Then, renewable, nuclear and gas usage for generating power (electricity) are the next best options for reducing CO₂ emissions. These options fall outside the purview of the refinery industry; nevertheless, cooperation in this field is possible, especially for the upstream and downstream integrated companies. The second generation of biofuels and industry fuel switching and CCS have direct influence on the refineries, but are only attainable at high costs.

An analysis by ExxonMobil (see Figure 18) shows that gas, wind and nuclear power generation are cost-effective options in the US when the CO₂ price is under $ 50.00 per tonne avoided. For transportation, only conventional vehicle fuel economy improvements provide cost-effective options in that range.
**FIGURE 18** CO₂ emissions by sector and cost-effectiveness of CO₂ avoidance in the US

**CO₂ EMISSIONS BY SECTOR**

- **Residential/commercial**
- **Industrial**
- **Power generation**
- **Transportation**

Emissions in the power generation sector will rise by about **35 percent** from 2005 to 2030.

**U.S. COST OF CO₂ AVOIDANCE vs. NEW COAL**

- **Biofuels, plug-in hybrids, electric vehicles**
- **Full hybrids**
- **Conventional vehicle fuel economy improvements**
- **Solar, CCS**
- **Gas, wind, nuclear**

Gas, nuclear and wind are cost-effective options for reducing CO₂ emissions, at less than **$50 per ton avoided**.

*Source: ExxonMobil, 2010*
The conclusion is that in relevant sectors such as transport and power generation many technical options for CO\textsubscript{2} reduction are available, but not many at a cost-effective level. Pricing of CO\textsubscript{2} like Europe is doing in ETS is an option for stimulating these kinds of options.

### 2.3.5 ETS III

The Dutch refineries are covered by ETS, the EU-wide cap on emissions legislation which targets reducing GHG.

Phase III of the EU ETS builds upon the previous two phases and has been significantly revised in order to achieve two-thirds of the EU’s unilateral 20% emissions reduction target by 2020 compared to 1990 levels (21% reduction by 2020 compared to the 2005 verified emissions baseline). This means that by 2020, 500 MtCO\textsubscript{2} will be saved per year. The intended effect of ETS III is an increased focus on (technological solutions for) reducing CO\textsubscript{2} emissions.

ETS III implications for the refinery industry are:

- Free allocation of carbon credits up to the average of the 10% of the best performing refineries in the EU, based on a benchmark (CONCAWE). The benchmark does integrate complexity, therefore some chain effects are integrated but others are not (e.g. premium fuels) and do not count as CO\textsubscript{2} reduction.

- Possible rising energy costs due to pricing of CO\textsubscript{2}, for which a lower percentage of free allocation of carbon credits will be available. This also concerns the energy production of refineries.

### 2.3.6 Issues concerning ETS III

Although Dutch refineries have a very good position as far as energy efficiency is concerned (see next section), resulting in a good performance on CO\textsubscript{2} emissions and competitive advantages in comparison with the majority of other European refineries, for most refineries these new rules lead to extra costs. Presumably, not all CO\textsubscript{2} can be reduced by profitable energy efficiency projects, because most refineries are already
highly energy efficient and improvements become more costly (no more low hanging fruit). The extra costs might lead to diminishing the already low margins and/or be partially included in the consumer prices (which would lead to an increased economic burden for households). It is anticipated that benchmarked against the top 10% of best performing refineries, there will be a shortfall of carbon credits for (on average) 15% of the Dutch refineries. At a rate of € 20/tonne CO₂, this means an additional cost burden of € 32 million per year.

Moreover, the possibility of carbon leakage is present as the refining industry is a world market. Due to increased cost for CO₂ credits, the EU domestic refineries lose competitiveness and as a consequence, relocation of production outside the EU could occur, where the same amount (or possibly more) CO₂ would be emitted. This is likely if the (marginal) extra costs of the ETS III per bbl are higher than the transport costs per bbl. Although the free allocation of carbon credits is a highly suitable answer to carbon leakage, the partial extra costs could still lead to carbon leakage. As a consequence, more refined products will be imported from outside Europe.

Although ETS III is almost finalised, three aspects might improve (the next ETS) system. First, an alternative for a CO₂ ceiling is a CO₂ tax for the total chain. This system might be simpler (and therefore less of an administrative burden for companies) and more transparent than a cap and trade system. Second, the money earned by governments from the ETS could be used directly for innovation in CO₂ reduction options (this is also true for a CO₂ tax). Third, to prevent carbon leakage, a worldwide CO₂ pricing system would be the best alternative. Another alternative, taxation of CO₂ of imported refined products is not seen as favourable, because it could be seen as a trade barrier.

2.3.7 Issues concerning CO₂ emissions
In addition to the issues concerning the ETS III, there are two specific issues for refineries in regards to CO₂ emissions: the diesel/gasoline ratio and the desulphurisation of bunker fuels.
Production of the right amount of diesels/gasoline to fulfil EU demand means further investments in hydrocrackers to produce middle distillates. These extra refinery steps require energy and as a consequence more CO₂ is emitted. Thus, in order to produce more diesel to improve the imbalance of import/exports, more CO₂ will be emitted by refineries in Europe².

In addition, legislation (IMO) for the international shipping community will entail further desulphurisation of vessel fuels (bunker fuels). This means more investment in desulphurisation units that also use energy and therefore emit more CO₂, as desulphurisation units of gasoline and diesels (which are already at a very low level) demonstrate.

This could lead to an increase of GHG emissions by the EU refineries up to a total of more than 200 Mton CO₂, due to the abovementioned issues and potential new specifications (see Figure 19).

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² Note that CO₂ emissions of diesel in the total chain (well-to-wheel) used to be lower than gasoline (see annex 1, figure 14). Due to more energy efficient gasoline vehicles, the differences in WTW CO₂ emissions per km of gasoline and diesel are currently not very large.
The more stringent the fuel specifications are, the more energy is needed and hence CO₂ emissions increase. Additional demand for diesel increases CO₂ emissions, in addition potential new specifications and marine fuels specification change to distillates could increase CO₂ in refineries.

Source: Europa, 2010
For the Dutch refineries, scenarios developed by ECN show the same developments in the run up to 2020; an increase in CO₂ emissions due to more heavy crude oils (that need more or more energy intensive steps to refine), higher quality standards (e.g. desulphurisation) and change in demand (diesel).
Energy use of Dutch refinery industry (left) and corresponding CO₂ emissions (right). Scenario RR2010-0 shows a projection of energy use and CO₂ emissions without further policies, scenario 2010-V shows projection with established policies, whereas 2010-VV is a projection of intended policies (ECN, 2010).
2.3.8 Desulphurisation
As already indicated in the previous section, the new EU regulation on bunker fuel specifications demands a lower content of sulphur. Worldwide the 4.5% sulphur content will decrease to 3.5% in 2012 and to 0.50% in 2020. In the Baltic and North Sea area, it will drop to 0.10% by 2015.

The extra investment costs to switch to IMO bunkers is expected to be 8-9 G$ (see Figure 21), which is lower than anticipated using other scenarios. This is due to the higher production of Hydrocracker bottoms used as a low sulphur blend component for LS bunker fuel, thereby reducing the need for investment in residue desulphurisation units.

**FIGURE 21 All expected process unit investments in European refinery industry**

<table>
<thead>
<tr>
<th></th>
<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMO case</td>
<td>$27</td>
<td>$34</td>
</tr>
<tr>
<td>Core-case</td>
<td>$35</td>
<td>$34</td>
</tr>
</tbody>
</table>

*Source: CONCAWE, 2010*

The European Commission expects investments required to upgrade European refining capacities in the period 2005-2030 will be between € 17.8 and € 29.3 billion, of which between € 3.3 and € 11.7 billion will be used for marine sulphur fuel specification changes[16]. As the market predictions show, investments could prove hard to earn back.
2.4 COMPETIVENESS OF DUTCH REFINERY INDUSTRY

As the previous section shows, changes in demand, product specifications and environmental requirements demand enormous adaptations from the refinery sector. In this changing environment it is crucial that Dutch refineries be competitive and be able to adapt to the changes.

The Dutch refineries are very competitive:

- Dutch refineries are efficient: Solomon benchmark indicates that the average of the Dutch based refineries is in the 1st quartile, benchmarked on: energy consumption, reliability, cost-effectiveness, economic performance. To stay ahead of the peloton, the refineries must make continuous improvements.

- Dutch refineries are energy efficient: Dutch refineries are in the 2nd quartile of the KBC energy-efficiency benchmark, see Figure 22. Energy costs comprise approximately 60% of the production costs (see Annex 1). However, energy efficiency is highly dependent on the utilisation rate, and is thus influenced by the market developments in the EU.
FIGURE 22 Energy benchmark of Dutch refineries

Average European Refinery BT ≈ 180%
Dutch refineries Average BT ≈ 168%

Source: VNPI, KBC, 2008³

³ 100% means BT (best technology) for all energy-efficiency technologies (2008).
Dutch refineries are flexible: most refineries have a complex configuration to process several feedstocks in changeable amounts. Most of the refineries have an adequate scale of economy as well.

Dutch refineries are well located: 4 refineries in ports of Rotterdam (deep water access), with pipelines to Germany and Belgium and (water) transport routes to Germany, Belgium and Switzerland.

Dutch refineries have many integration advantages: integration with the chemical industry in Rotterdam (pipelines for intermediates); co-siting and exchange opportunities with other industrial plants in Rotterdam; availability of relatively cheap hydrogen gas; and pipelines from the harbour for feedstock.

The Dutch labour force is well educated and motivated, and it has a progress-oriented culture, which lends itself to developing a capability to use new technologies.

However, the Dutch refinery industry also has some competitive disadvantages:

Process installations of Dutch refineries have been upgraded and rejuvenated many times over the course of their economic lifespans. The basic layout and infrastructure, however, was designed 20-40 years ago, creating limitations and disadvantages in comparison with brand new installations in source countries (outside the EU). Dutch refineries are competitive because of large investments since 1980, which were triggered in part by legislation. However, due to expected changes in demand (decline in Europe, growth in other parts of the world), the investments necessary to improve the refineries will be harder to attract from the corporate decision makers.

The situation regarding operational (environmental) permits is considered difficult for all Dutch refineries. The ambition of Dutch authorities is, in the run up to 2020, to implement the strictest level of requirements possible under EU legislation (e.g. for NOx and SOx), or to even go beyond that level. This is justified by the environmental
quality requirements of the local geographical situation. A combination of a densely populated area with a concentration of heavy industry next to natural reserve areas. Nevertheless, it could jeopardise the competitiveness of the Dutch refinery industry as big investments are needed in order to meet compliance regulations.

Due to the competitiveness of the Dutch refineries in comparison to EU refineries, it is expected that even when demand in Europe is decreasing, all 5 refineries would be able to continue operating up to and beyond 2030.

2.4.1 Image of the sector and environmental performance

Although Dutch refineries have improved their environmental performance over the last decade in order to be acceptable to regulators and to the public at large, the sector has a poor image when it comes to sustainability. Most of the products produced by the refinery industry, especially transport fuels, are not seen as sustainable, due the emissions of CO$_2$ and the fact that they are fossil resources.

The image of the sector is also a heritage of the past: most improvements in environmental performance are not noticed by the public at large. Notwithstanding the fact that 85% of the CO$_2$ emissions of petroleum products is generated during their end-use, there is a great deal of focus in the public debate on the environmental impact of refining and on crude oil production. The following aspects play a role in this.

The Dutch refineries are on an ongoing quest to deliver an environmental performance which is acceptable to regulators and the public at large. Performance has continuously improved over the last decade: SO$_2$: -55%; NO$_x$: -41%; VOC: -53%; fine particles: -86% due to various investments in abatement equipment and process improvement (see figure 23). Emission requirements in the Netherlands are among the most stringent in Europe. Under public pressure, the push to improve even further is expected to continue.
FIGURE 23  Emissions Dutch Refinery Industry

Source: CBS, Berenschot analysis
A second aspect is the environmental impact during the production of crude oil. This is outside the sphere of influence of VNPI, but nevertheless has an impact on the public perception of the industry. Crudes from different regions have different environmental footprints. Flaring of associated gas during crude production is often referred to as an unsustainable practice in this respect. VNPI members have encouraged crude producers to reduce this and have been successful over the last years⁴.

There are sources that advocate for the sector to improve its image by taking extra steps to make improvements on sustainability issues, from energy efficiency and CO₂ reduction to being responsible to people and the planet throughout the total chain from, well to wheel. In the next chapter these improvement options are described in more detail. The VNPI already publishes aggregated information on the environmental performance of its members⁵. More transparent communication concerning the improvements on sustainability issues (e.g. energy efficiency and emissions reduction) could boost the image of the sector even further.

2.4.2 Level playing field requisite
An important prerequisite for the competitiveness of Dutch refineries is a worldwide level playing field. Fair and competitive legislation is needed to achieve a level playing field on the EU level and in the Netherlands. Indicators of level playing field are environmental costs (SOₓ, NOₓ, CO₂), labour costs, harbour costs, electricity costs, density of legislation and taxation.

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⁴ In 2005, natural gas flaring accounted for 15% of the total demand for the energy industry sector, and is expected to be reduced by nearly 85% to less than 3% of demand in this category. Of course, reduction of flaring is not only good for the image of the sector, but can also lead to cost savings (source: ExxonMobil, 2010).

⁵ The VNPI already publishes the aggregated environmental performance parameters of its members. This flow of information is restricted to a certain extent by rules of equal trade and competition. It publishes the origin of crudes imported via the Rotterdam harbour. It is the common position of the sector as well as the EU and Dutch authorities that a system of crude certification would lead to redirection of trade flows and loss of sustainability.
(un)Level playing fields means:

- Competition from non-ETS countries (Middle East, Asia, which are allowed to operate under less stringent environmental conditions) is exacerbated.

- EU-ETS creates extra costs for Dutch refineries. Notwithstanding the free allocation of emission allowances, Dutch refineries will have to buy 32 million euro/year worth of emission allowances from 2013 on.

- EU refineries will have to meet more stringent emission requirements under the new Industrial Emissions Directive and the revised Refinery BREF. This will be implemented in the Netherlands with additional requirements in order to meet local expectations.

- The principal indicator should be the additional marginal manufacturing cost for a tonne of product due to EU-ETS plus additional local requirements.
## 2.5 SWOT AND SCENARIOS

### 2.5.1 SWOT

The previous sections on demand, macro and sustainability developments and the competiveness of the Dutch are summarised in the SWOT (below).

<table>
<thead>
<tr>
<th>Strengths 2011</th>
<th>Weaknesses 2011</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good performing refineries (energy-efficiency, Solomon benchmark first quartile), sufficient production scale and flexible</td>
<td>Not as many energy efficiency options in comparison to new built installations in the Middle East and Asia</td>
</tr>
<tr>
<td>Well located and many integration advantages in VARA area (Vlissingen-Antwerp-Rotterdam – Amsterdam)</td>
<td>Permit restrictions and legislation not taken into account in global business environment</td>
</tr>
<tr>
<td>Qualitative good labour force</td>
<td>Product mix (gasoline surplus) and export heavily dependent on demand from Germany and Belgium</td>
</tr>
<tr>
<td>High labour costs</td>
<td>No sustainable image and closed character of the sector</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Opportunities 2030</th>
<th>Threats 2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous investment in energy-efficiency and other process innovations</td>
<td>Investment decline due to demand growth outside Europe</td>
</tr>
<tr>
<td>New energy saving options like heat exchange with neighbours (co-siting) or carbon reduction options like CCS and CCU</td>
<td>No level playing field increased costs without benefits (e.g. ETS III and compliance with Dutch legislation over and above EU requirements)</td>
</tr>
<tr>
<td>Options for role in bio based economy (biomass co-processing and biofuels)</td>
<td>High investments due to bunker fuel desulphurisation and demand for more middle distillates (like diesel, which is driven by tax regime)</td>
</tr>
<tr>
<td>Integration with gas supply chain (LNG)</td>
<td>Substitutes like electric or biogas vehicles</td>
</tr>
<tr>
<td>More export outside EU</td>
<td>Shortage of well-educated future employees</td>
</tr>
<tr>
<td>Improved image through realising sustainability ambitions and communication about achievements</td>
<td>Continued negative image</td>
</tr>
<tr>
<td>Adapt to long term developments beyond 2030</td>
<td></td>
</tr>
</tbody>
</table>


The main conclusion from the SWOT is that the Dutch refinery industry has to continue improving its competitive advantages in a changing and highly competitive landscape. Permit restrictions and legislation, like ETS III and desulphurisation trigger innovation as well as high investment, while the market is slightly declining. As refineries act in a global business environment, the competitiveness of refineries might decline sharply due to permit restrictions and legislation. The result will be increasing pressure on margins (which are already low), in the end leading to closures of refineries.

Although many solutions for improving the competitiveness of the Dutch refineries are in line with more sustainability, improving energy-efficiency in particular will lead to a lower cost price and lower carbon emissions (which are discussed in the next chapter); the future of the refinery industry in the Netherlands and Europe depends heavily on regulations and other actions from policy bodies.
2.5.2 Scenarios
Based on the previous insights, 2 scenarios for the Dutch refinery sector can be proposed (see table below).

<table>
<thead>
<tr>
<th>Scenario 1 (Sustainable Progress)</th>
<th>Scenario 2 (Regression)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• New cooperation between refinery industry and (local) government, balancing environmental issues and economic aspects (long term holistic Planet and Profit approach)</td>
<td>• Stringent legislation and permit restrictions lead to higher costs (without benefits)</td>
</tr>
<tr>
<td>• Competitive Dutch refinery industry with a level playing field. Legislation and permit restrictions leads to innovations and therefore world class refining technology</td>
<td>• Slowly declining market demand</td>
</tr>
<tr>
<td>• Stable market demand and even possible higher volumes (due to closures of inefficient refineries in EU), and energy efficient production</td>
<td>• Competitiveness of Dutch refinery industry declining</td>
</tr>
<tr>
<td>• Shift to higher volumes of product in upgraded quality segments</td>
<td>• Leading to lower margins and capacity reduction</td>
</tr>
<tr>
<td>• Leading to economic benefits for the Netherlands and environmental benefits worldwide</td>
<td>• Leading to higher imports of refined products and decrease in (in)direct jobs, added value, knowledge</td>
</tr>
<tr>
<td>• Geographic advantages will allow Netherlands refineries to come out as winners in EU capacity rationalization</td>
<td>• Investors are unwilling to provide funds for needed technical rejuvenilisation</td>
</tr>
<tr>
<td></td>
<td>• Netherlands will bear its share of EU capacity rationalization</td>
</tr>
<tr>
<td></td>
<td>• Substantial CO₂ emission reduction as a consequence of, relocation to foreign areas</td>
</tr>
</tbody>
</table>
Scenario 1 leads to a stable, healthy volume development for the Dutch refinery industry, whereas scenario 2 leads to a decline in volume (as illustrated in the figure below).

The desirable scenario from the viewpoint of the Dutch refinery sector is (anticipated) scenario 1. Good understanding and cooperation between the industry and (local) governments are thus of crucial importance.
3. Dutch refinery chain and options for emission reduction

In the previous chapter the conclusion is that the Dutch refinery needs good cooperation between the industry and (local) governments, but also needs to invest and innovate in energy efficiency and CO₂ reduction projects in order to stay competitive. 6 options to reduce carbon emissions are described in this chapter. It begins with the energy usage of the Dutch refinery chain.

3.1 ENERGY USAGE

The Dutch refinery industry processes 2,500 PJ, of which 150 PJ is used for the refinery process itself and 2,300 PJ is turned into products (see Figure 24).
FIGURE 24 Energy usage of Dutch refinery industry and options for emission reductions

Source: CE Delft, 2010, Berenschot
All 6 options for emissions reduction are shown in Figure 24 and will be described in the following sections.

### 3.2 Introduction to Emission Reduction Options

The energy savings potential has been primarily culled from the reports as provided by the VNPI CO₂ & EE Working group, in particular reports of studies by CE Delft and KBC. A number of other sources can be found in the list of references. The sources are referred to where applicable, especially for data retrieved from the latter.

#### 3.2.1 Savings potential

For some options discussed in this chapter, there are two figures for the savings potential of the specific option. One figure, the technical savings potential, represents the potential that can theoretically be achieved by that specific option or technology. That is, when economic considerations are not a factor and the actual implementation is not hindered by a limit on cost expenditure. In most cases, however, investment decisions regarding energy saving projects are made in the context of economic limitations. Projects need to start paying for themselves within a certain time span. Therefore, the second figure, the cost effective savings potential, indicates the potential that can be achieved through projects that have a simple payback time of 5 years or less. Unless indicated otherwise, options that are provided with one figure are indicated in cost effective savings potential.

#### 3.2.2 Risk, rewards and resources

In order to weigh and compare the options for emissions reduction in this report, a “risk, rewards, resources” methodology is applied. Each option is scored for the perceived risks involved in the execution or implementation of such a project, what the rewards could be from implementation thereof and how many resources each requires for implementation (see table below for definitions).
<table>
<thead>
<tr>
<th>RRR definition</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rewards</strong></td>
<td></td>
</tr>
<tr>
<td>$\text{CO}_2$ (Mton)</td>
<td>Avoided $\text{CO}_2$ emissions</td>
</tr>
<tr>
<td>Energy (TJ)</td>
<td>Energy savings potential in TJ (either technical or cost effective); or Avoided energy usage of non-renewable origin in TJ</td>
</tr>
<tr>
<td>Operating income (€ mln)</td>
<td>Operating income = Revenue – Operating expenses</td>
</tr>
<tr>
<td><strong>Risks</strong></td>
<td><strong>Small (S)</strong></td>
</tr>
<tr>
<td>Organisational</td>
<td>Simple project</td>
</tr>
<tr>
<td></td>
<td>No partners involved</td>
</tr>
<tr>
<td></td>
<td>No issues concerning permits and legislation</td>
</tr>
<tr>
<td>Market</td>
<td>Stable market perspective and good customer acceptance</td>
</tr>
<tr>
<td></td>
<td>Good fit with strategy</td>
</tr>
<tr>
<td></td>
<td>Competition low</td>
</tr>
<tr>
<td></td>
<td>Timing good</td>
</tr>
<tr>
<td>Technology</td>
<td>Frequently used technology</td>
</tr>
</tbody>
</table>
**RRR definition**

<table>
<thead>
<tr>
<th>Resource</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment (€ mln)</td>
<td>Investments (out of pocket) in project before market introduction/implementation; or Investments (out of pocket) and hours (hourly rate) in project before market introduction/implementation</td>
</tr>
<tr>
<td>Investment (hours)</td>
<td>Investments (hours) in project before market introduction/implementation</td>
</tr>
</tbody>
</table>

Profitability (expressed as pay back time or internal rate of return) can be seen as the quotient of Rewards/ Resources. As such it is not encompassed as an element in the risk assessment methodology. Options are labelled as technical potential and cost-effective potential.
3.3 THEME 1: ENERGY EFFICIENCY

3.3.1 What is it?
In this theme options are considered that either directly improve the energy efficiency of the refining process through investments on-site or improve the energy efficiency of transport and transfer systems directly linked to the refinery.

Harbour to gate
Energy consumption in this segment is relatively small, especially when compared to refinery consumption (approximately 1.8%). CE Delft mentions a number of options for reducing energy consumption in the transport and transfer of crude to the refinery and the storage and transfer of products from the refinery:
- Insulating storage tanks;
- Efficiency improvement of hot water and steam systems;
- Usage of excess heat;
- Improvement of wastewater treatment efficiency;
- Reduction of lighting;
- Installing LED lighting;
- Energy efficient pumps.

The savings potential has therefore received lower priority and has not been taken into account in this theme 1.

Refinery on-site

Cost effective potential: 12,500 TJ/year
Technical potential: not specified. During the period 2008-2011 several studies were commissioned to shed light on the opportunities for energy saving in the Dutch refineries. The approach of these studies was different

KBC (May, 2008) identified options for enhanced energy efficiency based on a benchmarking methodology. These existed in the areas of furnace efficiency, heat integration, cogeneration of heat and power (CHP) and general energy housekeeping. There was no discrimination between savings at site or savings with third parties in the region. A total cost effective potential of 19.5 PJ/year was identified.

Davidse (July, 2010) took a technology based approach and focused on CHP implementation. This study is dealt with under theme 2 in paragraph 3.4.1. It created however overlap with the study by KBC.
ECN (December, 2010) published a literature assessment under the title: “Refineries towards 2030”. This report took a broader approach and included novel technologies. It also provided a view on the potential for existing technologies. The disadvantage was that reference to the physical situation at Dutch refineries was not taken into account, and again overlap was created with KBC and Davidse.

PDC (September, 2011) was commissioned to re-assess the studies of KBC, Davidse and ECN in order to specifically address the issue of double counting, to eliminate options that have already been implemented and to take into account the effect of incompatibility with measures that already have been taken.

As a result of their scrutiny the potential for cost effective energy efficiency improvement as mentioned in KBC was reassessed at 12.5 PJ/year.

Looking at possible technologies that were not included in KBC and Davidse, PDC considers the following novel technologies potentially viable in Dutch refineries: preflash columns/drums; dividing wall column, heat integrated distillation column; hydrogen recovery via membrane technology. In addition PDC looked at a number of technologies that will not lead to additional energy efficiency but may lead to other (environmental) benefits. They conclude that the overall technical potential of a number of these novel technologies is interesting but from the current perspective difficult to quantify. They do not expect a cost effective potential for any of these novel technologies under the current circumstances prevailing at Dutch refineries.

Cost effective potential: 0 TJ/year
Technical potential: > 2400 TJ/year
3.3.2 What are the known options?

<table>
<thead>
<tr>
<th>Options</th>
<th>Scope</th>
<th>Risks</th>
<th>Rewards</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harbour to gate</td>
<td>Harbour / storage</td>
<td>Limited technical risks</td>
<td>Small direct energy savings</td>
<td>Technology investments in plants</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low organisational risks</td>
<td>Small Indirect CO₂ reduction</td>
<td></td>
</tr>
<tr>
<td>Refinery on-site</td>
<td>Plant</td>
<td>Limited to high technical risks</td>
<td>Direct energy savings</td>
<td>Technology investments in plants</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Low organisational risks</td>
<td>Indirect CO₂ reduction</td>
<td></td>
</tr>
</tbody>
</table>

3.3.3 Risk reduction

As described above, a number of risks come with projects pertaining to energy efficiency. In the following, we list the strategies that have been identified by the VNPI members to cope with or mitigate these risks:

- Technical risks:
  - A refinery can focus on the implementation of proven technologies and measures first, such as the improvement of insulation and steam traps;
  - Perform a study on the refinery specific options for energy efficiency;

- Market:
  - Investigate co-siting options in light of short term policies;
  - Level playing field.

- Organisational:
  - Define priorities regarding projects with local authorities (on a long term scope) and realise arrangements on improving permit trajectories;
  - Projects should not only be ranked on simple payback time, but also in light of market, supply and legislation developments;
  - Ensure correct CO₂ allocations for energy efficiency projects;
- Improve communication on sector performance and company specific plans for energy efficiency to the general public;
- Provide more information on effects of increased desulphurisation legislation on energy efficiency to policy makers.

3.4 THEME 2: REGIONAL ENERGY EFFICIENCY

3.4.1 What is it?
This theme deals with options that might not directly improve the energy efficiency of a refinery site, but do so when taking the (direct) surroundings of the site into consideration.

Coupling of excess heat to regional demand (e.g. housing or industry) through a piping network

Cost effective potential: 2,000 TJ / year
Technical potential: 23,000 TJ / year

Just as excess heat can be coupled to heat demand of a refinery on-site, demand for heat can also be found in its surroundings. Residential districts, for example, require energy for heating in winter. Delivering excess heat from the refinery to homes and offices decreases the amount of energy needed for the heating installations of these buildings. The same applies for industrial areas where many production processes require energy for heating. Excess heat can be transported from the refinery to a place of demand through transport pipes carrying steam or water. This option is limited by the temperature, the amount of energy required and the distance to be bridged.

In some cases the transportation of heat can be coupled to the transportation of carbon dioxide, since this gas can function as a carrier of heat through transport pipes. For further information on the transport of carbon dioxide, see section 4.3.

With the implementation of ETS III in 2013, the exchange of heat provides emission rights. The realisation of a project for delivering heat to local residences, for example, would be awarded with 62.3 tonne CO₂ credits per Terajoule of
exchanged energy. In the event of the heat being transported to another installation under the ETS scheme, the emission rights would be awarded to the consumer of the heat, not the producer. The allocation of emission rights to such projects is rather limited [“Emissiehandel in Europa”, AgentschapNL, March 2010].

**Cogeneration of heat and electricity.**

Cost effective potential: 600 – 1,600 TJ / year
Technical potential: 1400 - 7,400 TJ / year

Cogeneration refers to the generation of both heat and electricity at one installation. Traditional installations for the creation of heat (process heat or steam) burn (fossil) fuels and transfer the heat of this process through a heat exchanger to a transport medium (mostly water or steam). In an installation for cogeneration, some of the energy from the fuel is used to generate electricity. This electricity can either be used on-site or delivered to the electricity grid. It’s the efficiency by which these systems generate both heat and electricity that leads to a reduction of fuel consumption for the generation of electricity in the Netherlands.

Cogeneration is a common technology in Dutch refineries and present at most sites. However, most installations produce steam and electricity. Recent developments in cogeneration technology have resulted in process integrated systems in which both process heat and steam are generated in addition to electricity. According to Davidse such systems offer great potential for Dutch refineries.

It should be noted that the demand for steam in the refinery process and the possibility of replacing steam furnaces are the limiting factors for the viable implementation of additional cogeneration capacity. However, if excess heat can be transported to a third party, the potential for cogeneration increases considerably. [Davidse, July 2010]
3.4.2 What has already been done?

Both cogeneration and the transportation of heat are proven technologies.

Cogeneration

“The currently installed base of installations for cogeneration at Dutch refineries amounts to an output of 255 MWe and 16000 TJ heat per year. (Davidse, July 2010)

In the report the following types of CHP options are discussed.

- Conventional CHP, where electricity and steam are generated in a stand-alone unit, without integration with refinery processing. These options have also been identified by KBC.

- Process integrated CHP whereby process streams are being heated up or evaporated in the heat recovery unit after the gas turbine. This technology is generally recognized in the refining industry as an effective measure to achieve substantial energy efficiency improvement.

- Furnace CHP, or “Repowering CHP”, whereby the exhaust gas from a gas turbine is used as combustion air in refinery furnaces. This is difficult to implement because substantial revamping of existing equipment is required.

PDC states in their assessment that Process CHP and Repowering CHP may (partly) be considered as examples of technology implementation that were not included in the KBC report. They confirm KBC’s assessment of a technical potential of 4500 TJ/year for these two sub-segments. However there are various hurdles for realization. Technical adaptations required on existing equipment, when changes are not implemented together with debottlenecking or capacity extensions, will entail excessive costs. Furthermore the fact that process integrated CHP will create additional steam generation capacity for which there will be no direct outlet in the refinery. Nevertheless it is anticipated by PDC that new process integrated CHP projects will be implemented in Dutch refineries before 2030 in combination with debottlenecking- and replacement projects.
Davidse concludes that the Dutch investment climate hampers cogeneration in the Netherlands. The economic risks involved are considered too high for a proper business case. Other European countries, such as Belgium, UK and Germany successfully apply incentive measures to reduce these economic risks, which results in a relatively high cogeneration install base. [Davidse, July 2010]

**Heat exchange**

Projects involving the transportation of heat have not been realised at Dutch refineries to date. An amount of heat is co-transported with the carbon dioxide (see further project WarmCO₂) in only a few cases in which carbon dioxide gas is transported to agricultural firms. Although the transportation of heat is a proven technology and has been successfully implemented in several industrial areas and residential districts throughout the Netherlands, the relatively high costs involved in investing in the decoupling of heat and the infrastructure for transportation appear to hamper the application of this option at Dutch refineries. Also, the specific situation for refineries makes commitments concerning security of supply (as often demanded by the consumer of heat) very hard to impossible without the investment in a full-scale back-up system. Both Shell and BP have investigated the business case regarding this option extensively, but have so far not been able to come up with a positive one.
### 3.4.3 What are the known options?

See also Annex 2

<table>
<thead>
<tr>
<th>Options</th>
<th>Scope</th>
<th>Risks</th>
<th>Rewards</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cogeneration ‘stand-alone’</td>
<td>Plant</td>
<td>Limited technical risks</td>
<td>Indirect energy savings</td>
<td>Shared Technology investments and business agreements</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Economic viability highly dependent on energy and CO₂ prices</td>
<td>Indirect CO₂ reduction</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(both cogeneration options 600 to 1,600 TJ / year cost effective)</td>
<td></td>
</tr>
<tr>
<td>Cogeneration process</td>
<td>Plant</td>
<td>Limited technical risks</td>
<td>Indirect energy saving</td>
<td>50 to 100 million euro (per installation)</td>
</tr>
<tr>
<td>integration</td>
<td></td>
<td>Economic viability highly dependent on energy and CO₂ prices</td>
<td>Indirect CO₂ reduction</td>
<td>Shared Technology investments and business agreements</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(both cogeneration options 600 to 1,600 TJ / year cost effective)</td>
<td></td>
</tr>
<tr>
<td>Heat transport</td>
<td>Regional</td>
<td>Limited technical risks</td>
<td>Direct energy savings</td>
<td>10 – 60 euro per tonne CO₂</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cooperation required</td>
<td>Indirect CO₂ reduction</td>
<td>Shared Technology investments, infra and business /public agreements</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2,000 – 23,000 TJ / year</td>
<td></td>
</tr>
</tbody>
</table>

### 3.4.4 Risk reduction

In the following, we list the strategies that have been identified by the VNPI members to cope with or mitigate the identified risks:

- Technical risks:
  - Improve the dissemination of both proven technology and innovations regarding regional energy efficiency
through cooperative projects and mobilisation of specialists to the sector.

- **Market risks:**
  - Several feasibility studies have been performed with a number of stakeholders and process/business conditions. Each of these studies was aborted due to a lack of business incentive and weak organisation of the stakeholders. The sector is prepared to re-enter these discussions as soon as it becomes clear that these pre-requisites have changed.
  - Close long term contracts and Service Level Agreements (SLAs);
  - Ensure a level playing field.

- **Organisational risks:**
  - Ask local authorities for co-creation or co-makership in managing multi-actor projects;
  - Implement project by project, do not implement multiple projects at once, and start off with the ones with the fewest anticipated risks;
  - Invest in the required infrastructure.

### 3.5 THEME 3: CCS AND CCU

#### 2.5.1 What is it?

This theme refers to both “Carbon, Capture and Storage” (CCS) and “Carbon, Capture and Usage” (CCU) technologies. Instead of emitting carbon dioxide into the air (for example) through a chimney, it is possible to extract the carbon dioxide from the effluent. In theory such technology can greatly reduce the emission of carbon dioxide from large fixed installations.

In refining, the capturing of carbon dioxide is considered to be most viable at the H\textsubscript{2} production process, since this process produces a relatively pure flow of carbon dioxide gas. Other sources of large amounts of carbon dioxide at the refinery are combustion processes (such as the furnaces). These flows, however, contain such small levels of carbon dioxide (or such high levels of components that need to be removed from the flow) that capturing the carbon dioxide is not considered viable.

Cost effective potential: 350 kton CO\textsubscript{2} / year (eq 6200 TJ/year, CE Delft)

Technical potential: not specified
After capturing (and cleaning) the carbon dioxide gas, two options are available: one is to utilise the gas for activities that require carbon dioxide (CCU); the other is to store it in a location in such a way that prevents emission to the environment (CCS).

3.5.2 What has already been done?
Although the Dutch government (like the EU commission) is in favour of CCS as a means of reducing CO₂ emissions, the unfavourable public opinion has so far hampered implementation of this technology. The first CCS projects that were planned to store carbon dioxide in empty natural gas fields underneath Dutch soil encountered so much resistance from the public that the Dutch government decided to not proceed with these projects and instead to start planning new projects in empty gas fields in the North Sea. Gaz de France has been injecting carbon dioxide in a field in the Dutch North Sea for over 5 years. [Source: http://www.rijksoverheid.nl/onderwerpen/co2-opslag/documenten-en-publicaties/kamerstukken/2011/02/14/ccs-projecten-in-nederland.html]

Three CCU projects have already been realised in the Netherlands. In all cases the carbon dioxide is used as a fertiliser for the growth of plants in greenhouses. The heat of the gas is also used for temperature control of the greenhouses. E.On captures carbon dioxide after combustion at the electricity plant “RoCa-III” and transports the gas to a number of agricultural firms in the “B-Driehoek” region. In the Terneuzen area, WarmCO₂ transports carbon dioxide from a local Yara plant to agricultural firms in the area. [Ministry of Housing, Spatial Planning and the Environment, March 2010]

Also, since 2005 the Dutch organisation OCAP has been operating a network for the transport of carbon dioxide gas in the Rotterdam region. The transported carbon dioxide is captured at Shell’s H₂ plant and transported through a pipeline to the greenhouses of agricultural firms in the region (see figure 25). Although this project is still running, from 2008 on under revised ETS regulations, the carbon dioxide can no longer be accounted for to the benefit of the refinery. [Shell]
OCAP continues to expand the transport network to reach new firms to which to deliver the carbon dioxide and to increase the capacity by connecting new sources of carbon dioxide. OCAP is also looking for new sources of carbon dioxide for delivery. Recently, the new Abengoa bio-ethanol plant has been connected to the network and expansion to two H₂ plants under construction by Air Products and Air Liquide is being investigated. [CE Delft, Nov 2010]
### 3.5.3 What are the known options?

<table>
<thead>
<tr>
<th>Options</th>
<th>Scope</th>
<th>Risks</th>
<th>Rewards</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCS - Storage in an empty natural gas field</td>
<td>Regional</td>
<td>Public opinion&lt;br&gt;Only point sources&lt;br&gt;Price of CO₂</td>
<td>No energy efficiency&lt;br&gt;Direct CO₂ reduction</td>
<td>Shared Technology investments,&lt;br&gt;Infra and business /public agreements</td>
</tr>
<tr>
<td>CCU – Usage in greenhouse or industry</td>
<td>Regional</td>
<td>An increase in co-generation at greenhouses reduces demand for CO₂&lt;br&gt;Public opinion&lt;br&gt;Only point sources&lt;br&gt;Competitive sources of CO₂&lt;br&gt;Price of CO₂</td>
<td>No energy efficiency&lt;br&gt;Direct CO₂ reduction&lt;br&gt;Not yet quantified</td>
<td>Shared Technology investments,&lt;br&gt;Infra and business /public agreements</td>
</tr>
<tr>
<td>CCU - Enhanced oil recovery</td>
<td>Regional</td>
<td>Public opinion&lt;br&gt;Only point sources&lt;br&gt;Competitive sources of CO₂&lt;br&gt;Price of CO₂</td>
<td>No energy efficiency&lt;br&gt;Direct CO₂ reduction&lt;br&gt;Not yet quantified</td>
<td>Shared Technology investments,&lt;br&gt;Infra and business /public agreements</td>
</tr>
</tbody>
</table>
3.5.4 Risk reduction

In the following, we list the strategies that have been identified by the VNPI members to cope with or mitigate the identified risks:

- **Technical risks:**
  - Combined R&D efforts to develop better CO₂ capture technology and materials that require a minimum amount of energy and provide research grants where needed;
  - CATO II.

- **Market risks:**
  - Perform a (market) study on the usage of CO₂;
  - Ensure that projects will be rewarded right in the ETS;
  - Focus on off-shore CCS.

- **Organisational risks:**
  - Ensure an appropriate legal framework;
  - Set up a well-aligned cooperation between industry and the government for a programme and set up public-private partnerships (PPPs) for the execution of projects;
  - Involve the general public and stakeholders to steer public opinion in favour of CCS and CCU.
3.6 THEME 4: RENEWABLE ENERGY

3.6.1 What is it?
Replace the energy from fossil sources with energy from renewable sources, such as wind, sun or biomass.

Available options are:
- Wind turbines on refinery or storage sites [CE Delft];
- Photovoltaic solar panels (PV) on petrol stations, refinery or storage sites [CE Delft];
- Biomass or biogas for transport vehicles (oil tankers, etc.), or (co)firing of refinery furnaces [interviews];
- Heat pump with heat storage for low temperature heat generation [CE Delft];
- Buying of renewable electricity or gas as replacement for current consumption.

Cost effective potential: 1PJ / year,
Technical potential 1.75 PJ/year (CE Delft)

3.6.2 What has already been done?
Sources of renewable energy have so far found limited application for covering the energy usage of Dutch refineries or sections of the petroleum chain.

Examples of what has been done so far:
- Wind turbines at the BP Refinery Rotterdam site (9 turbines, 22.5 MW);
- Solar installations, both photovoltaic and thermal, on a number of Dutch petrol stations.

FIGURE 26 Solar energy on the roof of a petrol station
### 3.6.3 What are the known options?

See also Annex 2

<table>
<thead>
<tr>
<th>Options</th>
<th>Scope</th>
<th>Risks</th>
<th>Rewards</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wind turbine</strong></td>
<td>Plant / chain</td>
<td>Local permits&lt;br&gt;Limited land availability&lt;br&gt;Safety&lt;br&gt;Price of electricity&lt;br&gt;Volatile government stimulation</td>
<td>Avoided use of fossil energy&lt;br&gt;Direct CO₂ reduction</td>
<td>Technology investments in plant or wind farms&lt;br&gt;Business agreements energy companies&lt;br&gt;Permits&lt;br&gt;Exploitation subsidies</td>
</tr>
<tr>
<td><strong>Solar pv</strong></td>
<td>Plant / chain</td>
<td>Limited land availability&lt;br&gt;Safety&lt;br&gt;Price of electricity&lt;br&gt;Volatile government stimulation</td>
<td>Avoided use of fossil energy&lt;br&gt;Direct CO₂ reduction</td>
<td>Technology investments in plant or solar farms&lt;br&gt;Business agreements energy companies&lt;br&gt;Permits&lt;br&gt;Exploitation subsidies</td>
</tr>
<tr>
<td><strong>Heat pump with heat storage</strong></td>
<td>Plant / chain</td>
<td>Only low temperature heat</td>
<td>Avoided use of fossil energy&lt;br&gt;Direct CO₂ reduction</td>
<td>Technology investments in plant&lt;br&gt;Permits&lt;br&gt;Exploitation subsidies</td>
</tr>
<tr>
<td><strong>Biofuel (co)fired furnaces</strong></td>
<td>Plant</td>
<td>Permits&lt;br&gt;Price of biofuel</td>
<td>Avoided use of fossil energy&lt;br&gt;Direct CO₂ reduction</td>
<td>Technology investments in plant&lt;br&gt;Permits&lt;br&gt;Exploitation subsidies</td>
</tr>
<tr>
<td><strong>Buy certificates of origin</strong></td>
<td>Plant / chain</td>
<td>Limited&lt;br&gt;Public opinion – “greenwashing”</td>
<td>Avoided use of fossil energy&lt;br&gt;Direct CO₂ reduction</td>
<td>Business agreements energy companies</td>
</tr>
</tbody>
</table>
3.6.4 Risk reduction

In the following, we list the strategies that have been identified by the VNPI members to cope with or mitigate the identified risks:

- Technical risks:
  - Cooperate to transfer technology and knowledge regarding proven technologies.

- Market risks:
  - Ensure a level playing field for renewable alternatives;
  - Cooperate with NGOs and authorities to assure the long term acceptability of the used sources of biomass.

- Organisational risks:
  - Sector wide cooperation (buying power);
  - Ensure that CO2 rewards are accounted for.

3.7 THEME 5: BIO-BASED FEEDSTOCK

3.7.1 What is it?

Replace mineral feedstock in part with bio-based feedstock

In Dutch refineries all feedstock (e.g. the crude oil) is currently of mineral origin. Part of the mineral feedstock could be replaced by an oil or liquid of biological origin (e.g. biomass).

Options:

- Feedstock of vegetable oil from soybean or linseed oil (up to 10%) into diesel hydrotreater for production of hydrogenated vegetable oil (HVO);
- Two step hydrodeoxygenation of pyrolysis oil from biomass into conventional refinery products.
- These products will be supplied to the refineries

Cost effective potential 2,600 TJ/year
Maximum Technical potential 4,300 TJ/year, (CE Delft)
### 3.7.2 What are the known options?

See also Annex 2

<table>
<thead>
<tr>
<th>Options</th>
<th>Scope</th>
<th>Risks</th>
<th>Rewards</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>HVO production</strong></td>
<td>Plant / chain</td>
<td>Unproven technologies&lt;br&gt;Increased operating risks&lt;br&gt;High H2 demand&lt;br&gt;Requires additional transport and storage facilities&lt;br&gt;Pricing/availability of biomass&lt;br&gt;Legislation / permits</td>
<td>Current RED regulations limit accountable rewards&lt;br&gt;Avoided use of fossil feedstock&lt;br&gt;Indirect CO₂ reduction</td>
<td>Technology investments plant, logistics and business /public agreements</td>
</tr>
<tr>
<td><strong>Feed-in of pyrolysis oil</strong></td>
<td>Plant / chain</td>
<td>Unproven technologies&lt;br&gt;Requires additional transport and storage facilities&lt;br&gt;Increased operating risks&lt;br&gt;Pricing/availability of biomass&lt;br&gt;Legislation / permits</td>
<td>Avoided use of fossil feedstock&lt;br&gt;Indirect CO₂ reduction</td>
<td>Technology investments, logistics and business /public agreements</td>
</tr>
<tr>
<td><strong>Feed-in of algae biomass</strong></td>
<td>Plant / chain</td>
<td>Unproven technologies&lt;br&gt;Requires additional transport and storage facilities&lt;br&gt;Increased operating risks&lt;br&gt;Pricing/availability of biomass&lt;br&gt;Legislation / permits</td>
<td>Avoided use of fossil feedstock&lt;br&gt;Indirect CO₂ reduction</td>
<td>Technology investments, logistics and business /public agreements</td>
</tr>
</tbody>
</table>
3.7.3 Risk reduction

In the following, we list the strategies that have been identified by the VNPI members to cope with or mitigate the identified risks:

- Technical risks:
  - Cooperate with universities to develop solutions for current technical complications;
  - Set up a pilot or demonstration plant.

- Market risks:
  - Perform a market study to identify potentials and options;
  - Demonstrate that product quality is controllable and can be guaranteed at a high level;
  - Promote the products as high value products;
  - Encourage the labelling of biomass according to sustainability criteria.

- Organisational risks:
  - Develop a proprietary culture (e.g. patents) for the protection of intellectual property;
  - Cooperate with both suppliers and stakeholder. Stakeholders in particular might have targets for increasing the usage of bio based materials for their production.
3.8 THEME 6: PLANT-TO-WHEEL

3.8.1 What is it?
This theme considers all options that influence energy consumption involved in the transportation of Dutch refinery products to the end-user and the actual consumption of said products. (See also figure 27).

Distribution of products
Some of the known options for improving the energy efficiency of the distribution and transport of refinery products are:

- Efficient logistics through extra storage facilities and modal shift. The efficiency of the logistics network can be improved, for example, through the reduction of 'empty miles' – the amount of miles that transport vehicles travel empty (e.g. after delivery of product);

- Energy efficient transport vehicles, such as boats and trucks. Fuel efficiency is an issue of increasing importance for manufacturers of transport vehicles and boats. Subsequent EU directives push technical development in this respect by imposing efficiency regulations. However, vehicles that achieve better fuel efficiency than required are available in the marketplace;

- Energy efficient operation of transport vehicles (e.g. ‘nieuwe rijden’ and ‘nieuwe varen’). As is widely promoted amongst car drivers, boats and trucks can also be operated in a fuel efficient manner. Technological aids (such as route-planners and cruise control) and training in fuel efficient driving can greatly improve the fuel efficiency of transport.

Potential Cost effective potential: 782 TJ / year
1264 TJ/ year technical potential (CE Delft)

End-user
Options:

- Energy efficient fuels. A number of energy efficient fuels are available at the Dutch petrol stations. Most of the companies have their premium brands communicated that way. The claim is that these fuels offer improved
mileage for most vehicles, and sometimes also less emissions. Energy efficient fuels can therefore reduce the volume demand for fuels; less consumption means less used energy and lower emissions in this use phase of the life cycle.

**FIGURE 27** *Future energy demand Dutch transport*

Source: TU Delft/Niria
Field tests have indicated that up to 3% of fuel savings may be achieved. Based on the total Dutch transport fuel consumption this would create a technical potential of 15 PJ.

Technical potential: 15,000 TJ / year

• Biofuels will replace some of the mineral fuel demand. This will reduce the tank to wheels GHG emissions for transport but the impact on local emissions is not clear.

The blending of biofuels into the fossil fuel stream is managed by the downstream petroleum distribution and marketing companies. Most of these are members of VNPI, but they do not participate in the Covenants MEE of MJA3. Five of these are sister companies to the Dutch refineries.

Blending of biofuels in the transport fuel segment is governed by EU legislation (RED and FQD). Currently (2011) Dutch operators are allowed to blend up to 10% (vol) of alcohol in gasoline and up to 7% of biodiesel into fossil diesel. The average level of biofuels that will be achieved in 2011 is approximately 5% (vol).
Biofuels are not produced by the Dutch refining industry. They are products of the chemical industry or of the vegetable and animal oil and fat processing industry.

It is estimated that it will become technically feasible by 2020 to blend in 10% (on energy basis) over the entire fuel pool. In practice this may turn out to be less, due to double counting of biofuels derived from waste, woodbased biomass, and the use of renewable electricity for electrical transport (TNO, CE, 2009). The additional technical savings potential, over and above the level practiced in 2011, is estimated at 15-25 PJ.

Decisions to enhance blending of biofuels are, strictly speaking, outside control and involvement of the refining sector.

- Shift from gasoline to diesel. A highly disputed option, since different experts do not agree on the net effects on the reduction of CO₂ emissions. Some state however: If diesel powered vehicles are more fuel efficient than gasoline powered vehicles, increasing the production capacity of diesel might further stimulate the market uptake of diesel vehicles over others.

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Cost effective potential: not quantified
Technical potential: 15,000-25,000 TJ / year
### 3.8.2 What are the known options?

The options at a glance:

<table>
<thead>
<tr>
<th>Options</th>
<th>Scope</th>
<th>Risks</th>
<th>Rewards</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy efficient fuels</td>
<td>Chain</td>
<td>Public opinion, claims are distrusted – but can be good for image and marketing&lt;br&gt;Price limited to level regular fuel&lt;br&gt;R&amp;D in cooperation with car manufacturers required</td>
<td>Direct energy saving and indirect CO₂ reduction in use phase&lt;br&gt;Fuel saving effect might be mitigated by increased energy use in production&lt;br&gt;Increased added value/ Customer loyalty</td>
<td>R&amp;D programmes with engine manufacturers/lubricants&lt;br&gt;Technology investments, Infra and business/public agreements&lt;br&gt;Private market channels</td>
</tr>
<tr>
<td>Biofuels</td>
<td>Chain</td>
<td>Change of the RED directive or other government policies&lt;br&gt;Technical limits (car/engine) to the maximum volume% of biofuel in the blend&lt;br&gt;Decreased control over quality of mixed fuels&lt;br&gt;(Logistic) constraints to the availability of raw bio material&lt;br&gt;Public opinion on influence of raw bio material on global food and deforestation issues</td>
<td>Direct energy saving and indirect CO₂ reduction in use phase&lt;br&gt;Contribution to ETS targets&lt;br&gt;Improves sector image and customer loyalty&lt;br&gt;Less mineral carbohydrate feed needed, reduction of price&lt;br&gt;Increased added value</td>
<td>R&amp;D programmes with engine manufacturers&lt;br&gt;Strategic alliances with top universities&lt;br&gt;Specific competences in R&amp;D&lt;br&gt;Logistics and business/public agreements&lt;br&gt;Pyrolysis oil can be processed in current facilities, so it isn’t too demanding</td>
</tr>
</tbody>
</table>
### Options

<table>
<thead>
<tr>
<th>Options</th>
<th>Scope</th>
<th>Risks</th>
<th>Rewards</th>
<th>Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix diesel / gasoline</td>
<td>Chain</td>
<td>Tax regulations negative to diesel powered vehicles</td>
<td><strong>Positive aspects</strong></td>
<td>High capital investments</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Energy efficiency improvements in diesel powered cars can outdo those of petrol powered cars</td>
<td>Direct energy saving and indirect CO₂ reduction in use phase</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Consumption of diesel is linked to PM emissions</td>
<td>The major option to upgrade fuel oil</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Requires considerable engineering effort for design &amp; construction of additional diesel production</td>
<td>Reduced gasoil imports and saving of resources</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td><strong>Negative aspects</strong></td>
<td>Increased energy usage in production</td>
</tr>
<tr>
<td>Efficient distribution and logistics</td>
<td>Chain</td>
<td>Limited influence</td>
<td>Direct energy saving and indirect CO₂ reduction in use phase</td>
<td>Technology investments, Infra and business /public agreements</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fuel saving effect</td>
<td>Private market channels</td>
</tr>
</tbody>
</table>
3.8.3 Risk reduction

In the following, we list the strategies that have been identified by the VNPI members to cope with or mitigate the identified risks:

- **Technical risks:**
  - Explore engine technology using diesel/gasoline fuel mixes;
  - Study the options;
  - Pollutant emissions petrol vehicles lower than diesel vehicles.

- **Market risks**
  - Benchmark environmental performance with alternative fuels;
  - Outsourcing of credibility. Let an independent party show that it works;
  - Study of impact of the petroleum industry on these markets;
  - Communicate on realisations.

- **Organisational risks:**
  - Cooperate with party with technical knowledge;
  - Have more dialogs (or studies) between (with) car manufactures and oil industry;
  - Cooperate with other industries;
  - Demonstrate to legislators that increasing diesel/gasoline ratio is detrimental to CO₂ emissions;
  - Lobby for shift towards higher break even annual km between gasoline & diesel particularly in Germany (now at 15000 km/a);
  - Feed in renewable fuels due to mandatory blending (still) has more impact on CO₂ reduction than other alternative fuels;
  - Fund university programmes as Dutch refining industry;
  - Lower fuel tax on efficient fuels or offer other incentives.

3.8.4 Risk and Rewards of 6 options

The following table and graphs show the rewards in CO₂ reduction and the risks of the 6 options. The resources must be quantified in a possible subsequent step.
## Risks vs. Rewards

<table>
<thead>
<tr>
<th>Theme</th>
<th>Scope</th>
<th>O</th>
<th>M</th>
<th>T</th>
<th>(\text{CO}_2) (kton/year)</th>
<th>(\text{CO}_2) (kton/year)</th>
<th>(E(TJ/\text{yr}))</th>
<th>(E(TJ/\text{yr}))</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost effective</strong></td>
<td><strong>Technical potential</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1a. energy efficiency</td>
<td>Harbour/plant</td>
<td>M</td>
<td>M</td>
<td>S</td>
<td>822</td>
<td>\textit{NYQ}</td>
<td>12500</td>
<td>\textit{NYQ}</td>
</tr>
<tr>
<td>1b. Novel technology</td>
<td>Plant</td>
<td>M</td>
<td>M</td>
<td>L</td>
<td>0</td>
<td>133</td>
<td>0</td>
<td>2400</td>
</tr>
<tr>
<td>2. Regional efficiency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. cogeneration</td>
<td>Plant</td>
<td>M</td>
<td>L</td>
<td>S</td>
<td>33-38</td>
<td>78-411</td>
<td>600-1600</td>
<td>1400-7400</td>
</tr>
<tr>
<td>b. Heat transport</td>
<td>Regional</td>
<td>L</td>
<td>L</td>
<td>S</td>
<td>100</td>
<td>900</td>
<td>2000</td>
<td>23000</td>
</tr>
<tr>
<td>3. CCS and CCU</td>
<td>Regional</td>
<td>XL</td>
<td>XL</td>
<td>M</td>
<td>350</td>
<td>\textit{NYQ}</td>
<td>6200</td>
<td>\textit{NYQ}</td>
</tr>
<tr>
<td>4. Renewable energy</td>
<td>Plant</td>
<td>M</td>
<td>L</td>
<td>S</td>
<td>55</td>
<td>97</td>
<td>1000</td>
<td>1750</td>
</tr>
<tr>
<td>5. Bio-based feedstock</td>
<td>Plant</td>
<td>M</td>
<td>M</td>
<td>L</td>
<td>120</td>
<td>170</td>
<td>2600</td>
<td>4300</td>
</tr>
<tr>
<td>6. Plant to wheel</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Distribution</td>
<td>Chain</td>
<td>S</td>
<td>L</td>
<td>M</td>
<td>43</td>
<td>70</td>
<td>782</td>
<td>1264</td>
</tr>
<tr>
<td>b. End-user</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b.1. Energy efficient fuels</td>
<td>Chain</td>
<td>S</td>
<td>M</td>
<td>M</td>
<td>\textit{834}</td>
<td></td>
<td>15000</td>
<td></td>
</tr>
<tr>
<td>b.2. Biofuels</td>
<td>Chain</td>
<td>S</td>
<td>M</td>
<td>M</td>
<td>\textit{834-1388}</td>
<td></td>
<td>15000-25000</td>
<td></td>
</tr>
<tr>
<td>b.3. Mix diesels/gasoline</td>
<td>Chain</td>
<td>M</td>
<td>L</td>
<td>L</td>
<td>\textit{NYQ}</td>
<td></td>
<td>\textit{NYQ}</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>26700</strong></td>
<td></td>
</tr>
</tbody>
</table>

*Calculated by \(1TJ = 0.05555 \text{ kton CO}_2\)*

\(\textit{NYQ} = \text{not yet quantified}\)

*italic is calculated. Abbreviations see page 76*
This yields the following CO₂ graph:

And also the following PJ graph
Known
Known Unknown
Unknown Unknown

1. Theme 1
2. Theme 2
3. Theme 3
4. Theme x

Rewards
Risks:
• technological
• organizational
• market

Resources
4. Next steps

4.1 THE SECTOR HAS A WELL-ORGANISED INNOVATION PIPELINE

The VNPI members are constantly looking for innovative technical options both to create a positive business case and meet, or over-perform, sustainability targets.

THE OPTIONS PIPELINE

The “refineries innovation pipeline” is constantly scrutinised for new (unknown) possibilities which could offer a solution to both criteria mentioned. Known solutions are studied carefully and are divided into Rewards, Risks and Resources information, as in Chapter 3. It is of the nature the sector to do so.

The nature of the sector can be described as:

- Say what you do and do what you say:
- Power of deliberation and implementation:
- Best truly long-term / future outlooks compared to other sectors:
- Fact and evidence driven:
- Legislation drives innovation:
- Culture of capital intensive, safety and compliance, but therefore also risk avoiding:
- Relatively impassive towards short term politics and public emotion.

Most of the known solutions are studies and have been piloted. However they still have risks and are “put on the shelve, but ready to apply” as soon as better future financial conditions or better future organizational conditions with other stakeholders emerge. The sector sees new developments only as implementable when there is a favorable business case. That means that risks are compensated by benefits that can be expressed in financial terms. When there is an imbalance, the developments are qualified as unlikely, or even impossible in the business envelope of a refinery.
The development themes that have been identified may be divided into two categories. There are developments that entail essentially application of existing proven technology and concepts. These developments are nominated for capital on the basis of primarily financial considerations.

There are developments that include real technological innovation. These will be incorporated in strategic and technological efforts of the corporate entity. Refineries may be chosen for further implementation of these developments on the basis of their competitive performance and alignment with other strategic considerations. The investment climate is of crucial importance in these cases.

4.2 “PERCEIVED PRESSURE” IS INCREASING RAPIDLY
On the other hand, the “perceived pressure” on the Dutch refinery sector is rising rapidly. This is felt on a day-to-day basis but especially on moments of future planning. The pressure originates from both outside and inside the refinery world.

From outside:
- Increasing pressure from CO₂ costs (ETS III) on an unlevel playing field (global and EU);
- Increasing pressure from shifting the product mix to diesel (more CO₂ in the plants);
- Increasing pressure from long term declining market and export demands;
- Increasing pressure from public opinion;
- Increasing pressure on lack of CCS options (Barendrecht, Groningen);
- Increasing pressure from “dictated” ambitions and short term policy.

From inside:
- Increasing pressure from the Solomon benchmark performances within the companies;
- Increasing pressure from global footprint/presence discussions within HQ of the companies;
- Increasing pressure from having no more options of low hanging fruit.
This should be interpreted and understood in the context of the corporate structure of the refining industry in the Netherlands. All refineries are essentially operating companies of large multinational corporations. Their task is to operate oil refining activities in the interface of two world markets as efficiently as possible. That of crude oil and that of refined products. Each of them plays a role in a worldwide network and is in competition with refineries elsewhere in the world, both outside and within the corporation. Typical activities like strategic planning, financing, research & development, technology and marketing to end customers reside with the shareholder company or within other legal entities.

This increasing pressure indicates that scenario “Regression” (Section 2.5.2) is much more likely to happen than the scenario “Sustainable Progress”. This pressure in combination with “ready to apply innovations” impels the need for a breakthrough.

4.3 THE ANSWER IS IN REDUCING THE RISKS BY WORKING ON THE CONDITIONS

In Chapter 3 all risks are mentioned in relation to the different themes, but ideas for mitigating the risks are also offered.

So, in fact, the next step will not be a “classical” technology MEE roadmap, starting all kind of new studies on innovations but a working programme on the conditions. Working on the “boundary “ conditions will reduce risks and will stimulate the introduction of innovations in the innovation pipeline.

This programme results in a multi-stakeholder agenda for working on these “boundary” conditions in order to reduce the risks and reap the rewards in the end. Ultimately this should result in a business climate which would accommodate scenario 1: “Sustainable Progress.”
<table>
<thead>
<tr>
<th>Organization</th>
<th>Next steps</th>
</tr>
</thead>
</table>
| **Refineries**      | Stay competitive and continuously improve energy efficiency  
|                     | Continue to strive for big reductions of CO₂ emissions within the ETS scheme  
|                     | Communicate (clearly) on economic and environmental impact and progress  
|                     | Concentrate efforts on the themes that are pictured in the RRR figure  |
| **Companies**       | Continue investing in improvements in the overall chain, including refineries  
|                     | Open a transparent dialog with all relevant stakeholders, focusing also on issues concerning refineries and communicating more on improvements achieved  |
| **VNPI**            | Invest in 3 ideas for improving image of Dutch refinery industry (more resources might be needed to implement all 3 ideas)  
|                     | Communicate energy efficiency developments and the advantages of having a refinery industry in the Netherlands/Europe  
|                     | Position VNPI in relevant political and regulatory bodies and the investment climate particulars that will facilitate the scenario of “Sustainable Progress”  |
| **Local governments** | Continue to be a good partner in discussions with refineries (e.g. on permits) and, with the industry jointly strive to find the optimum in economic and environmental benefits via frequent consultations  
|                     | Develop a holistic view on the implementation of regulations which is in line with EU requirements and which recognizes and supports the development of a refinery industry as outlined in the scenario of Sustainable Progress  |
| **Dutch government** | Develop a long term vision on the (energy) industry including the refineries and implement (secure) this long term vision (license to operate); scope needs to be 20 years instead of 4 years  
|                     | Keep improving the business climate in the Netherlands from a global perspective and secure a level playing field  
|                     | Recognise the economic and environmental impact of the Dutch refinery industry (i.e. the industry is the basis for the knowledge economy), and have a transparent dialog with the refinery industry  |
| **Knowledge institutes** | Maintain scientific and independent position  
|                     | Develop realistic (cost effective) projections for energy efficiency and CO₂ reduction (in cooperation with the industry)  
|                     | Develop independent comparisons (benchmark) tools for energy efficiency (improvement) and well to wheel options (Life Cycle Analysis)  
|                     | Cooperate with the industry on developing new energy efficiency technologies  |
5. VNPI views on findings and following steps

The pre-study reveals several issues that require further follow-up. They may be distinguished in issues of a technical nature and of a policy nature.

In this pre-study a total volume of projects was identified representing potential energy savings equivalent to 27 PJ per annum, approximately 18% of the energy consumption of the sector. The consultants have labeled these project as cost effective.

About half of these savings may be achieved by refineries, within the perimeter of refineries. The other half may be achieved in cooperation with other stakeholders in the region. In most cases this means that the energy consumption remains the same at the refinery, but the savings are achieved via supply systems to third parties that currently consume energy in the direct vicinity of the refinery.

The VNPI is of the opinion that the follow up of these technical projects is at the discretion of the individual refineries. The decisions to be taken are closely related to the specific refinery configuration. They are different and unique for each refinery and highly sensitive in terms of competitive information. Decisions are also closely related to the business strategy and technology development within shareholding companies. Moreover, the decisions are often related to global choices that each company makes regarding investment strategies for new developments. Frequently they are part of a pan-European marketing strategy. The VNPI cannot create added value for its members in an attempt to influence these decisions from a Dutch perspective.

In the context of Covenant MEE, the refineries will periodically prepare Energy Efficiency Plans. This will be the forum in which it is possible to discuss individual choices and opportunities per company.
This is equally valid for savings that may be obtained in a possible cooperation with other stakeholders. In most cases it concerns existing and proven technology. The implementation is dependent on the regulatory environment and investment climate. Refineries are interested in entering into dialogue with stakeholders in individual cases. Especially because the technical potential of these opportunities is much larger than the volume presently identified as cost effective within the perimeters of the individual refineries. Individual companies have already done so on several occasions in the past, but as yet with only limited success. Nevertheless, they will continue to do so if and when critical business parameters change. Decisions can only be made on the basis of individual business cases. Due to the competitive nature of the industry and the limited numbers of players, the VNPI is prohibited from playing a coordinating role in this process. Moreover, it is believed that the protracted take-off of these opportunities is partly a consequence of involvement of parties that do not have a real business interest in such projects.

Apart from the above there is the need for a serious and detailed discussion with government about the strategic role that refineries will have to play in The Netherlands in the process of energy transition in the long term. This entails a discussion about the conditions that need to be fulfilled in order for the optimum climate for the scenario of “sustainable progress” to materialize. This has everything to do with the investment climate and license to operate for refineries in the Netherlands. It will be about the dilemma of an industry, which is on the one hand urged to disappear in the long term, but on the other hand is equally urged to make large investments in process improvement, product refocus, emission abatement and energy reduction on the short and medium term.
Discussion with governmental stakeholders is needed, but the VNPI is of the opinion that the setting of Covenant MEE, which is predominantly technical, is not the right platform. This dilemma, the responsibility for ensuring security of supply during the transition period and the ambition of the Netherlands to maintain its economic position calls for a far broader forum.

The members of the VNPI intend to attempt to define these criteria and seek this vital dialogue.
ANNEX 1.  
*Further (quantitative) information*
DEMAND

See Figure 1 for the different refined products produced in the EU

FIGURE 1  Refined products from EU refineries and their uses

Source: Europia, IEA
EU-27 Refinery production in 2007

Excludes Bulgaria, Lithuania and Romania

- **40.5%** White spirit
  - motor fuel
- **21.7%** Gasoline
  - motor fuel
- **14.9%** Fuel oil
  - fuel oil for power generation, marine fuel
- **14.7%** Industry
- **6.8%** Kerosine
  - heating, cooking, aviation fuel
- **2.2%** Aromatics
  - chemical feedstock
- **0.1%** Paraffin
  - industry
- **5.5%** Naphtha
  - chemical feedstock
- **1.2%** Lubricants
  - transportation and industry
- **0.5%** Sulphur
  - fertilizer
- **0.5%** Coke
  - electrodes for metal industry
- **3.3%** Bitumen
  - road construction, roofing
- **2.5%** LPG
  - heating, cooking, chemical feedstock
- **0.2%** White spirit
  - paint industry, cosmetics
- **0.2%** Waxes
  - industry
- **21.7%** Gasoil
  - heating, marine fuel, industrial fuel
- **63.6%** Transport
- **1.2%** Lubricants
  - transportation and industry

Excludes Bulgaria, Lithuania and Romania
See Figure 2 for the change of consumption patterns of refined products in the EU. A decline in gasoline and fuel oil and an increase in kerosene and gasoil (diesel) can be observed.
FIGURE 2  EU refined product consumption growth

Source: Europia, Historical data: IEA and Local sources, Forecasts: PFC Energy
Figure 3 shows the European exports and imports of refined products. In 2008, net imports of gasoil/diesel amounted to 20 million tonnes, equivalent to 6.9% of EU gasoil/diesel consumption, while net exports of gasoline amounted to 43 million tonnes, equivalent to 31% of EU gasoline production. If net imports of kerosene and jet fuels are taken into account, the EU shortfall in middle distillates amounts to upwards of 35 million tonnes of net imports per year.
**FIGURE 3 EU trade deficits**

Source: European Commission, 2010
Figure 4 shows the worldwide oil demand by region. Note that oil consumption is expected to decline in OECD countries and to grow in the rest of the world. The total worldwide growth is expected to decline after 2030.
FIGURE 4 Oil demand by region and sector

Figure 5 shows the global supply of primary energy in the run up to 2030.
FIGURE 5  World total primary energy supply

Source: Shell, 2010
Figure 6 shows the global demand by fuel over the last 150 years and for the coming decades.

Source: ExxonMobil, Smil, 2010
SUPPLY
Figure 7 shows the supply and demand growth expected till 2030. Demand growth primarily in Asia and supply from biofuels and OPEC countries.
FIGURE 7 Supply and demand oil and biofuels

Source: BP, 2011
Figure 8 shows the supply of biofuels in the run up to 2030.

**FIGURE 8 Supply biofuels**

![Graph showing biofuels supply](image)

Source: BP, 2011

**UTILISATION AND MARGINS**

Figure 9 shows the European utilisation of the refinery capacity and shows that the utilisation is by and large above 80%.
FIGURE 9 European utilisation of refinery capacity

1. Restructuring of the European industry following the second oil crisis
2. Recession in early 1990s
3. Impact of economic downturn in Asia
4. Minor recession in some EU countries
5. 6% year drop in utilisation due to economic crisis

Source Europia, BP Statistical Review, PFC Energy
Figure 10 shows the gross margins of Northwest European FCC cracker, showing that margins fluctuate heavily between 5 and 1 $/bbl and are expected to be around 2 $/bbl in the coming years.
FIGURE 10 Margin outlook – NEW gross margin for FCC cracking Brent

The gross margin is calculated from the gross products produced by the refinery minus the cost of the crude delivered to the refinery.

Source: Europia, Wood Mackenzie
Figure 11 shows the observed refinery crude runs, in which improvements in 2010-2011 are conspicuous.
FIGURE 11 Observed Refinery Crude Runs Netherlands

Source: EIA, 2011
Figure 12 shows an example of the differences between the gross margin and the net margins of a refinery. This illustration shows that energy costs are the most dominant cost factor for a refinery.
FIGURE 12 Margins for a refinery (exemplary illustration in NW Europe, UDS/bbl)

- Refineries buy the crude that is then processed.
- Energy is by far the most important cost factor.
- Depreciation increase from investments in low sulfur fuels and energy efficiency.
- This illustration is a snapshot as the margin is subject to continuous change due to volatile crude oil and oil product prices.

Source: Roland Berger, 2008
Figure 13 shows that the impact on the crisis on the refinery sector is huge: many refineries are for sale and a few are shut down or conversion is planned.
FIGURE 13 Summary of EU refineries planned/actual divestments and shutdowns since 2008

Source: European Commissions, 2010
CO$_2$

Figure 14 shows the CO$_2$ emissions and expected development of those emissions by region, showing an increasing impact from Non-OECD countries.
FIGURE 14 CO₂ emissions by region

By 2030, two-thirds of energy-related CO₂ emissions will come from non-OECD countries.

Growing economic output could more than double global emissions by 2030.

Improvements to efficiency, plus the use of cleaner-burning fuels will drive actual emissions lower.

Large gains in efficiency will reduce emissions growth by two-thirds.

Source: ExxonMobil, 2010
Figure 15 shows the options which are calculated in the SULTAN scenario to determine if a 95% reduction of CO₂ emissions of the European transport is feasible.

Notes:
Many of the scenario options will affect more than one category to a greater or lesser extent, however they have been grouped in the following table into their primary category area of action, as follows:
A Decarbonising energy carriers (i.e. reducing the GHG intensity of transport energy)
B Improving vehicle efficiency (i.e. improving the technical energy efficiency of new vehicles)
C Efficient organisation of transport system (i.e. improving the structural efficiency by improving operational efficiency)
D Improving vehicle use (i.e. using vehicles more efficiently by improving operational efficiency)
E System efficiency (e.g. improving the economic efficiency of transport via economic instruments, by internalising selected external subsidies and creating a level playing field
### FIGURE 15 Summary list of the illustrative scenarios defined in SULTAN

<table>
<thead>
<tr>
<th>Scenarios defined in SULTAN</th>
<th>Area</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single scenarios</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Reduce GHG intensity of fuel (all modes)</td>
<td>A</td>
<td>Technical</td>
</tr>
<tr>
<td>2. Mandatory new vehicle emission limits (all modes, with/without biofuel)</td>
<td>A, B</td>
<td></td>
</tr>
<tr>
<td>3. Package of cycling and walking improvement measures (walk/cycle)</td>
<td>C</td>
<td>Non-technical</td>
</tr>
<tr>
<td>4. Improved spatial planning (road and rail)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Package of mobility management measures incl. improved public transport</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Improved freight intermodality (road, rail and inland shipping)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Improved speed enforcement (road)</td>
<td>D, (E)</td>
<td></td>
</tr>
<tr>
<td>8. Harmonised EU motorway speed limit (road)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Fuel-efficient driver (FED) training (road, rail)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Company car tax reform (cars)</td>
<td>(A, B, C, D,)</td>
<td>E</td>
</tr>
<tr>
<td>11. CO₂ price tax (all modes, based on central/low/high CO₂ costs)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Non-CO₂ price tax (road, internalise cost of NOx, PM and energy security</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Equivalent duty and VAT rates for fuels (all modes)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Combination scenarios</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C1. Technical measures: reduce energy GHG intensity (biofuels)</td>
<td>A</td>
<td>Technical</td>
</tr>
<tr>
<td>C2. (All) Technical measures: mandatory new vehicle limits + biofuels</td>
<td>A, B</td>
<td></td>
</tr>
<tr>
<td>C3. Scenario C2 + Spatial planning and modal shift measures</td>
<td>A, B, C</td>
<td>Technical and</td>
</tr>
<tr>
<td>C4. Scenario C3 + speed and driver training measures</td>
<td>A, B, C, D</td>
<td>non-Technical</td>
</tr>
<tr>
<td>C5. Scenario C4 + taxes (with central/low/high CO₂ prices), i.e. all technical and non-technical measures scenario</td>
<td>A, B, C, D, E</td>
<td></td>
</tr>
<tr>
<td>C6. Non-technical measures: planning + modal shift + speed + FED training + tax (central/low/high CO₂ prices)</td>
<td>C, D, E</td>
<td>Non-technical</td>
</tr>
</tbody>
</table>

*Source: European Commission, 2010*
Figure 16 shows the WTW energy usage and GHG emissions for gasoline and diesels. It shows that diesel has a better WTW performance, but as already stated this gap might shrink in future.
FIGURE 16 WTW energy usage and GHG emissions

WTW report, 2007
Figure 17 shows the gravimetical energy density of liquid/gaseous fuels compared to electrical energy storage.
FIGURE 17 Energy density

Source: Europia, ExxonMobil
Optional figures (whether to include to be determined)
CO₂ emissie

1990 2005 2025 2025

RCI -50%

vergeleken met 1990

-1

-7

17

4

3

8

29

13

15

3

46

-20

-6

12

-1

15

13

17

15

12

17

15

12

17

15

12

17
ANNEX 2

Calculations
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<tr>
<th>Oil barrel</th>
<th>US gallon</th>
<th>Litres</th>
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<tr>
<td>1</td>
<td>42</td>
<td>159</td>
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<tr>
<td></td>
<td></td>
<td>(1 gallon = 3.79 litres)</td>
</tr>
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</table>

Density (average)

0.85 kg/l

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<thead>
<tr>
<th>Bbl/day</th>
<th>Tonne/year</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>100,000</td>
<td>4,932,975</td>
<td>49.33</td>
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</tbody>
</table>

Calculations use phase
ANNEX 3

Sources and references
<table>
<thead>
<tr>
<th>Nr</th>
<th>Title</th>
<th>Source - Author</th>
<th>Date</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>Implications of the planned ETS auctioning in the refining sector in the Netherlands</td>
<td>Roland Berger</td>
<td>10-2008</td>
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<td>2</td>
<td>White Paper on EU Refining</td>
<td>Europia</td>
<td>05-2010</td>
</tr>
<tr>
<td>3</td>
<td>EU Transport GHG: Routes to 2050?</td>
<td>Advice to EU DG Environment by AEA et al.</td>
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<tr>
<td>4</td>
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<td>5</td>
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<td>6</td>
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<td>7</td>
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<td>Berenschot/VNCI</td>
<td>10-2010</td>
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<td>8</td>
<td>“On Refining and the Supply of Petroleum Products in the EU”</td>
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<td>11-2010</td>
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<td>9</td>
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<td>BP</td>
<td>01-2011</td>
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<tr>
<td>10</td>
<td>Signals and Signposts, Shell Energy Scenario’s to 2050</td>
<td>Shell</td>
<td>02-2011</td>
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<td>11</td>
<td>A Roadmap for moving to a competitive low carbon economy in 2050</td>
<td>EU Commission</td>
<td>02-2011</td>
</tr>
<tr>
<td>12</td>
<td>White Paper on Fuelling EU transport</td>
<td>Europia</td>
<td>03-2011</td>
</tr>
<tr>
<td>13</td>
<td>Fuel &amp; Energy outlook for the Marine &amp; Aviation Sectors, 9th CONCAWE Symposium</td>
<td>Wood Mackenzie</td>
<td>03-2011</td>
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<td>14</td>
<td>“VNPI Scan” - Summary of energy/sustainability sections of VNPI members websites</td>
<td>MSL Communication Consultants</td>
<td>03-2011</td>
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<tr>
<td>15</td>
<td>Energy Benchmarking of Dutch Refineries - VNPI Summary Report</td>
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<td>17</td>
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<td>CE-Delf</td>
<td>11-2010</td>
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<td>18</td>
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<td>03-2011</td>
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<td>19</td>
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<td>10-2011</td>
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