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Energy-efficiency opportunities for the Dutch energy-intensive industry and refineries towards 2020

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Acknowledgement/Preface
This report is prepared within the framework of the basic research programme of the ECN unit Energy Efficiency in Industry as part of the PROVER projects 7.6471 and 7.6499

Abstract
A projection for energy use and CO_2 emissions towards 2020 compared with 2020 policy targets shows the tasks the Dutch economy faces with regard to reduction of energy use and CO_2 emissions. This report focuses on the challenges for the industry herein, on the potential contribution of selected technologies, and on the implications for the research and development efforts for these technologies.

Keywords
CO_2 emissions, energy use, energy-intensive industry, policies, baseline projection, refineries, research, technologies

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Executive summary

The industry is likely to face a considerable task with regard to reduction of energy use and CO_2-emissions towards 2020, based on comparisons of projected national energy use and CO_2-emissions on the one hand and probable policy targets on the other. The industry, being a sector with relatively many reduction possibilities in the lower cost range (lower than 50 €/tonne CO_2) is likely to face a more than proportional share, especially as current policies tend to spare the industry. Current technologies are unlikely to be able to meet these tasks, and therefore research on options for energy savings and emissions reduction is imperative.

Sound decision-making on subjects for an R&D programme with regard to industrial energy efficiency requires a clear perspective on the future need for these technologies. This depends on the policy targets for energy use and CO_2 emissions. Moreover, as there may be various ways to meet the targets, information from various sources is required to identify which technologies are important for meeting the targets.

The reference projections 2005-2020 provide baseline projections for energy use and CO_2 emissions. It indicates that between 2000 and 2020 Dutch energy use increases with 24% to 3870 PJ, and the CO_2 emissions increase with 21% to 205 Mtonne. The industry is an important sector both from an energy use perspective and with regard to emissions. It is, after the energy and transport sectors, the largest sector with regard to direct CO_2 emissions, and with regard to primary energy use it is the largest and after the transport sector the fastest growing sector. It is also the largest with regard to primary energy use for energetic purposes, and thereby the largest cause of CO_2 emissions (direct and indirect via the energy sector). In comparison with other sectors, policy pressure on industrial energy use and emissions is relatively low, typically ranging between 17€/tonne CO_2 for the energy intensive industry and 30€/tonne CO_2 for the energy extensive industry. Therefore, the industry may still leave a lot of relatively low-cost possibilities unused, especially compared to sectors such as households, services and transport, with policy pressures typically higher than 80€/tonne CO_2.

Until 2020, expected industrial energy savings amount to roughly 1% a year. Only the contribution of CHP is readily identifiable, between 10 and 20% of total industrial savings.

There are no clear-cut targets for Dutch energy use and CO_2 emissions around 2020. However, policy documents such as the NMP4 give an indication of what 2020 targets might look like. Based on the 2030 targets of the NMP4, the 2020 emissions targets could lie between 121 and 155 Mtonne. With the 205 Mtonne CO_2 emissions of the baseline projection, the Dutch economy would face reduction targets between 50 and 84 Mtonne. In terms of €/tonne, the industry and power generation are the only sectors that face relatively low policy pressures and in comparison to other sectors they may have a lot of relatively low-cost reduction possibilities in 2020. From a national perspective it is rational to realise a more than proportional share of the required emissions reduction in these sectors: Each Mtonne CO_2 emission reduction in the industry and power generation may cost two to six times as less as in other sectors.

At a cost range up to 100 €/tonne CO_2, energy demand reductions, renewable electricity generation and CO_2-sequestration are likely to emerge as important technologies. However, actual realisation and the prospects for research on specific technologies is also influenced by policies such as emission trade and energy taxes, transition policies, the EOS energy research strategies and specific technology directed policies. This kind of information allows a very rough evaluation on the strong and weak points with regard to research and application of technologies: Energy efficiency technologies, CO_2-sequestration, biomass resource and biomass transport fuels.

Energy efficiency technologies offer possibilities to reduce energy consumption and emissions at a very wide range of cost levels, from zero or negative costs to over 250€/tonne CO_2. They will be required in any future with limited energy supplies, be it fossil or renewable. However, the readily applicable low-cost potential is limited, and research should aim at developing new potential and decreasing the costs of identified potential.

CO_2 sequestration is probably the only possibility to achieve major emission reductions in the short term at cost levels below 100 €/tonne CO_2. Between costs levels of 50 and 90 €/tonne CO_2, emission reductions in de power sector and industry of 60-70% should be possible with sequestration. The obvious drawback is that its contribution to energy supply security is a negative one. The efficiency penalties involved in the separation and compression of CO_2 considerably increase the depletion of fossil fuels.

The use of biomass feedstock will probably have a key-role in a chemical industry less dependent of fossil fuels. Its costs are still rather high, especially for biomass as a substitute for oil-based resources. Research tasks include the development of new processes, the decrease of costs of existing processes and improvements of yield and product quality.

Biomass fuels will be important as energy carriers for the transport sector. It is the only option for large-scale application in the short-term. Costs are still high and the range of commercial processes is still limited. Research should aim at reducing costs and increasing the range of biomass that can be converted to transport fuels. A main advantage is that there are already concrete European targets.

No single group of technologies is capable of meeting both the CO_2-emissions reduction tasks and the supply security tasks of the industry in 2020. Meeting these tasks at costs less than 30€/tonne, is not possible at all, with whatever combination of technologies. A well-balanced portfolio of research items, directed at both creating new low-cost potential and reducing the costs of options already identified is necessary. In addition, incentives for the application of higher costs options than currently may further enhance cost-reduction rate of options in the industry.

Reductions in the industry and power sector are the most cost-effective ones. For this reason, it would be logical to enforce higher energy-efficiency standards and lower emissions in the industry. This does not imply that the industry should bear these higher costs. If consumers were to pay the additional costs of options in the industry, it would cost them less than if they had to realise the same emission reductions themselves.

1. Introduction

1.1 Background of this report

Sound decision-making on research objects requires a clear perspective on possible developments and targets and the efforts required to meet these targets. The program unit Energy-Efficiency in Industry has asked the program unit Policy Studies to provide such a perspective on possible developments in the industry and refineries, on longer-term targets and on policies.

1.2 Approach

This report addresses the policy targets for the Dutch industry and refineries with regard to energy use and CO_2-emissions, and the opportunities these targets offer for new or improved technological concepts and the research thereon. It evaluates the opportunities for new technologies until 2020 and the required role of research in the realisation of these options. In order to do so, it provides a baseline projection towards 2020, and compares this with the desired situation, with regard to energy and emissions. Further, it analyses the directions in which existing and intended policies look for solutions and evaluates the support these policies may provide for several technologies and the research on these. Finally, it gives a rough evaluation of the perspectives the obtained background gives to some selected technologies

1.3 Report structure

The structure of the report reflects the approach described. Chapter 2 briefly describes the current situation and recent history with regard to the energy use in the industry and refineries, including policies. Chapter 3 describes the main assumptions and results of a baseline projection with regard to economical developments and policies, based on the Reference Projections 2005-2020. Chapter 4 offers a more in-depth description of the results for the Dutch industry. This description includes the refineries, of the nature of the activities and the kind of technologies applied. Chapter 5 addresses the medium-term and long-term targets and policies. It describes both the size of the required emission reductions, and the role policies play in the favoured directions. Chapter 6, finally, merges the information from the previous chapters in an analysis on the prospects of selected technologies against the background of the baseline projection, the medium and long-term targets and the various policies.

2. 1990-2000 developments

2.1 Industrial structure in 2000

At 40%[1] of Dutch primary energy consumption, the industry is the largest sector in terms of energy consumption.

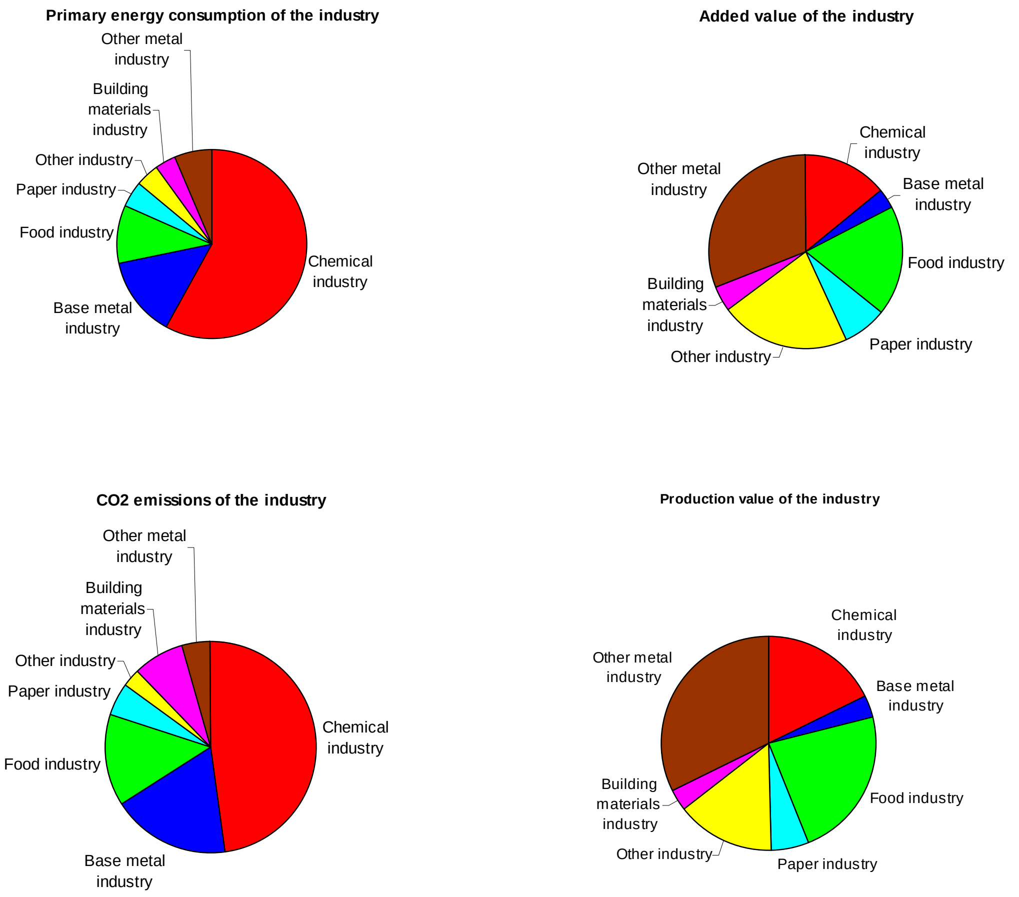

Figure 2.1 *Shares of industrial sectors excluding refineries in total industrial primary energy consumption, CO_2-emissions, production value[2] and added value[3].*

The chemical industry has a share of about 58% in Dutch industrial primary energy consumption, while its share in the production value is 18%, and its share in the added value is only 14%. However, a large part of its energy consumption is feedstock, which does not result in comparable CO_2 emissions in the industry itself[4]. Therefore, it is responsible for only 48% of CO_2 emissions. The base metal industry has the second highest energy intensity, 0.1 GJ/euro

[1] Including feedstock, 2000.
[2] Value of shipments or turnover.
[3] Equals the value of products minus the value of purchased resources.
[4] A recent change in the calculation of CO_2 emissions has considerably reduced the CO_2-emissions of the industry. The CO_2 emissions of short-cycle feedstock, formerly attributed to the producing sector, now emerge in the consuming sector. As a major part of the consumption takes place in other countries, this methodological has also resulted in lower national CO_2 emissions.

added value, but its high share of coal consumption makes its energy consumption very carbon intensive, resulting in the highest relative CO_2-emissions. The chemical industry's counterparts are the other metals industry (including electronics) and the other industry with together 10% of primary energy consumption and 53% of production value.

Table 2.1 *2000 primary energy consumption, CO_2-emissions, added value*

2000	Primary energy		CO2 emissions		Added value			
	PJ	%	Mton	%	Meuro	%	Euro/GJ	Euro/Mton
Chemical industry	703	58%	14.8	48%	8412	14%	11.97	569
Base metal industry	163	14%	5.6	18%	2029	3%	12.42	362
Food industry	122	10%	4.4	14%	10909	18%	89.77	2503
Paper industry	54	4%	1.6	5%	4273	7%	79.69	2740
Other industry	47	4%	0.8	3%	12890	22%	276.84	15230
Building materials industry	45	4%	2.4	8%	2492	4%	55.57	1044
Other metal industry	76	6%	1.4	5%	18484	31%	241.98	13072

2.2 Economic developments and savings 1990-2000

On average, the Dutch industry and refineries have realised a growth of production value of 1.9% per year during the 1990's. The buildings material industry was the fastest grower with 3.9%, the base metal industry the slowest with 0.2%. Energy-intensive sectors such as chemical industry and the paper industry realised growth percentages of 2.5 and 3.0, respectively.

Table 2.2 *Yearly growth of production value, primary energy use and CO_2-emissions by industrial sub sector during the 1990s*

	1990-2000 production value	Primary energy use	CO_2-emissions
Base metal industry	0.2%	0.0%	-1.5%
Paper industry	3.0%	1.2%	-1.2%
Chemical industry	2.5%	1.2%	-3.4%
Food industry	1.7%	1.8%	0.5%
Other industry	2.2%	-1.8%	3.4%
Building materials industry	3.9%	-0.8%	-1.7%
Other metal industry	1.4%	1.6%	0.1%
Refineries	2.3%	0.0%	0.4%
Total industry (including refineries)	1.9%	0.9%	-2.1%

2.3 Policies and their effects, 1990-2000

Energy policies have already played an important role in the shaping of the above 2000 situation. According to [Jeeninga et al 2002], industrial energy savings between 1990 and 2000 amount to about 180 PJ, equivalent to about 12 Mtonne CO_2-emissions. CHP accounts for about 4 Mton CO_2-emission reduction, leaving 8 Mtonne for reductions in final energy use. In terms of savings on primary energy use, the industry has realised savings of about 1.3% a year [Boonekamp, 2002] during the 1990-2000 period according to the approach of the energy savings protocol [Boonekamp, 2001]. For the 1995-2002 period, a lower effect of about 1% was found [Boonekamp, 2004].

Estimates state about 2 Mtonne effect [Jeeninga et al 2002] by policies of the total 4 Mtonne reductions caused by CHP, with a contribution of policies to the effect on final energy use being between 2.4 and 4Mtonne. The major components of industrial energy policies include covenants (MJA's), fiscal stimulation (EIA/VAMIL), CO_2-reduction plan, energy taxes and information programmes (MAP/MPI), and specific CHP-policies. Different policies interact in various ways; they may be complementary, synergetic or antagonistic. Policy results always apply to a package of policies. As a result, estimates of the effects of individual policies are always indicative[5].

MJA

In the 1990's, the MJA was by far the most important policy instrument directed at the industry, covering about 75% of industrial energy use excluding feedstock. The MJA as such offers no direct financial incentives for energy savings. Its main effect is the greater knowledge about economic possibilities to save energy. It is difficult to indicate the actual effect MJA's have had on energy savings. [Jeeninga et al 2002] estimate an effect of between 1.8 and 3 Mtonne on final energy use.

EIA/VAMIL

The Energie-investeringsaftrek and the Variabele Aftrek MILieuinvesteringen both are fiscal instruments. Together they result in a subsidy of about 19% of additional investments for energy savings. According to [Jeeninga et al 2002], the effect of these instruments is between 0.1 Mtonne (calculations with the SAVE-model) and 0.3 Mtonne (6PJ) annually. Expenditures between 1990 and 2000 on the EIA amount to 95 million €.

CO2-reduction plan

The CO_2 reduction plan started in 1996. As no projects have been completed before 2000 its contribution in the period 1990-2000 is nil.

Energy taxes

Energy taxes include the regulating energy tax (REB) and the fuel tax (BSB). The effect of the REB is negligible, as there is no tariff above 1million m^3 natural gas consumption and 10 million kWh. The major part of industrial energy use is by consumers with larger consumptions. The BSB is relevant, its effect equalling about 3 PJ or 0.2 Mtonne of CO_2.

MAP, MPI

Energy companies provide funds for energy savings from the MAP and MPI (Gasunie). Strictly speaking, these are not part of governmental policies. Part of the effects of MAP and MPI are already included in the estimated effects of the MJA. Some 0.2 Mtonne is estimated to be the effect in companies not participating in the MJA.

CHP-policies

During the 1990's the capacity and production of CHP rose considerably, accounting for an effect of approximately 4 Mtonne CO_2 in the industry. For industrial CHP, several policies have played a role in this, including those already mentioned. There were also some specific CHP-policy instruments:

- A special gas price arrangement (from May 1990).
- Exemption from the regulating energy tax (REB) on CHP gas consumption.
- Exemption from the regulating energy tax (REB) on the steam production of CHP consumed by the company itself.
- Project bureau CHP (PW/K)[6].
- Subsidy arrangement on new energy-efficient combinations of CHP-systems.

Further, CHP producers received a guaranteed electricity price from the SEP.

5 Determination of policy effects often takes place by considering a package of policies, "peeling off" the individual policies in a certain order, and evaluation of the mutations for each peeled off policy. The actual effects found for each instrument depends on the order applied. A clear example is the combination of subsidies and the EPN (energy performance standard) for newly built offices. If the EPN is removed first form the policy package, there remains a residual effect for the subsidies. However, if the subsidies are removed first, there is no effect.

6 Part of the 1987 CHP-stimulation programme. Its target is increased cooperation between energy companies and end-users.

3. A baseline projection towards 2020

3.1 Assumptions and approach

The baseline projection towards 2020 is based on the Global Economy scenario of the Reference Projections 2005-2020 [Van Dril, Elzenga, 2005]. The Reference Projections provide a detailed projection for energy use and CO_2-emissions for the period 2005-2020, and also include detailed information on the factors that shape the development of energy and CO_2-emissions. The Reference Projections 2005-2020 applies conservative policy assumptions: it includes only existing policies and new policies definitively decided on. In this way, it shows the extent to which current policies are sufficient to attain targets, and what the policy gap is that has to be filled.

The actual approach of the Reference Projections is strongly bottom-up. Economic and demographic projections, translated into sector-specific developments, detailed policy assumptions and extensive data on technologies with their costs and effects together result in the results on energy and emissions. All together this constitutes a fairly complete view of plausible developments towards 2020, allowing analyses on individual policies in individual sectors, both with regard to the effects on energy use, emissions and costs.

The baseline projection derives part of its inputs from various external sources. The CPB provides the scenario-context and macro-economic and meso-economic data. The assumptions for the current baseline projection are based on the Global Economy long-term scenario of the CPB. This scenario is characterised by a breakdown of international barriers, and a relatively limited government influence. For the period towards 2020 the main consequences of the choice of the GE-scenario are a relatively high growth of both the Dutch population and the economy.

3.2 Economy

The economy is the starting-point for the determination of the sector developments. The assumptions for economic developments come from the Global Economy scenario of the CPB, with an economic growth of around 2.7% per year. The industry performs well, with an average growth of 2.3% per year.

Table 3.1 *Economic growth by main sector and national*

Added value, yearly growth	1995-2000	2000-2005	2005-2010	2010-2015	2015-2020
Agriculture	1.0%	0.0%	1.6%	1.2%	1.3%
Industry	2.9%	0.1%	2.3%	2.3%	2.4%
Energy and water	-2.2%	0.7%	0.0%	-1.5%	-1.0%
Construction	3.0%	2.0%	3.8%	2.6%	2.6%
Services and government	4.4%	2.0%	3.4%	3.1%	3.1%
Total	3.7%	1.6%	3.1%	2.7%	2.8%

Energy prices in the Reference Projections show a moderate development. The figure below shows the commodity prices for coal, natural gas and electricity. These prices do not reflect the recent rise in the oil price. Only the electricity prices show a clear rise, due to the gradual disappearance of overcapacity, capacity and the effects of CO_2-emission trading.

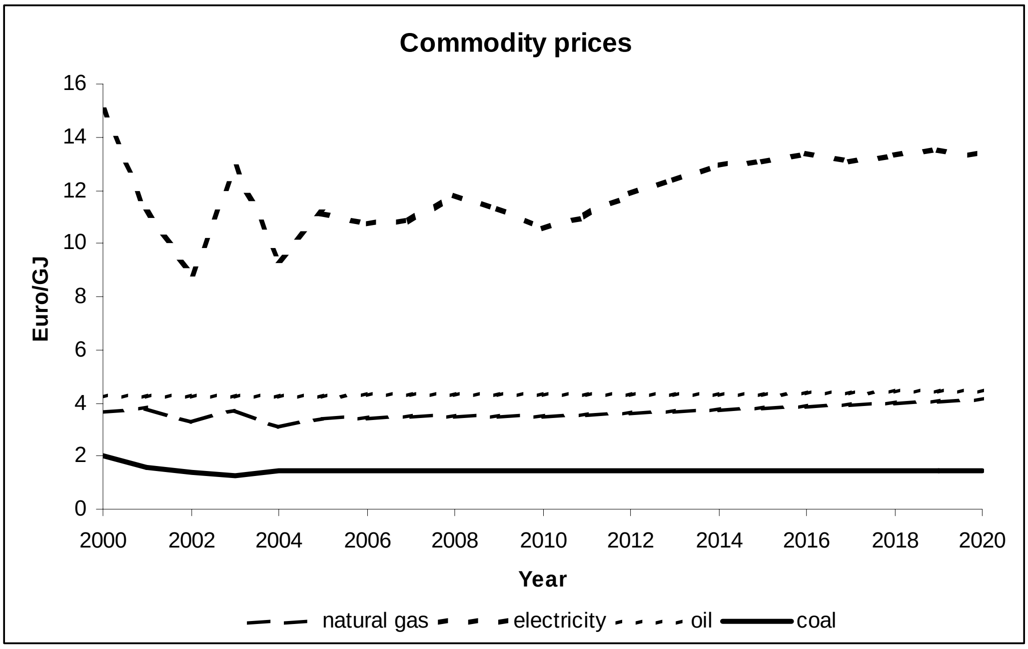

Figure 3.1 *Energy commodity prices in the baseline projection*

3.3 Policies

As stated before, the baseline is conservative with regard to the inclusion of policies. Without giving an exhaustive overview of the included policies, it is nevertheless necessary to give a short overview on the most important developments with regard to policies. The most important development in the baseline projection is the introduction of the European CO_2-emission trade system. In the Netherlands, the energy sector and the major part of the industry will participate in this emission trade system. The importance of the emission trade system not only resides in its absolute impact, but also in the fact that it will gradually replace and make obsolete many of the existing policy instruments. In the baseline, the impact of the emission trade system is indeed rather limited, both financial and in terms of emission reduction. CO_2-prices are not higher than 11 €/tonne in 2020, and the major part of the emission rights is given for free to companies by a system of grand fathering.

Other policies include energy taxes, subsidies, regulatory measures, benchmarks and voluntary agreements. The EIA of the 1990's continues, but its impact decreases due to a lower corporation tax[7]. Furthermore, the Reference Projections assume the energy taxes of the non-trading sectors to be at least as high as the CO_2-price for the trading sectors translated in the equivalent effect on the energy price. The introduction of the CO_2-trading system and the described coupling of the energy tax for non-trading companies can be regarded as first steps towards a rationalisation and economic optimisation of energy and CO_2-policies. Rising CO_2-taxes will eventually result in a gradual convergence of the marginal costs[8] of energy use and CO_2-emission reduction in different sectors. From a national perspective, this will lead to relatively lower costs of CO_2-mitigation measures. Still, in the baseline such convergence is only in its initial phase, and the marginal costs of CO_2-emissions reduction differ strongly by sector.

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7 The resulting subsidy level decreases from 19% to around 13%.

8 In this case, marginal costs are the additional costs per tonCO_2 reduced that companies and individuals face because of policies. Taxes and CO_2-prices directly translate into the accompanying marginal costs: they cause energy savings measures to be more economically attractive. In this case the marginal costs are equal to the CO_2 price, or to the level of the energy tax times the emission factor of the respective fuel. In case of standards, regulations and covenants it is more difficult to estimate the resulting marginal costs. In such a case they are determined by the costs of the most expensive measure required to meet the standard, and this may vary considerably for individual situations.

Table 3.2 *Estimated policy pressure on CO_2 emissions by sector or technology in 2020, expressed in €/tonne CO_2 emitted* [9]

Sector	Marginal reduction costs	Explanation
Households	~60-150 €/tonne CO_2	Energy tax, EPN
Industry (energy intensive)	~17 €/tonne CO_2	CO_2-emission trade (11€/tonne), energy tax (6 €/tonne), benchmark, EIA
Industry (energy extensive)	~30 €/tonne CO_2	Energy tax(30 €/tonne), MJA-2, EIA
Agriculture	~20-30 €/tonne CO_2	GLAMI, energy tax
Services	~40-150 €/tonne CO_2	Energy tax, EPN (only new buildings)
Transport	~350-550 €/tonne CO_2	Fuel excises (diesel low, gasoline high).
Power generation	~11 €/tonne CO_2	Benchmark, EIA
Technology		
Renewable electricity	~40-100 €/tonne CO_2	MEP and electricity price effect of CO_2-emission trade system; Lower range: mixed biomass; middle: wind onshore, pure biomass; higher range: wind offshore; hydro
CHP	~15 €/tonne	Electricity price effect of CO_2-emission trade system, EIA

Table 3.2 serves to give a rough indication of the differences in marginal reduction costs by sector. Sectors such as the industry agriculture and power generation still may offer opportunities for relatively low-cost energy savings and emission reduction. From a national cost perspective, these savings are much more attractive than further savings in the households and services sectors. However, if each sector has to bear the major part of the costs itself, energy-intensive sectors exposed to foreign competition will probably get in trouble, while the sheltered sectors, which are usually less energy-intensive, do not face any considerable problems.

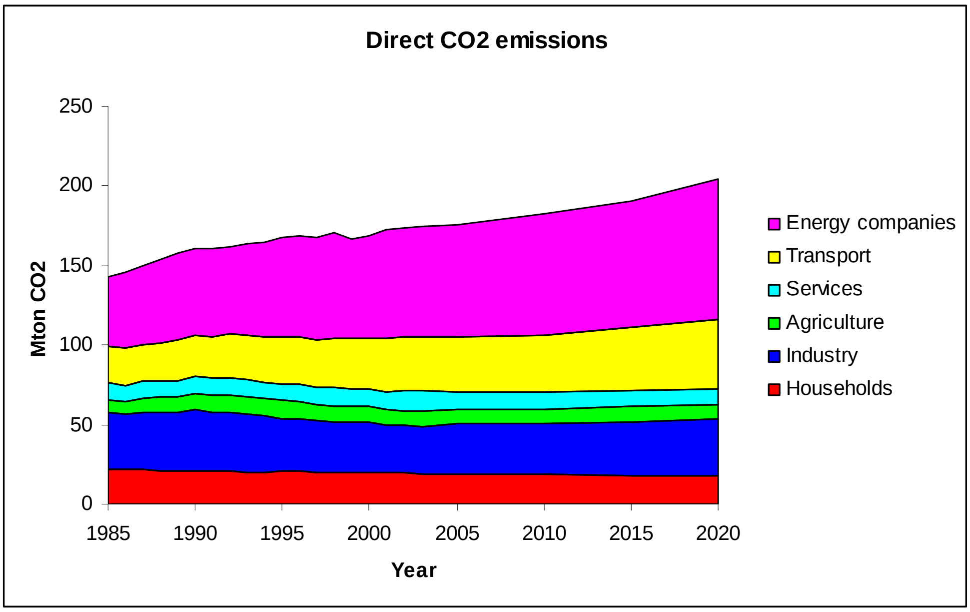

Figure 3.2 *Direct CO_2-emissions by main sector*

9 This concerns a rough translation of a wide variety of policy measures into one indicator: €/ton CO_2. of the marginal option that is either required or economically attractive because of policies. Estimations are based either on policy induced energy costs increases that are translated in €/ton CO_2, or on the approximate costs of the marginal option required to meet standards and regulations. Within sectors, there may be considerable variations due to location specific factors, support for specific measures or projects, etcetera, hence the often-considerable ranges stated.

3.4 Energy use and emissions

The fossil energy use and CO_2-emissions continue to increase towards 2020, despite considerable energy savings and the application of renewables. The next chapter will show in deeper detail how industrial energy use and emissions develop. However, it is also important to consider industrial energy use and emissions in relation to other sectors, in order to evaluate the importance of the industry in GHG and supply security issues. In terms of direct CO_2 emissions (Figure 3.2), both the energy sector and the transport sector are larger, and faster growing. Industrial direct CO_2 emissions (excluding refineries) continue to increase, though at a moderate rate. Direct emissions of households, services and agriculture decrease at a slow rate. However, an important part of changes in the emissions of the energy companies originate in developments in the end-use sectors. Figure 3.3 of the total primary energy use by end-use sector (energy use including conversion losses at the energy companies) shows that the industry is both the largest and one of the fastest growing energy consumers. From a supply security perspective, the industry emerges here as the most important sector, the more so as its energy consumption consists for a major part of oil and oil products.

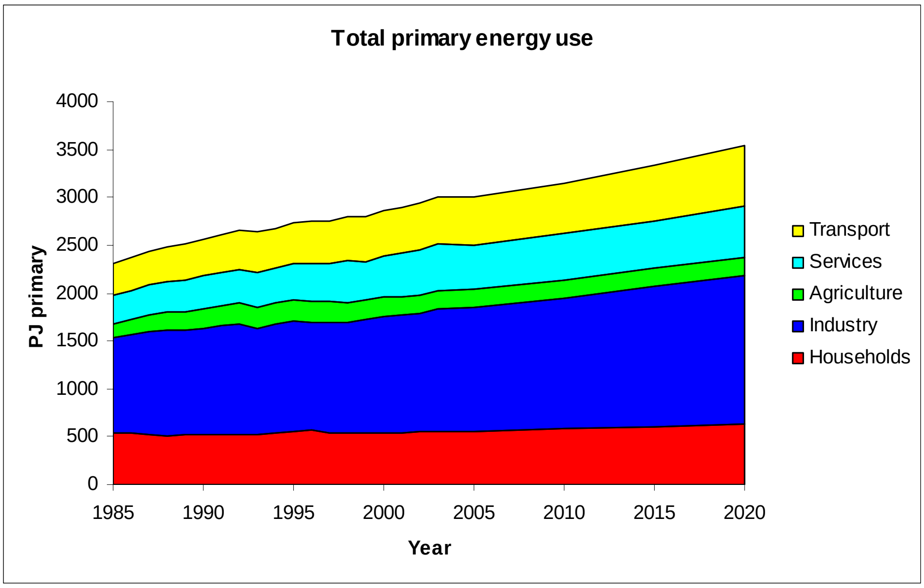

Figure 3.3 *Total primary energy use by main sector*

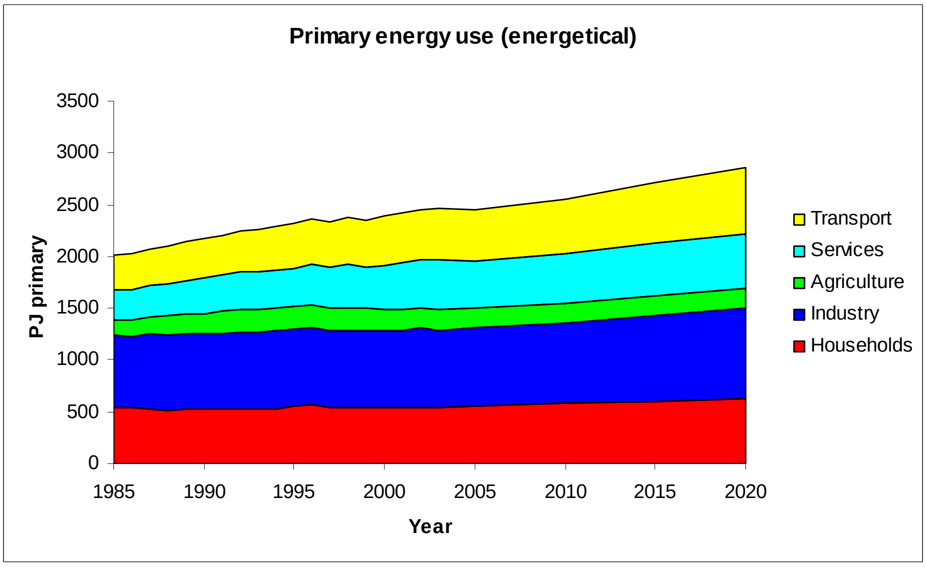

Figure 3.4 *Primary energy use for energetic purposes by main sector*

For a breakdown of Dutch CO_2-emissions to end-use sectors, total primary energy use is not a good measure. In the industry, a major part of energy use is feedstock, which does not result in emissions in the sector itself. Primary energetic energy use, shown in Figure 3.4 is a better indicator. Based on this, the industry again emerges as the most important sector, but not nearly as dominant. Moreover, the energetic primary energy use of the industry grows in a much slower rate than the non-energetic energy use.

The increase in energy use does not imply that there are no energy savings. According to the definitions of the energy savings protocol [Boonekamp, 2001; Boonekamp, 2004] are the savings relatively to a reconstructed frozen-efficiency energy use[10]. Yearly savings in the 2005-2020 period average on about -1% for the Dutch economy as a whole. Table 3.3 shows that savings differ considerably by sector.

Table 3.3 *Annual energy savings by main end use sector and national*

[%]	Savings according to protocol		
	1995-2002	2000-2010	2010-2020
	Historical	GE	GE
Industry	-1.0	-1.0	-0.8
Transport	-0.4	NA	NA
Households	-1.2	-1.3	-1.1
Trade, Services and non-commerci	NA	-0.4	-0.4
Agriculture	-1.7	-1.7	-1.3
Energy companies	-0.1	0.0	-0.2
National	-1.0	-1.0	-1.0

[10] The sign of the saving numbers expresses the influence on actual energy consumption. A savings percentage of -1% a year implies that the actual consumption of energy grows 1% a year slower or decreases 1% a year faster than the hypothetical energy consumption in case of a constant energy-efficiency would do. Therefore, negative numbers indicate an increase in energy-efficiency, while positive numbers imply a decline in energy-efficiency.

4. The Dutch industry and refineries towards 2020

4.1 Economy

With an economic growth of 2.3%, the industry grows only marginally slower than the national average. Within the industry however, growth rates differ considerably. Contrary to the global and European trends, energy intensive sectors in the Netherlands are expected to grow at above average rates, especially the base chemical industry. This specifically Dutch situation is due to the advantages resulting from the geographical position of the Rotterdam harbour area and the presence of well-developed chemical-industrial agglomerations. It is also consistent with the developments in the 1990-2000 period.

Table 4.1 *Economic growth by industrial sub sector*

Added value	2000 (M€)	1996-2000	2001-2005	2006-2010	2011-2015	2016-2020
Base metal industry	2029	2.1%	0.2%	2.3%	0.9%	0.9%
Paper industry (excluding printing)	1683	2.6%	0.6%	1.9%	1.1%	1.1%
Chemical industry	8412	2.8%	2.4%	3.5%	4.0%	4.2%
Food industry	10909	1.2%	1.4%	3.2%	3.6%	3.6%
Other industry	14185	2.8%	-0.5%	2.3%	0.8%	0.8%
Building materials industry	2492	3.6%	-0.3%	2.2%	1.9%	1.8%
Other metals industry	18484	4.2%	-1.4%	1.2%	1.8%	1.7%
Refineries, cokes and nuclear	1411	-10.0%	2.1%	3.6%	4.1%	4.1%
Total manufacturing	59605	2.5%	0.1%	2.4%	2.3%	2.5%

4.2 Energy and CO_2-policies

Historically, the policy pressure on the industry has generally been low. The costs of the energy saving or CO_2-emission reducing options, induced by energy taxes or required to meet the targets for companies, have never been very high[11]. In this respect, the baseline projection is no different. The only policy measure providing additional incentives for CO_2-emission reduction is the CO_2-emission trading system, with a gradually (but slowly) rising CO_2-price. The importance of other policies is likely to decrease as the CO_2-prices rises. As a result, the net policy pressure on the industry will hardly rise. The policies listed here include only the ones that are supposed to be active and concrete.

Total effects

In determining the policy effects it is important top distinguish the effect of current policies and those of past and future policies. In the reference projections for example, the anticipated end of the emission trade system influences investments in CHP after 2020. In addition, the energy policies of the 1990, especially the MJA’s have contributed to making companies aware that energy savings can result in considerable costs savings, and that active search for savings options can be profitable. The policy effects listed here include these past and future influences.

The total effect of energy and CO_2 policies is about 60 PJ, or 6 Mtonne CO_2, of which about 2.7 Mtonne is due to savings on final energy use. It is not really possible to give a breakdown of the effects by policy measure. Effects overlap and complement each other, resulting sometimes in antagonistic or, on the contrary, in synergetic effects. In addition, part of the policy effects is due to the very fact that there has been already a long history of energy policies. As a result of

[11] MJA's and benchmarking covenants take cost-effectiveness as a precondition.

this, companies have a stronger focus on energy savings than would otherwise be the case. Even if all energy policies were suddenly abandoned, companies would only revert to their "policy-free" attitude after a very long period. It will be clear that this kind of interactions allow only a very approximate indication of the effects of individual policies.

CO_2-emission trade system
For the industry, the European CO_2-emission trade system is more important than for the Dutch economy as a whole. Within the baseline projection, it is the only newly introduced policy measure, and the only source of increasing policy pressure on the industry, however small. The relatively low CO_2-price combined with the free allocation of emission rights gives no reasons to assume a deterioration of the Dutch industry's competitiveness. Therefore, the projection does not include effects such as a slow-down of economic growth. The effects of CO_2-emission trade system are likely to be strongest in sectors with a high consumption of fuels with high emission factors, such as the primary steel industry. Table 4.2 shows the development of the CO_2-price and the equivalent effects on the marginal costs of combustion of natural gas and coal. It will be clear that the effects of the CO_2-price in the projections are very limited in the case of natural gas, especially in comparison to the commodity price of around 4.2 €/GJ. For coal, with a commodity-price of around 1.5 €/GJ the effects are much more substantial.

Table 4.2 *CO_2-prices and effects on combustion costs of natural gas and coal in ct and%*

	-2004	2005-2007	2008-2012	2013-2020
CO2-price €/tonne	0	2	7	11
Effect on cost of natural gas combustion (€ct/m3)/%	0	0.35/3%	1.24/11%	1.95/15%
Effect on cost of natural gas combustion (€/GJ)/%	0	0.11/3%	0.39/11%	0.62/15%
Effect on cost of coal combustion (€c/GJ)/%	0	0.20/14%	0.70/48%	1.10/76%

The financial impact of the emissions trade system on the industry is rather limited. CO_2-prices are low and companies acquire the major part of the required emission rights for free by a system of grandfathering. It is not to be expected that companies get in serious financial problems due to the emission trade system. To illustrate this, Table 4.3 shows the costs associated with emissions trade for the chemical industry, for five CO_2-prices and four different amounts of emissions rights the sector has to buy. In comparison with an added value of over 8 billion in 2000 and over 11 billion in 2010, the impact is very low, even in the most unfavourable situation. With expected CO_2 prices until 2020 of no more than 11 €/tonne CO_2, it will be clear that at current price projections and allocations, the Dutch industry has nothing to fear from the emissions trade itself. Only the resulting increase in electricity prices may be a cause for concerns.

Table 4.3 *Financial impact of CO_2-emission trade on the chemical industry for varying CO_2-prices and allocation deficits in 2010.*

Chemical industry	2010 emission (Mtonne CO_2): 13.5				
	Electricity consumption (PJ_e): 34.8	Allocation deficit (% and Mtonne CO_2)			
		5%	10%	15%	20%
Equilibrium price	Maximum rise in electricity costs	0.79 Mt	1.58 Mt	2.37 Mt	3.16 Mt
(€/t CO_2)	(€/MWh)	Costs of required additional emission rights (M€)			
5	21	3	7	10	14
10	42	7	14	20	27
15	63	10	20	30	41
20	84	14	27	41	54
25	105	17	34	51	68

Energy taxes
From 2004 onwards, the REB (regulating energy tax) and the BSB (fuel tax) merge into the EB (energy tax). It is a degressive tax: the marginal tariff is lower when the energy consumption is

higher. The EB applies to fossil fuels and electricity. To prevent double taxation, fossil fuel consumption for power generation is exempt. As most industrial companies, and especially energy-intensive companies are among the larger consumers, the typical industrial marginal tax is low, and the effects of the tax are only weak. The reference projection assumes a coupling between the CO_2-prices in the emission trade system in such a way that the tax for a non-trading sector is always minimally as high as the tax of a trading sector plus the increase in the marginal costs of combustion in the trading sectors due to the CO_2 price.

Benchmarking

The Benchmark Covenant has been the most important policy instrument directed at the energy-intensive industry. It doesn't have a strongly coercing nature; its effect is much more that it forces companies to consider energy-saving measures and to explore more possibilities than they would have done otherwise, rather than that it forces companies to take these measures. The Benchmark covenant obliges companies to belong to the world top of energy-efficient companies in their sector. In practice, it is often not very difficult for companies to show that they belong to the world top, especially when CHP is included in the overall efficiency.[12] In addition, the covenant obliges companies to take energy saving measures if these have an internal rate of return of 15% or higher. Only if companies are not capable to meet the Benchmark, a lower internal rate of return criterion of 6% applies. In some case this may force companies to take measures otherwise not taken. Despite its limitations, the Benchmarking Covenant makes companies more attentive to possibilities for energy saving, and increases the number of energy-saving projects evaluated and implemented. By and large, the Benchmarking Covenant applies to the same companies that participate in the CO_2-emission trade system; it also plays a role as a basis for the allocation of CO_2-emission rights. With increasing CO_2-prices, the additional effects of the Benchmark are likely to disappear, because the economic incentive to reduce emissions prevails.

MJA-2

The MJA-2 is the follow-up of the first generation MJA's, and applies to the companies not participating in the Benchmarking Covenant. It is therefore less relevant for the energy-intensive industry. In addition to many terms that are more or less comparable with the Benchmarking Covenant, the MJA-2 also includes the "verbredingsthema's". These refer to efforts of the industry to develop and design products in such a way that they use less energy during further processing, transport and in the consumption phase. It will be clear that the effects of this usually do not become visible within the producing company, but in other sectors.

MEP-WKK

The MEP-WKK is a subsidy on the electricity production by CHP, granted as €ct/kWh. After an introductory year in which the subsidy applies to each generated kWh, from 2005 onwards the MEP-WKK is based on the so-called blue kWh. These are the kWh that, in comparison with separate generation of heat and electricity, are considered CO_2-free. The share of blue kWh depends on the CHP-type and the way of operating it. The level of the MEP (in €ct/kWh) is based on the required additional electricity price that is just sufficient to allow cost-effective operation of the CHP. The actual level is not fixed for a longer period, but is determined each year anew, and may even become zero. As a consequence, changes in electricity prices will lead to a compensating adjustment of the MEP. The uncertainty of the actual level reduces the effectiveness of the MEP; it is unlikely that investors take the MEP in account in their decisions on new CHP-capacity. It may only play a minor role in increasing the production of existing plants and prevention of their closure. In the baseline projection, the practical importance soon decreases to zero, due to the projected gradual rise in electricity prices.

[12] see Van Dril 2005

EIA
The EIA is a fiscal instrument, allowing discount on company taxes of the amount invested in energy saving measures. In effect, it works out as a subsidy of on average 13% of the invested amount, regardless of the energy saved. A recent revision of the EIA has reduced the number of measures eligible. This serves to reduce the number of free riders[13].

CO_2-reduction scheme
The CO_2-reduction scheme is a fund for subsidies for CO_2-emission reduction projects. Proposals for projects are evaluated individually.

4.3 Energy savings

Energy savings according to the definitions of the savings protocol are the savings relatively to a reconstructed frozen-efficiency energy use. Savings are expressed as an annual percentage. The savings protocol attributes savings of CHP, whether owned by the sector or by energy companies, always to the end-use sector. The tables on the sectoral energy use characteristics in paragraph 4.4 include the annual savings for the period 2000-2010 and 2010-2020.

Measures
Energy use in the industry is very diverse, and apart from CHP it is hard to identify savings by categories of energy saving measures. ICARUS, the database of saving measures that is used for the baseline projection does not categorize savings measures other than CHP. CHP typically takes account of 10-20% of sectoral energy savings. Other categories of measures that are important include good housekeeping and energy management, process integrations, heat recovery and diverse measures on separation processes. Generic process improvements are the most important sources of better energy efficiency.

4.4 Results for individual sectors

The results presented here refer to the sectoring that has been applied to determine the allocation of CO_2-emission rights. As a consequence, joint venture CHP-installations[14] are part of the power sector. Therefore, emissions of industries consuming CHP-heat are relatively low. In some cases this results in almost opposed trends in the primary energy use and the CO_2-emissions. In recent history as well as in the reference projection, most of the new CHP-plants are joint ventures. This comes out most clearly in the increase in the heat received in most sectors.

4.4.1 Oil refineries

The development of the refineries depends strongly on the demand for transport fuels in the Netherlands. Domestic use consumes about two-thirds of the Dutch production, while one-third is exported.

Both the founding of new locations and the disappearance of existing locations are not very likely, confining production growth possibilities to de-bottlenecking and on-site capacity increases. Important for the refineries are the European standards for sulphur contents in transport fuels. These require the refineries to make large investments, and necessitate a huge

[13] Here, free riders are investors that would have applied a measure even without subsidy, but still receive the subsidy. By exclusion of measures that are becoming profitable without subsidy, policy makers hope to increase the efficiency of the subsidy.
[14] CHP's managed by a joint venture of the company where the installation is physically present and to which it delivers its heat, and an energy company.

increase in production of hydrogen for desulphurisation. This results in additional energy use and CO_2-emissions, without a comparable growth in the product output.

Table 4.4 *Refineries energy use characteristics*

Refineries		1990	2000	2010	2020
Added value	M€		1411	1874	2807
Direct CO_2-emissions	Mton	11.0	11.5	13.1	15.4
Final heat consumption	PJ	89	113	141	175
Final electric consumption	PJ	6	9	12	15
Electricity production	PJ	6	10	8	3
Heat received	PJ	-8	-8	4	20
Primary energy use	PJ				
Fossil fuel consumption	PJ	172	189	191	203
Energetic	PJ	121	151	182	192
Non-energetic	PJ				
Specific savings on primary energy use	%/year			est -0.5	est -0.4

Most new CHP-installations are joint ventures, while some existing industry-owned CHP-installations are closed down. As a result, the refineries change from a net heat producer into a net heat consumer. If the refineries were to generate the delivered heat themselves, 2020 CO_2-emissions would be approximately 1,5 Mtonne higher. Keeping the heat surplus at the 2000 level would result in an additional 0.7 Mtonne CO_2 emissions.

4.4.2 Chemical industry

In the baseline, the Dutch chemical industry and especially the base chemical industry grows faster than other industrial sectors. The growth is also structurally higher than that of the chemical industry in other European countries. This trend is completely consistent with the historical developments, and has its origin in location and agglomeration advantages. In the near future, the construction of the Tweede Maasvlakte offers opportunities to develop new green field locations in the vicinity of existing petrochemical complexes. Another factor to the advantage of the base chemical industry is its relatively low labour intensity, making it relatively insensitive to the unfavourable wage differences with other regions in the world.

Table 4.5 *Chemical industry energy use characteristics*

Chemical industry		1990	2000	2010	2020
Added value	M€		8412	11272	16855
Direct CO2-emissions	Mton	20.9	14.8	13.5	15.6
Final heat consumption	PJ	255	241	281	317
Final electric consumption	PJ	39	42	42	48
Electricity production	PJ	20	11	7	8
Heat received	PJ	10	78	130	140
Primary energy use	PJ	625	703	816	945
Fossil fuel consumption	PJ	561	576	651	763
Energetic	PJ	296	200	186	217
Non-energetic	PJ	260	368	456	535
Specific savings on primary energy use	%/year			-1.1	-0.8

The huge growth in heat received shows that there is a considerable increase in joint venture CHP-capacity. If the chemical industry were to generate this heat itself with natural gas based boilers, 2020 CO_2-emissions would be approximately 8 Mtonne higher.

4.4.3 Paper industry

Developments in the paper industry are determined mostly on European markets. Most producers are European companies with production locations in various European countries, dividing the expansion of their production capacity fairly evenly over the various countries.

The projected savings on primary energy use are rather low before 2010, but after 2010 savings increase considerably due to new drying techniques. The paper industry is an example of a sector in which the trends in primary energy consumption and direct emissions of CO_2 are opposed. This is due to the very important role of CHP, in combination with an expansion of JV-CHP capacity and a decrease in industry-owned capacity. If the paper industry were to generate the heat received itself, the CO_2 emission would increase with at least 1 Mtonne, doubling the emissions.

Table 4.6 *Paper industry energy use characteristics*

Paper industry (including printing)		1990	2000	2010	2020
Added value	M€		4273	4637	5134
Direct CO2-emissions	Mton	1.8	1.6	1.6	0.9
Final heat consumption	PJ	24	26	27	26
Final electric consumption	PJ	11	14	16	17
Electricity production	PJ	5	4	5	1
Heat received	PJ	0	6	8	12
Primary energy use	PJ	47	54	58	59
Fossil fuel consumption	PJ	31	28	28	16
Energetic	PJ	31	28	28	16
Non-energetic	PJ				
Specific savings on primary energy use	%/year			-0.5	-1.2

4.4.4 Base metal industry

In the primary iron and steel industry, both new locations and closing down of current locations are rather unlikely events. De-bottlenecking and capacity increase on the existing locations is the most likely possibility to increase production. A further shift to the upper market segments may contribute to a sustained economic growth.

Table 4.7 *Base metal industry energy use characteristics*

Base metal industry		1990	2000	2010	2020
Added value	M€		2029	2296	2521
Direct CO_2-emissions	Mton	6.5	5.6	9.1	10.1
Final heat consumption	PJ	32	32	40	42
Final electric consumption	PJ	27	31	33	36
Electricity production	PJ	0	1	1	1
Heat received	PJ	1	1	1	1
Primary energy use	PJ	164	163	195	211
Fossil fuel consumption	PJ	92	90	115	124
Energetic	PJ	35	36	44	46
Non-energetic	PJ	56	54	71	78
Specific savings on primary energy use	%/year			-0.3	-0.1

In the sectoring applied by the Dutch statistics institute, coke production is not part of the base metal industry. Both for this reason and because of the large amounts of excess coke oven gas and blast furnace gas exported to the power generation sector, the CO_2-emissions associated with fuel use in the base metal industry are much higher than the amounts shown here.

4.4.5 Food industry

The food industry is divided into roughly two parts. One part is strongly linked to the Dutch agriculture as the main source of its raw materials. Within this part, the raw materials are processed into bulk products, which in their turn are processed into higher value products. The other part of the Dutch food industry depends more on the world markets to obtain its resources. The part concerned with the processing of the raw materials is by far the most energy-intensive. The growth of this part is quite low, due to the meagre prospects of the delivering agricultural activities, in which the gradual cutbacks in EU agricultural support policies combined with environmental demands play a major part. Examples include the dairy industry, part of the starch production, the sugar production and the meat industry. Growth of those parts of the food industry not dependent on domestic raw materials is much more vigorous, due to the traditionally strong position of the Dutch food industry and the available knowledge.

Table 4.8 *Food industry energy use characteristics*

Food industry		1990	2000	2010	2020
Added value	M€		10909	13658	19393
Direct CO_2-emissions	Mton	4.1	4.4	4.4	5.2
Final heat consumption	PJ	58	68	71	85
Final electric consumption	PJ	17	23	28	38
Electricity production	PJ	4	5	5	3
Heat received	PJ	1	7	10	11
Primary energy use	PJ	102	122	136	173
Fossil fuel consumption	PJ	70	76	76	88
Energetic	PJ	70	76	76	87
Non-energetic	PJ	1	0	0	1
Specific savings on primary energy use	%/year			-1.1	-1.0

Despite a nearly constant primary energy use, CO_2-emissions decrease slightly. The major cause for this is the increase in heat delivery by joint venture CHP-installations. If this heat were to be generated by boilers in the sector itself, the direct CO_2-emissions would be around 1 Mtonne higher.

5. Key policy issues in the medium term

5.1 2020: targets and realisations

As a logical consequence of its conservative approach towards policies, the reference outlook does not include a massive introduction of innovative technologies that help in the reduction of CO_2-emissions. In order to get insight in the potential role of new technologies, it is imperative to identify the gap between the emissions in 2020 and the 2020 policy targets. Unfortunately, Dutch policies have not yet explicitly defined targets for the CO_2-emissions in 2020. However, the NMP4 does specify several indicative targets for 2030[15], which may act as a basis for estimation of the 2020 policy targets.

Interpolation based on the 2010 Kyoto targets and the 2030 targets offers the best available estimate for indicative targets in 2020[16]. These serve as a starting-point to identify the gap between emissions and target that additional policies have to bridge, thereby providing potential incentives for the introduction of new technologies. Table 5.1 shows the indicative 2020 targets, each with the resulting distance to target as compared to the emissions in the baseline projection.

Table 5.1 *2020 emissions and indicative targets 2020*

	2020	Indicative target 2020				Distance to target 2020			
		NMP4		Half ambition NMP4		NMP4		Half ambition NMP4	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
CO_2 (Mt CO_2 eq.)	205.4	121	140	145	155	84	65	60	50

The analysis on the possibilities to meet the 2020 targets is based on some very important basic assumptions.

- The analysis is based on the assumption that the Dutch efforts to meet these targets are part of a global effort to reduce GHG-emissions. So, the Dutch economy will not face competitive disadvantages. This also rules out all possibilities to reduce emissions that would merely involve relocation of activities to other countries.
- Emission reduction options will be introduced by order of their marginal costs, cheapest first, unless specific policies provide additional incentives and advantages for particular options, or if certain barriers overrule this order of introduction.
- The specific costs of a particular option will be higher if the speed of introduction is increased, because options will have to be implemented at less favorable moments and locations. In practice, this will make it much more difficult to realize very large reductions.

Table 5.2 shows that in 2020 the industry (excluding refineries) has a share of about 17% or 35.2 Mtonne in the direct emissions of CO_2. The refineries emit 15.4 Mtonne in 2020, or 7%. of national emissions. By their electricity consumption, industry and refineries are also responsible for a large part of the emissions in the power generation sector, approximately 28 and 2 Mtonne, respectively. This brings the total share in emissions to 80.5 Mtonne, or 39% of the total

[15] The NMP4 specifies 2030-targets for GHG-emissions between a minimum of 87 Mtonne CO_2-equivalent and a maximum of 131 Mtonne CO_2-equivalent.

[16] This approach originates from the option document 2020, which makes an inventory of the options available to reduce CO_2-emissions and other emissions in 2020. Interpolation of the 2030 targets from the NMP-4 with the 2010 Kyoto targets results in a set of indicative 2020 targets. In addition to the targets as mentioned in the NMP, the option document also applies targets based on halving the 2030 ambition levels. The NMP-4 only mentions targets for all greenhouse gases together. The option document deduces separate targets for CO_2 by assuming the same ratio between CO_2 and other GHGs as applied in the 2010 Dutch domestic targets.

emissions. It might therefore seem reasonable to have the industry and refineries solve a proportional share of the 2020 distance to target by direct emission reductions and by reduction of electricity consumption. However, in comparison with other sectors such as households, transport and services, policy pressure on the industry and power generation sector in terms of €/tonne CO_2 has been relatively low, both historically and in the reference projection. As a result, 2020 marginal costs of further CO_2 emissions reduction are lower in the industry and power sector than in other sectors. A relatively high further reduction of CO_2-emissions in the industry is much cheaper than proportional allocation of emissions reduction targets[17]. If further reduction of CO_2 emissions requires considerable efforts and causes strongly rising CO_2-mitigation costs, the call for a more cost-effective distribution of reduction tasks will become louder. From this perspective, the aforementioned 24% of the 2020 reduction task is an absolute minimum rather than a fair share. Even when based on this minimum, the additional CO_2-reduction task for the industry would be between 12 and 20 Mtonne of CO_2. An estimated fair share would probably imply at least a doubling. In an evaluation of the effects on the industry and the viability of some new technologies, the implications for other sectors are also important. If for example high emission reductions are possible in the power sector at a lower price than in the industry, the need for the industry to reduce its emissions will decrease accordingly.

Table 5.2 Direct emissions of CO_2 by main sector

	CO_2-emission (Mt)			
Sector	1990	2000	2010	2020
Households	21.1	20.2	18.4	17.9
Industry	38.1	31.0	32.1	35.2
Construction	0.8	1.1	1.2	1.4
Agriculture	10.3	10.1	9.4	9.5
Services	11.0	10.8	10.3	9.8
Transport	26.1	32.5	35.8	43.2
Refineries	11.0	11.5	13.1	15.4
Energy sector (excluding refineries)	42.9	53.0	63.0	73.0
Total	161.3	170.0	183.3	205.4

5.2 Policies and measures for the 2020 policy targets

There are several policies and policies presently under consideration that may become effective before 2020. Some of these are very concrete measures (standards, funds, subsidies and taxes), while others have a more facilitating character, or support and direct the research for options. In addition to indicating the direct effect of policies, this text also focuses on the information that policies and policy intentions give with regard to the direction in which policy makers seek for solutions. With this kind of information it is possible to indicate in a very rough way which technologies are more likely to receive additional stimulation in the future.

From this perspective, three dominant factors emerge: the European emission trade system, transition policies and the EOS research strategies. In addition, there may be some specific technology directed factors, such as clean fossil fuel policies and the European targets on bio fuels. The latter, though directed especially on the transport sector, is still important for the industry because of its possible role in the production of bio fuels and the synergy with technologies for biomass feedstock use.

[17] This does not necessarily imply that the industry also has to bear all the costs. A situation in which the households and services contribute to the costs of reduction in the industry may be advantageous for both the industry and the national economy, and also for the households and services.

5.2.1 Emission trade and energy taxes

Emission trade is the policy instrument par excellence that aims at an economically optimised implementation of options, i.e. lowest cost options first. Emission trade as such does not discriminate on the kind of technology, only on the price per tonne CO_2 avoided. The contribution of individual technologies depends on the costs of the technologies and their potentials. With regard to a shift in the applied technologies, energy taxes have an effect similar to that of emission trade[18]. The baseline projection assumes the energy tax in non-trading sectors to be at least as high as the CO_2 price (translated into an energy tax) in the trading sectors, thereby avoiding borderlines and extending the optimising influence of the emissions trade system[19].

The baseline projections assumes a low CO_2-price, and therefore the effects of the emission trade system are only limited. However, if there is sufficient international political commitment to realise larger emission reductions, this will result in much higher CO_2-prices. In order to come near the derived Dutch national targets in 2020, an estimated CO_2-price would be required of at least around 90 €/tonne. In this price range, considerable efficiency increases and energy savings are possible, as well as many renewable power generation options and CO_2-capture[20] and storage [Hamelink et al, 2001]. The CO_2-emission reductions of the latter two categories would probably dominate.

In theory, CO_2-emission trade results in the most cost-effective application of options. Therefore, each additional policy resulting in a different application results in a less-than-optimal situation. As a result, additional policies directed at particular technologies will reduce the cost minimising effect of CO_2-emission trade. Still, there may be reasons to support particular technologies, for example because they contribute to the solution of other problems, or because specific support in the initial stages of a technology helps to open up large and low-cost future potentials. The latter argument is also important in research policies.

5.2.2 Transition policies

Transition policies focus on the process of change towards particular directions. They are not based on targets, but on ambitions. The transition policies in the Netherlands also aim at involving the relevant sectors in the determination and realisation of the long-term targets. The transition process can be regarded as a joint effort of government and companies to find viable ways to realise the long-term ambitions. The transition process leaves the final solutions open: it is also a selection process during which the best and most viable options come to the surface. Concrete experiments and research play an important role in this selection process. Particular options have a better chance of receiving research funds after successful experiments.

As a part of the transition policies, the government expresses the commitment to support the options that emerge as promising and viable from the transition process, on the condition that in the long term the options eventually do not require specific support, other than a substantial CO_2-price. If there is no political commitment on the European or Global level to sustain sufficiently high CO_2-prices, most ambitions will not be viable at all.

[18] There are differences with regard to among others the effect on non-energetic consumption of energy-carriers. If these generate no CO_2-emissions, emission trade will have no effect while taxes have. Another difference is that the impact of CO_2-emissions trade is proportional to the carbon content of the consumed energy carriers, while this is not necessarily the case with energy taxes.

[19] This assumption is based on the preferences of policy makers.

[20] An estimated emission reduction potential of 70 Mton CO_2-emissions reductions by CO_2-capture is available in 2020 at costs of less than 90€/ton. If this potential could be realised in 2020, all the most ambitious of the targets mentioned would be in reach at costs below 90€/ton CO_2.

While the current transition policies try to make clear what the most viable options are, they also give a broad indication of the directions in which policymakers currently think that solutions lie. These broad directions are expressed in the five main transition routes (Table 5.3).

Table 5.3 *Transition routes and subjects*

Transition route	Subjects
Efficient and green gas	- Energy savings - New gases (hydrogen, biogas etc.) - Integration of heat, cold and electricity production, including micro CHP
Chain efficiency	- Process efficiency - Efficient product design, logistics, industrial areas - Use of by-product heat
Green raw materials	- Synthesis gas from organic materials - Manufacture of semi-manufactures and products from biomass
Alternative transport fuels	- Natural gas - Bio fuels - Hydrogen
Renewable electricity	- Biomass - (Offshore) Wind - Various small-scale renewables

The fifth, renewable electricity is not anymore the subject of explicit transition policies, as there is already a history of concrete support measures. Still, the renewable electricity technologies have to prove that in the long term they can do without specific support. For the transition experiments, specific funds are available from the “unieke kansen regeling”.

5.2.3 EOS: energy research strategies

Energy research policies are among the best indicators of the priorities in the perception of the policy makers. The EOS report [SenterNovem, juni 2004; SenterNovem; augustus 2004] gives very good insight in the priorities of the policy makers with regard both to the perceived future role of technologies and the research efforts the Netherlands should make. The contribution to an economically efficient and ecologically sustainable energy supply system with guaranteed security of supply is one of the main criteria for research to be supported.

Table 5.4 *Characterisation of research subjects in EOS*

	Contribution to sustainable energy supply	No contribution to sustainable energy supply
The Netherlands has a leading international position	Priority topics	Export of knowledge topics
The Netherlands has no leading international position	Import of knowledge topics	Non-relevant topics

EOS discerns priority research items based both on their possible contribution to such a sustainable energy system and a top position of Dutch research in the field. Knowledge will be imported on topics that may have an important contribution but in which the Netherlands do not have a top position. The position of sixty research items in the EOS-matrix has been evaluated. EOS 2003 groups these in five focus areas for energy RD&D (Table 5.5).

Table 5.5 *Focus areas of EOS 2003*

- Energy efficiency-improvement in the industrial and agricultural sectors
- Biomass
- New gas/clean fossil fuels
- Built environment
- Power generation and networks

These are the areas that qualify for the proposed RD&D portfolio and will be supported by means of specific policy instruments. Generic policy instruments such as technology subsidies are to support other topics.

The five main transition routes overlap more or less the five focus areas of EOS 2003, but there is no one-to-one relation. If a technology fits both in the EOS profile and in a transition path, this might give better guarantees that there will be funds for pilot projects in case if research is successful.

Table 5.6 *Overlap and correspondence between transition route subjects and EOS focus areas*

Transition route	Corresponding/overlapping focus areas
Efficient and green gas	Energy efficiency-improvement in the industrial and agricultural sectors, New gas/clean fossil fuels, built environment
Chain efficiency	Energy efficiency-improvement in the industrial and agricultural sectors
Green raw materials	Biomass
Alternative transport fuels	Biomass
Renewable electricity	Power generation and networks

From the five focus areas of EOS 2003, the first three contain research items that are relevant for the industry and refineries. The following tables show the items from these three focus areas, with those spearheads that are relevant for industry and refineries in **bold font**.

Table 5.7 *EOS characterisation of research subjects of the focus area energy efficiency improvement in the industrial and agricultural sectors*

Energy efficiency-improvement in the industrial and agricultural sectors	
Priority topics	**- Thermic treatment processes** **- Inorganic membrane technology** **- Heat management in industry and agriculture** **- System approach in horticulture**
Import of knowledge topics	- System approach in the industry - Multifunctional reactors - Cooling technology, industry and built environment

Table 5.8 *EOS characterisation of research subjects of the focus area biomass*

Biomass	
Priority topics	- Biomass, gas cleaning and conditioning **- Bio refining** - Biomass conversion, combustion in power plants
Import of knowledge topics	- Biomass, preparation/food - Bio fuels (transport sector)

Table 5.9 *EOS characterisation of research subjects of the focus area new gas/clean fossil fuels*

New gas/clean fossil fuels	
Priority topics	**- Underground CO_2 storage** **- CO_2-capture technology** - Fuel cells (PEMFC, SOFC) **- Hydrocarbon reforming to H_2** - Advanced coal conversion with CO_2-capture
Import of knowledge topics	- Natural gas conversion, gas turbine technology

5.2.4 Technology directed targets and policies

Clean fossil fuels

In addition to the MEP for renewable power generation and CHP, there is also money put aside for power generation technologies applying CO_2-capture. However, there is still no concrete MEP-tariff[21]. If there is going to be one, it is very probable that the tariff will be determined in the same way as the current tariffs for renewables, i.e. based on the additional costs per kWh_e generated, and with a predetermined maximum. Based on the currently specified maximum, the MEP might be between 6 and 7€ct/kWh_e for existing power plants and between 4 and 5€ct/kWh_e for new power plants, but this is highly speculative and also depends on the electricity markets and the CO_2 price in the emission trade system.

On the other hand, clean fossil fuel technologies are also likely to play an important part in the price setting of CO_2 emissions rights, provided that the emission reduction targets are strict enough and the major part of emissions reduction has to be realised within Europe. If the potential is large enough, CO_2-capture may constitute a natural upper limit for the CO_2-price, and thereby to the marginal costs of other energy saving measures. For existing power, the CO_2-capture costs are between 70 and 90€/tonne, for new power plants the costs are lower, between 50-70 €/tonne. If energy prices in 2020 are higher than assumed in the baseline projection, the costs of CO_2-capture will be somewhat higher, due to the efficiency penalties associated with CO_2-capture.

Bio fuels

For bio fuels, there are rather concrete 2010 indicative European targets. All EU member states should have at least a 6% share of bio fuels in their total automotive fuel consumption. The share mentioned for 2020 is much higher, 25%. In addition to CO_2 emission reduction, bio fuels also contribute to a decreased dependence of foreign fossil fuels.

As the Netherlands have not yet introduced concrete policies to meet these targets, in the reference projection the Netherlands do not make a start with the introduction of bio fuels. However, there are now some concrete plans to increase the share of bio fuels. It is likely that in the end, the Netherlands will try to catch up with the European trends. The most likely active

[21] There is no information on the actual level of this MEP-tariff, only a maximum of 7€ ct/kWh is specified. The available budget until 2006 will be around 23M€ per year. At 7€ct/kWh this is sufficient for about 0.33TWh, thereby avoiding between 0.12 and 0.24 Mton of CO_2 for natural gas based and coal based power generation, respectively.

support policy is a lower or even zero consumer tax on bio fuels. This will create a considerable incentive for the introduction of bio fuels. A consumer tax-free bio fuel would imply a support level of over 300 €/tonne CO_2 for diesel-substitutes and of over 500 €/tonne CO_2 for gasoline-substitutes. It will be clear that such high support levels can only be sustained during a relatively short start-up period with a low share of bio fuels, during which bio fuel production costs have to drop considerably.

5.3 Longer term policy challenges

In the longer term, it is much more difficult to define quantitative policy objectives. However, identifying the items that are likely to play a prominent role in policies is much easier.

In the first place, global warming is likely to remain an important issue. Continuing and worldwide efforts will be required to cut back fossil energy use and CO_2-emissions However, the costs and consequences associated with global warming are not evenly divided between countries. There is a chance that some countries will refuse to take costly measures to reduce emissions, as they see more advantages than disadvantages in climate change. Another important consideration that may prevent countries from taking measures to reduce CO_2-emissions is that in some cases the costs of adaptation are lower than the costs of mitigation. In addition, the effects of the adaptation are more certain as they do not depend on the willingness of other countries to cooperate. So there is a considerable chance that, even when there is global consensus about the antropogenic-increased greenhouse effect, there will be no consensus about the way this problem should be addressed. The developments with regard to the Kyoto agreement give no reason to great hope, in this respect.

Other issues that will be of growing importance are security of supply and the depletion of fossil energy resources. Especially for oil it is likely that there will be an absolute shortage in the mid 21^{st} century, but the marginal extraction costs will rise long before that. In addition, many countries with oil resources are not among the politically most stable states and economies. Even without the global warming threat, this will provide enough reasons for many countries to decrease their dependency on the finite oil reserves. So, while the greenhouse effect may be the more urgent matter, fossil fuel depletion and other supply security issues are likely to play a role in future policies.

6. Prospects for selected technologies

6.1 Options for the 2020 targets

With the broad outline of the targets and policies that play a role towards 2020 and beyond, it is now possible to give a very rough indication of the extent to which the research on and application of some selected technologies is likely to be supported. Such information can be vital to the choice and selection of research programmes. In addition, it may help in identifying gaps in the policies: situations in which there is insufficient support for technologies that still may play an important role in the realisation of the 2020 and longer term targets.

The criteria for the evaluation of technology prospects are in essence as follows:

- Costs. In the long run, technologies have to be viable without additional specific support policies. Generic policies such as CO_2-emission trade and energy taxes, and (rising) energy prices as such have to be sufficient to provide technologies with the required competitive power. The transition policies even explicitly state that support should only be temporal, to aid technologies in their initial phase. In addition to the costs per se, the potential reduction of CO_2 emission or energy use should be sufficient to justify additional support in the initial stages. Both the costs range in €/tonne CO_2 and €/GJ_{prim}. savings are important, indicating respectively the costs of their contribution to solving the climate change problem and the supply security problem. The lower the (long-term) costs, the larger the chance that technologies will penetrate due to CO_2-emission trade, energy taxes or high energy prices, and will not require specific support policies.
- Transition paths. Inclusion of a particular technology in a transition path is an indication that it is recognized as a potential contributor to the future energy system. Dutch government has declared its commitment to support the promising outcomes of the transition paths. It will be clear that inclusion in a transition path improves the prospects for future support policies.
- Key-role. Within a transition path or a sector, a particular technology may be essential, for example because of the lack of alternatives, or its facilitating role for other technologies.
- Targets. Targets not met indicate the need for (additional) support policies and standards. Targets may give an indication of policies or policy intensifications to come, and of the ambitions of policy makers with regard to specific technologies.
- Support policies and standards. This is the most concrete indication of the perceived importance of a technology. If options are eligible for specific support policies, or play a role in meeting certain standards, there are additional incentives on top of the effects of emission trade and energy taxes.

Recognition of a technology as promising may be necessary for eliciting the required research funds in the Netherlands, but it is not sufficient. Other factors also influence the chances that research on a technology will be awarded funds.

- Contribution of research. Research has to be able to contribute to solving the barriers that prevent the actual implementation, such as technical problems and high costs. The contribution of research depends among others on the development phase. In the initial phases, research usually contributes more to cost decreases than in the final phases. In the final phases, the major part from cost reduction originates in learning by doing.
- Position in EOS. The EOS energy research strategy classifies options based on their potential contribution to solving long-term energy problems and on the knowledge position of the Netherlands, as described in the previous chapter.

The following tables give an indication of the prospects of some selected technologies and of research thereon. The technologies receive a rating on several individual aspects, such as costs range, position within a transition path, key-roles and others. However, due to the entirely different nature of the criteria, it does not make sense to give an overall rating. A technology may have a good rating on almost every aspects, and still face insurmountable problems in one.

Energy-efficiency in the industry

Energy-efficiency in the industry includes a wide variation of options. The transition path chain efficiency mentions process-efficiency, optimised product design and logistics and use of waste heat. Improvement of energy-efficiency has many hues, and both the technologies involved and the costs vary widely. The currently identified saving potential at lower cost levels is rather limited, and it is probably one of the main research tasks to open up a larger low-cost potential. Energy-efficiency improvements fit within all conceivable transition paths, and they often contribute in an important way to the feasibility of these paths, as they reduce the need for energy generation and conversion and thereby the energy losses of these.

Table 6.1 *Prospects of energy-efficiency technologies in application and research*

Technology prospects		
Costs range (€/tonne CO_2)	Net benefits (below zero costs) to very high costs (>250), contributions in every costs range. However, the potential in the lower cost ranges is fairly low.	--/++
Costs range (€/GJ_{prim} savings)	Net benefits to very high costs (>), contributions in every costs range. However, the potential in the lower cost ranges is fairly low.	--/++
Transition path	Efficient and green gas; Chain efficiency	++
Key-role	In the long term required for the feasibility of virtually every transition path with sustained economic growth.	+
Targets	Savings of 1.3% a year nationally, current realisation about 1%. Current savings in industry about 0.9%. Attaining the national target will require policy intensifications	+
Support policies, standards	Currently the EIA and Benchmark/MJA2 provide very moderate incentives. Policy makers are showing renewed interest in energy savings, but this has not yet resulted in new policies.	-/+
Research prospects		
Research tasks	Include both the development of new options for energy saving and research for cost-decrease possibilities for known ones. Implementation often requires scrupulous tuning on specific process requirements.	+
Position in EOS	One of the five focal areas, three spearheads	+

CO_2-sequestration

CO_2-sequestration is not undisputed because of the supposed risks of underground and undersea storage, the fact that it results in more rather than less energy-use and the fact that is not sustainable. As such it has adverse effects on fossil fuel depletion and supply security, and it does not contribute to a sustainable energy supply system and an increase of supply security. If fossil fuel depletion causes prices to rise, this will decrease the attractiveness of CO_2-sequestration. Likewise, energy taxes have an unfavourable effect on the attractiveness of CO_2-sequestration.

The main attractiveness of CO_2-sequestration is that it opens up a very large potential in the costs range below 100€/tonne CO_2. In order to achieve really substantial CO_2-emission reductions in the middle term (2020), CO_2 sequestration may be essential. In the longer run, renewable based energy technologies are likely to take over, but in 2020, availability of easy-to-implement, relatively low-cost renewables will be in short supply.

Table 6.2 *Prospects of CO_2-sequestration technologies in application and research*

Technology prospects		
Costs range (€/tonne CO_2)	From about 50€ to 120€, depending on the fuel, technology and new capacity versus retrofit. Large potential at around 80€/tonne.	-/+
Costs range (€/GJ_{prim} savings)	Negative: Efficiency loss	--
Transition path	Efficient and green gas	+
Key-role	In the middle term probably essential for realising considerable CO_2-emissions reduction at costs below 100€/tonne.	+
Targets	None specific	-
Support policies, standards	Currently none, but there is a very limited budget for a MEP-subsidy on power generation with CO_2-capture	-/+
Research prospects		
Research task	Lower costs and efficiency penalties are required for large-scale implementation.	+
Position in EOS	Focal area New gas/clean fossil fuels with four spearheads	+

Biomass feedstock use

Biomass feedstock use is an alternative for the use of oil feedstock. Current use of biomass as a resource is generally limited to the use as such (e.g. wood, paper) or the extraction, concentration and modification of valuable compounds already present in the biomass, (e.g. for pharmaceutics). However, biomass feedstock may also be used as an alternative for crude oil. Various processes may convert crude biomass to liquid and or gaseous hydrocarbon compounds.

Biomass feedstock use may compete with use as bio fuel if biomass is in short supply. However, in case of the conversion of by-products from bio fuel production there may be synergies. A ranking of biomass uses from low to high value applications ranks from stationary energy, mobile energy, materials, to biochemicals and medicines.

Table 6.3 *Prospects of biomass resource technologies in application and research*

Technology prospects		
Costs range (€/tonne CO_2)	Varying, wide cost range, no direct CO_2-effect if carbon is fixated in the products	-/+
Costs range (€/GJ_{prim} savings)	Varying, wide cost range	-
Transition path	Green raw materials	+
Key-role	Only possibility to achieve an industry not dependent on fossil fuels	+
Targets	Currently none	-
Support policies, standards	Currently none	-
Research prospects		
Research task	Research both the development of new processes, the decrease of costs of existing processes and improvements of yield and product quality	+
Position in EOS	One of the five focal areas (Biomass), with one spearhead (Bio refining)	+

Biomass transport fuels

Biomass transport fuels are an important alternative for fossil transport fuels. An advantage of bio fuels is that they offer a technologically relatively easy way of reducing CO_2-emissions of the transport sector. Most modern cars are capable of using bio fuels without major adaptations. Other potential solutions, such as H_2-consuming cars or electric cars require much more radical changes of both cars and the energy infrastructure of the transport sector. Forced reduction of mobility will stumble across huge societal resistance, while solutions such as CO_2-capture are hardly feasible. The lack of short and middle term alternatives for measures in the transport sector may be the most important factor to the advantage of bio fuels. Without additional measures such as CO_2-sequestration and use of renewable electricity, hydrogen and electric cars hardly contribute to reduction of CO_2-emissions and reduction of fossil energy use. So, at least in the middle term bio fuels are likely to have the field for their own as an alternative to fossil fuels in the transport sector.

Current bio fuels are based on relatively high value resources such as ethanol from sugar beets and biodiesel from rapeseed oil. New processes capable of converting low-grade biomass will open up a much larger potential of low-cost biomass, and may result in considerable cost reductions.

Table 6.4 *Prospects of biomass transport fuel technologies in application and research*

Technology prospects		
Costs range (€/tonne CO_2)	>200, highly variable and depending on both biomass resource and conversion process	-
Costs range (€/GJ_{prim} savings)	>25, highly variable and depending on both biomass resource and conversion process	-
Transition path	Alternative transport fuels	+
Key-role		+
Targets	European indicative targets, 5% bio fuels use in 2010	+
Support policies, standards	Currently none, probably fiscal measures before 2010	-/+
Research prospects		
Research task	Stage varying from initial to commercial application. Still considerable cost reductions required. New processes may open up low-quality biomass resources that have much lower prices.	-/+
Position in EOS	In one of the five focal areas, perhaps one spearhead (Bio refining), one knowledge import theme (Bio fuels)	-/+

6.2 Conclusions and recommendations

One main research task emerges as important: Costs reduction. This should not be wondered at: 2020 is not that far away and in order for a technology to play an important role in 2020, its broad technological contour should be known already. Apart from high costs, there should not be much more that stands in the way of implementation.

Another research task that emerges, be it somewhat more hidden, is enlargement of potentials. This is especially important in the longer term, to ensure continuing improvements in energy use and emissions, including the period after 2020.

No single group of technologies is capable of meeting both the CO_2-emissions reduction tasks and the supply security tasks of the industry in 2020. Meeting these tasks at costs less than 30€/tonne, is not possible at all, with whatever combination of technologies. The major part of the CO_2 emission reduction potential is in the costs range of 50 to 100 €/tonne. Especially CO_2 sequestration has a large potential in this costs range. However, CO_2 sequestration, while offering a solution for the CO_2 emissions problem, aggravates the supply security problem. The category of energy-efficiency technologies is the only one to offer a fair potential in the lower costs categories, below 50 €/tonne CO_2. However, even this potential is very limited in comparison to the targets. Biomass based technologies are one of the few to offer perspectives on a fossil fuel free industry. Yet the costs involved are still very high, and as a consequence it is unlikely to play a major role in the near future.

No single technology offers a panacea. A well-balanced portfolio of research items, directed at both creating new low-cost potential and reducing the costs of options already identified is an appropriate answer to the challenges faced by the industry. In addition, providing incentives for the application of higher costs options may further enhance cost-reduction rate of options in the industry.

Reductions in the industry and power sector are the most cost-effective ones. For this reason, it would be logical to enforce higher energy-efficiency standards and lower emissions in the industry. This does not imply that the industry should bear these higher costs. If consumers were to pay the additional costs of options in the industry, it would cost them less than if they had to realise the same emission reductions themselves.

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