Opportunities for export of Dutch sustainable energy technologies

Possible impacts of an international climate agreement

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Abstract

The negotiations for an international agreement on Climate Change could eventually lead to significant necessary investments in technologies that help to reduce emissions. The aim of this project was to find out which technological sectors in the Dutch industry have a high potential to contribute to these global reductions and hence, position the Netherlands as an exporter of low-carbon technologies. Four technologies have been identified and their market potential has been subsequently reviewed and assessed based on potential outcomes of possible scenarios for a global climate agreement.

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Executive Summary

According to the IEA in its Energy Technology Perspectives 2008 (ETP 2008) study the economy is set to grow four-fold globally and ten-fold in developing countries, such as China and India, between now and 2050. This cannot be accomplished without a very substantial increase in energy use. To alleviate the unsustainable pressure on natural resources and the environment, a strong decline in the reliance upon fossil fuels will have to be realized. This means that a large increase of investments in low-carbon technologies will have to be undertaken; the IEA refers to this as 'a new energy revolution'.

Several reports, amongst which the IPCC's Fourth Assessment Report, already provide a clear indication of the current situation and the necessities to meet the energy need in a sustainable fashion: presently, all of the technologies that could lead to the needed reduction in global emissions, if deployed at a large scale globally, are technically viable (IPCC, 2007; ETP, 2008). In addition, some technologies, with a special focus on Carbon Capturing and sequestration (CCS), need to be commercially proven in the next two decades. The additional necessary investment and financial flows in low-carbon technologies and systems (e.g. in 2030 to reduce global emissions to 2005 levels by then) are large by today's measure, but only a tiny fraction of total global investment (under 2% in 2030). In addition, much of the need for low-carbon technologies, both in the short and long term, will be in developing countries.

If these approaches would become an effective post-2012 climate framework component, they might provide opportunities for Dutch industry to add value by export of equipment, know-how and services in low-carbon technology. The Dutch low carbon industry has not benefited much[1] from the export potential created by the Clean Development Mechanism (CDM) and Joint Implementation[2] (JI), although carbon market services have created added value. However, within the European Union the Dutch low-carbon industry is a marginal player[3], and if a situation was to arise where developing countries have targets that include abatement options up to 200 USD[4], its global position could expand considerably. This report analyses how and to what extent the Dutch industry of low-carbon energy technologies could benefit from an international climate agreement, and what policy measures could further influence these opportunities. The underlying assumption is that new export markets will be created that have an impact on the economic situation in the home market, respective the Netherlands. Although at the time of writing the COP 15 had concluded without a binding agreement, the basis of an agreement has been established and it is assumed that it is merely postponed, not negated.

Four technologies have been selected as the study focus as they possess the necessary potential to be interesting for the export market. The four selected technologies are: photovoltaic (PV), Carbon Capture and sequestration (CCS), biomass (specifically 2nd generation biofuels) and offshore wind. Expected export potential has been measured on the basis of the forecasts within the ACT and BLUE scenarios of the Energy Technology Perspectives 2008 of the IEA. For four

1 For example, 13 different Dutch companies have submitted project design documents (PDDs) for a total of 49 CDM projects, whereby only 3 companies offer actual low-carbon technologies. The majority of the projects, 38, offer consultancy services for the mitigation of industrial non-CO2 gases. (UNEP Risoe CDM/JI Pipeline, www.cdmpipeline.org)

2 The mechanism known as 'joint implementation,' defined in Article 6 of the Kyoto Protocol, allows a country with an emission reduction or limitation commitment under the Kyoto Protocol (Annex B Party) to earn emission reduction units (ERUs) from an emission-reduction or emission removal project in another Annex B Party, each equivalent to one tonne of CO2, which can be counted towards meeting its Kyoto target. (http://unfccc.int/kyoto_protocol/mechanisms/joint_implementation/items/1674.php)

3 The Dutch sustainable energy technology sector is ranked 10th by turnover in a EU comparison by the EurObserv'ER 2009.

4 As described by the ETP 2008 for the 'Blue' scenario.

plausible scenarios, the opportunities and risks for the Dutch industry have been outlined. Each of the four studied technologies underlies specific framework conditions concerning current market position of the Dutch industry and its future perspectives. The export potential is linked with the expectation of the contribution of this particular technology to reduction of GHG emissions.

Most low-carbon technologies occupy each level of a product development value chain (i.e. RD & D, diffusion and deployment), meaning that varying competitive advantages exist for the selected technologies, e.g. operation & maintenance of offshore wind. By nurturing these specific competences the Netherlands could establish a strong market position that could be beneficial for its position as a technology exporter.

In this increasingly global market it is arguable if other parts of the value chain, where the Netherlands may have less established competences, will ‘catch up’ in the future, if larger, more competent firms, or entire sectors, exist abroad. However, if the technology is globally still in a very early stage of development, and the surrounding conditions exist (i.e. established R&D institutes) the opportunity exists for the Netherlands to occupy market niches that can provide technology and knowledge exports in the future. As global RDD&D competition grows (e.g. US becoming more active in low-carbon technologies), governmental support for proven and promising technological opportunities in the Netherlands is needed. The type of policy instrument that can be used to further stimulate each sectors’ international presence varies greatly, and requires a specific, tailor-made policy framework.

The role of international collaboration in bringing technologies to the market needs to be understood. It will not be possible from a national perspective to bring certain technologies (e.g. CCS) to the market due to the high investment cost necessary in the demonstration phase. International research collaboration benefits the Dutch industry sector as they will have access to larger financial resources from international funding bodies to demonstrate their technology, while at the same time strengthening the domestic industry players. In the following, more detailed policy advice is provided for each technology. The diagram below also shows the investment in the most likely, yet still ambitious, ‘Blue minimal’ scenario for each of the chosen sectors.

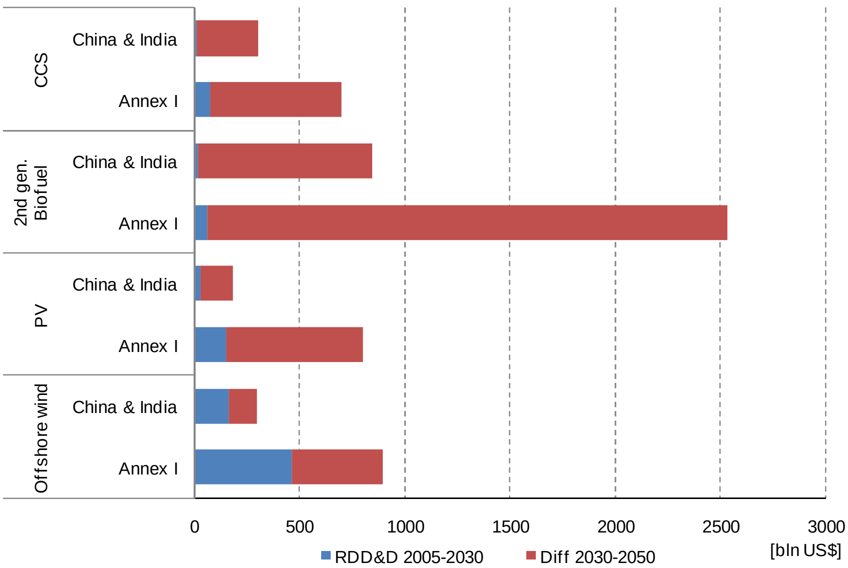

Figure S.1 *Expected investments in a blue minimal scenario*

Photovoltaic (PV)

The Dutch PV sector has suffered from low domestic demand. However, this has made the industry resilient to fluctuations in domestic demand and has forced it to search opportunities abroad. With the increased deployment in Spain and Germany exports have been able to rise slowly, especially from companies like Solland Solar. The increased development of high end manufacturing technology has also increased export flows to China, and has allowed for further diversification in the industry.

Policies needed to strengthen the Dutch PV industry are still based on an increasing local demand. The balance of system industry depends on this, and costs can be reduced for entire systems this way. Germany and Spain, for example, have implemented policies that have expanded their domestic industry, and allowed all components of the PV industry to flourish. This could be done by adopting subsidies that are related to the electricity generation such as feed-in-tariffs, instead of the conventional subsidies that leverage investment costs. This spurs the industry to produce more efficient modules, increasing private R&D investments.

On the other hand research in solar cells is currently very strong and this needs to be maintained. The Netherlands does not enjoy a traditional semi-conductor industry, but it does fairly well in niche products for this sector. The same could be said for PV. To continuously establish itself in the future, research in novel devices and manufacturing techniques must be continued. Building integrated devices offer large potentials for industrialised countries, and the technology efforts needed are more related to manufacturing techniques, than material research. Strong industry cooperation is needed to be able to exploit foreign markets, especially within the EU.

Offshore Wind

The Dutch offshore wind industry is well-positioned within the process engineering sector. This includes e.g. planning, development of foundations, setting-up and operation and maintenance of offshore wind farms. Dedicated harbours for equipment loading and storage are also an advantage. The relative strength in process engineering has benefited from previous experience in the oil & gas sector, however it should be clarified that both sectors have different characteristics and still a lot of experience is gained through learning by doing. Process engineering know-how has the advantage that it cannot be easily replicated elsewhere and is more resistant to external threats such as simple cost reductions for hardware parts (e.g. turbines). Independent research institutes in the Netherlands contribute to the competitive advantage of the Dutch industry through important research on wind park testing and development of key components such as novel foundations that need to be able to cope with the various degrees of water depth in the North Sea. Research also depends on international collaboration to a large extent as R&D is a global issue, not confined only to EU. Research results contribute to the competitive edge of the Dutch industry.

The North Sea area represents an attractive location for offshore wind deployment as water depths are generally not a barrier, despite some deep water areas in the North of the UK and Norway. In addition, most economies located around the North Sea already fully utilized their onshore capacities or decided to focus on offshore wind. Other, less developed world regions as Annex I countries will first develop their onshore potential due to favourable costs.

To keep and strengthen the Dutch position a policy framework for offshore wind should serve both deployment and R&D objectives. To trigger the domestic market for offshore wind a clear and long-term policy is necessary to serve industry with the perspectives for investment security. Besides, learning effects are important for the industry. The current national target of 6,000MW installed offshore wind until 2020 is surely ambitious. It also depends how hard the government is really pursuing the target and which timing to reach the target is applied. R&D support should foster independent research for the institutes, collaborations with industry and international cooperation in research consortia.

Biomass (2nd generation biofuels)

The Dutch biomass sector has established a strong foothold in the trading and blending of currently mainly 1st generation biofuels. The Netherlands benefit from their strategic location as a large number of biofuel feedstocks enter Europe via the Dutch ports. Rotterdam's importance as a trading hub is growing not only because of its importance in Europe, but also due to available blending opportunities. Currently, the R&D focus is on novel 2nd generation production processes such as Fischer-Tropsch, biomass-to-liquid (BTL) and biochemical pathways. This process technology can be utilized through integrated biorefineries that have multiple outcomes, besides biofuels also chemicals, materials or by-products, creating an overall higher value. Biorefineries have the potential to replace traditional oil-based refinery concepts in the future.

It is expected that the Netherlands will further develop to become a major biofuel trading hub in Europe as domestic sources are scarce. Sophisticated biorefinery process technology could emerge as a second industry pilar with opportunities for export. Countries such as Brazil, Sweden, Germany and the US are strong competitors, although some of those countries are still more focussed on feedstocks/production processes for 1st generation biofuels.

The shift towards 2nd generation integrated biorefinery processes requires significant initial investments to realize this new opportunity and gain lessons learned from the operation of demonstration facilities. The Dutch government should foster the investment climate for biorefinery concepts by providing a clear and stable policy framework as a signal of long-term interest towards the industry. Policies related to the initial deployment of biorefinery demonstration plants can help to overcome high investment cost as this technology is in an early stage of development. In addition, continued R&D support is necessary to further improve the effectiveness of processes and enhance efficient use of feedstocks for multiple purposes (e.g. fuel, materials, heat).

Carbon capture and sequestration (CCS)

The Netherlands has two main strategic advantages in the CCS sector:

- Its vast (domestic) experience with offshore engineering and gas and oil exploration, provides the necessary knowledge and experience for the realisation of CCS demonstration sites.
- Its location provides both the advantages of suitable and nearby on and offshore sites, and the proximity of countries like Germany and Belgium, may lead to a transboundary CO_2 pipeline network.

However, there are still several uncertainties surrounding CCS that hinder development in the Netherlands. There has been much controversy regarding onshore CCS in Barendrecht, as nearby inhabitants have purposefully proven at this demonstration site, near the industrial region of Rotterdam. This, combined with the population density of the Netherlands, will most likely force future project to offshore sites increasing both transport and storage costs. In addition, CCS is absolutely depending on EU or international agreements regarding CO_2 prices, to support the financial feasibility of a project. As it does not generate electricity, but instead reduces the efficiency of coal fired power stations, the private sector needs strong and clear indications that the public sector regards this as a necessary future technology.

These two features- the favourability of offshore sites and the reliance on high (international) volumes and CO_2 prices to validate these investment create uncertainty for the Dutch CCS sector. On the other hand, the IEA states that to reach acceptable CO_2 emissions by 2030 and 2050 CCS is absolutely necessary and the associated investments are very large (up to 600bn USD in Annex I countries alone). To leverage private sector investments in CCS, the Dutch government will have to invest heavily in demonstration sites in this phase, either through transboundary network support with neighbouring countries or direct investments in sites. In addition, research will need to be carried out to improve the current efficiency loss due to CCS, requiring dedicated subsidies to programs related to capture processes and CO_2 storage behaviour. It's strategic advantages coupled with increased research focus at scientific institutions and universities, are both factors that could lead to successful offshore demonstration sites, and may lead to a position as global frontrunner in the field.

1. Introduction

1.1 Background

According to the IEA in its Energy Technology Perspectives 2008 (ETP, 2008) study the economy is set to grow four-fold globally and ten-fold in developing countries, such as China and India, between now and 2050. This cannot be accomplished without a very substantial increase in energy use. To alleviate the unsustainable pressure on natural resources and the environment, a strong decline in the reliance upon fossil fuels will have to be realized. This means that a large increase of investments in low-carbon technologies will have to be undertaken; the IEA refers to this as 'a new energy revolution'.

Several reports, amongst which the IPCC's Fourth Assessment Report, already provide a clear indication of the current situation and the necessities to meet the energy need in a sustainable fashion: presently, all of the technologies that could lead to the needed reduction in global emissions, if deployed at a large scale globally, are commercially viable (IPCC, 2007; ETP, 2008). In addition, some technologies, with a special focus on Carbon Capturing and Storage (CCS), need to be commercially proven in the next two decades. The additional necessary investment and financial flows in low-carbon technologies and systems (e.g. in 2030 to reduce global emissions to 2005 levels by then) are large by today's measure, but only a tiny fraction of total global investment (under 2% in 2030, ETP,2008). Much of the need for low-carbon technologies, both in the short and long term, will be in developing countries.

It is especially the last point that presents a major challenge towards reaching a global climate agreement. Developing countries are asked to play a substantial role in emission reductions while industrialized countries must commit to appropriate financing mechanisms. Several flexible mechanisms and policies have been discussed, such as sectoral agreements (e.g., cement production, fossil-fuel production but also large sets of human activity, e.g. passenger-car transport), which could support this investment need and provide industry's decision makers with more certainty over future demand.

If these approaches would become an effective post-2012 climate framework component, they might provide opportunities for Dutch industry to add value by export of equipment, know-how and services in low-carbon technology. The Dutch low carbon or sustainable energy industry has not benefited much[5] from the export potential created by the Clean Development Mechanism (CDM) and Joint Implementation[6] (JI), although carbon market services have created added value. However, within the European Union the Dutch low-carbon industry is a marginal player[7], and was a situation to arise where developing countries have targets that include adoption of more high tech low-carbon technology options up to 200 USD[8] per ton CO_2, its global position could expand considerably. This report will analyse how and to what extent the Dutch industry of low-carbon energy technologies could benefit from an international climate agreement, and what policy measures could further influence these opportunities. The underlying as-

5 For example, 13 different Dutch companies have submitted project design documents (PDDs) for a total of 49 CDM projects, whereby only 3 companies offer actual low-carbon technologies. The majority of the projects, 38, offer consultancy services for the mitigation of industrial non-CO2 gases. (UNEP Risoe CDM/JI Pipeline, www.cdmpipeline.org)

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sumption is that new export markets will be created that have an impact on the economic situation in the home market, respective the Netherlands. Although at the time of writing the COP 15 had concluded without a binding agreement, the basis of an agreement has been established and it is assumed that it is merely postponed, not negated.

1.2 Research questions

Based on the research description the following research questions have been specified that provide guidance for the study and help to establish the further methodology.

1. Which low-carbon energy technologies are expected to be stimulated by a global emission reduction agreement?
2. Who are the Dutch technology suppliers and research institutes of low-carbon technologies, and how is their specialisation positioned globally or in the European market?
3. What possible effects could a global climate agreement have on these Dutch opportunities?
4. What policy measures could further strengthen these opportunities?

1.3 Assumptions

1.3.1 Scenario choice

The first assumption made in the process is that an international agreement regarding a future framework on emission reduction, will be implemented in the very near future. The level of commitment will be indexed by the two scenario maps, Blue and ACT, presented in the Energy Technology Perspectives (ETP) 2008, published by the International Energy Agency (IEA). These maps present investment needs to reach two different levels of CO_2 concentrations in the medium (2030) and long term (2050), differentiated by both technology and region.

In the ACT map, greenhouse gas (GHG) emission reduction is basically frozen at 2005 levels in 2050, while the Blue map is more ambitious and foresees a reduction of 50% of current levels in 2050. These maps have varying consequences for the level of deployment or research per technology *and* region. The parties involved have been split into three groups: Annex I Parties[9], the major emitting and emerging economies of China and India and the remaining countries. By varying the maps across the different regions, 4 scenarios have been created. Table 1.1 shows an overview of these scenarios.

Table 1.1 *Possible global climate agreement scenarios*

	Annex-I Parties	China and India (major emitting emerging economies)	Remaining countries
1. Blue worldwide	Blue	Blue	Blue
2. Blue progressive	Blue	Blue	ACT
3. Minimal Blue	Blue	ACT	-
4. Minimal ACT	ACT	-	-

1.3.2 Scenario descriptions

As mentioned above each scenario will be presented per technology, while the scenarios themselves have been differentiated geographically. The effects are that differences in commitment for a region, say China and India, will also affect Annex-I countries. The globalised market for renewable and low-carbon technology is the main reason for this effect, as well as increased

[9] Annex I Parties include the industrialized countries that were members of the OECD (Organisation for Economic Co-operation and Development) in 1992, plus countries with economies in transition (the EIT Parties), including the Russian Federation, the Baltic States, and several Central and Eastern European States. (Source: UNFCCC).

technology transfer due to higher market uptake. Below is a brief description of the potential effects on these markets for each chosen group.

Blue worldwide
This scenario assumes that all counties would subscribe to the BLUE map; a reduction of GHG emissions by 50% in 2050, which is the most ambitious scenario of the four. Large technology investments would be triggered by increased public spending and policy measures that favour cleaner technologies. For Annex-I countries it would imply a complete overhaul of the current carbon based energy industry, and through increased technology collaboration with countries such as China and India the deployment phase will be sped up, due to generally lower wages in the latter. Emerging economies will implement domestic strategies to develop their economies in a low-carbon fashion relying heavily on renewables and creating industries for elements of the manufacturing chain. Least Developed Countries (LDCs) will benefit from both the lower costs of technology, and the commitment of richer nations to finance an almost complete shift to cleaner technologies.

Blue progressive
This scenario assumes that both Annex I parties as well as the emerging economies of China and India would be committed to reduce GHG emissions by 50% in 2050. This represents a quite ambitious target. This outcome requires large technology investments in both Annex I countries and China and India, as well as trade agreements to ease technology transfer between these parties. It does, however, imply that cleaner technologies will be implemented to a lesser degree in LDCs and other developing countries. However, as these countries represent a small share of total emissions it will not have considerable investment differences. The main change is the reduced financial burden on Annex-I parties and China and India and may lead to increased research and development opportunities.

Minimal Blue
This scenario assumes that only Annex-I countries will commit to the blue investment map while China and India will agree on reducing their emissions based on the ACT map. High investments would still be made in both these groups, but international R & D collaboration will suffer. Private investments from Annex-I parties to China and India would still occur, but public investments in the latter countries would not be sufficient to sponsor international R & D efforts. The investments in the remaining countries will follow a business as usual scenario, and will not be assessed when referring to Dutch opportunities.

Minimal ACT
This scenario is seen as the minimal outcome of the negotiations. In this scenario Annex-I countries would stabilise GHG emissions in 2050 to current levels, still requiring higher increased investments compared to the baseline. Other countries will not make any binding commitments. This scenario assumes that technology transfer is restricted to Annex-I parties, although manufacturing options can still exist outside of this group. Mainly deployment and diffusion is stunted by the fact that the ACT map applies, as opposed to BLUE.

1.4 Limitations of our study

This study is based on a selection of possible scenarios as an outcome of a global climate agreement. Based on the assumed scenarios, conclusions can be drawn regarding the impact on the Dutch sustainable energy industry. Depending on the agreements made, the impact on the technology export will be higher or lower. However, this not only depends on the agreements made. In time, countries with demand for low-carbon technologies might catch up in terms of R&D and a shift of production will take place. World market conditions can change rapidly, e.g. a particular domestic industry could enjoy high governmental support to develop a certain technology.

Therefore, this study represents a ‘snap-shot’ of the current situation regarding the expected outcome of the climate negotiations and the status of Dutch energy technology industry. Based on the current status, it is possible to draw conclusions for the future potential. However, it can only be precise for the present situation. The methodology which has been used is only partly quantitative in its nature and based on certain assumptions. The validity and outcomes of this methodology can be questioned. A further adjustment through interactive consultation would be meaningful.

2. Methodology

2.1 Introduction

As explained above, the final output of this study is a policy recommendation based on several scenarios for a possible international agreement. The methodology for providing answers to the research questions consists of the following steps:
1. Selection of eligible technologies.
2. Inventory of Dutch technology suppliers and R&D institutes.
3. Technology differentiation.
4. Evaluation of current global positions and specialisations.
5. Future projections and assumptions.
6. Assessment of future potential

The technologies are analysed by studying the technology roadmaps from the ETP 2008, Dutch sustainable energy technology statistics and using expert consultations. The technologies are broken down for further analysis into components, for example thin-film solar cells in the photovoltaic technology sector, with regard to the highest future potential and the strongest existing basis in the Netherlands. The following diagram shows the work flow that is used to reach the desired output:

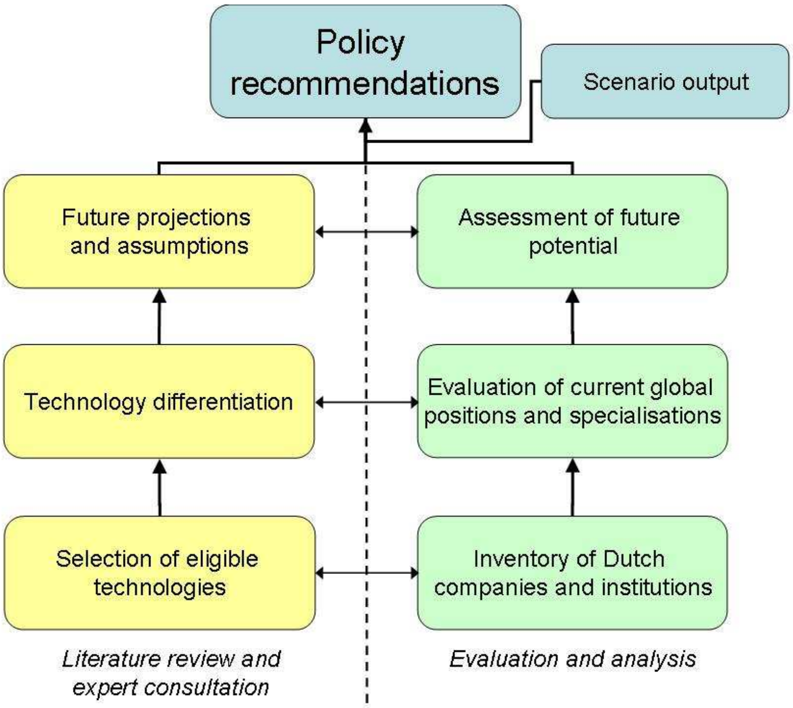

Figure 2.1 *Overview of Methodology*

The literature review and analysis at each stage interact to create a further, more detailed selection to be analysed. The final outcome is a scenario output per technology, which is then used for the policy recommendations. The following subchapters further describe the methodology behind each step.

2.2 Selection of eligible technologies

The starting point of the technology selection is the list of 17 technologies presented in the ETP 2008. Each technology has its own particular roadmap for both the BLUE and ACT map, where the level of deployment and investment is detailed. However, the level of activity in the Netherlands for each technology varies which has consequences for the impact that it will have in the case of increased deployment. Only the technologies that have a potential to profit from increased global deployment will be eligible for further study and must possess the following:

- Deployment must have no ties with international political considerations. The technology must be able to be deployed at the rate of market demands, and not subject to international or domestic scrutiny. An example would be the deployment of nuclear power stations and to a lesser extent, CCS.
- Export potential and possibility to link to existing export trends, implying that the technology can be adaptable to markets beyond the Netherlands.
- A substantial element if used in a larger low-carbon technology system. Technology that represents a fragment or component in a complete system will not be considered.

Each technology assessment is based on literature research and expert interviews conducted at respective units (e.g. Solar, Wind, Efficiency and Infrastructure (E & I) and Biomass, Coal and Environment (BKM)) within the Energy research Centre of the Netherlands (ECN).

2.3 Inventory of Dutch technology suppliers and R&D institutes

It is assumed that the growth of a global industry will primarily be enjoyed by institutions either large in size, or with strong international ties that would allow them to penetrate foreign markets. For research institutes this is characterised by existing connections to sustainable energy industries and work in international research networks, for example European Commission research programs. Private partners have been selected based on their existing export capacity and relative size[10]. Since some of the technology roadmaps contained technologies that were still in very early stages of development, expert interviews were used to evaluate the institute's or companies' respective advances, in relation to other global players. If a technology chosen in the step above would not possess a suitable institute or industrial presence, it would not be selected for further analysis.

2.4 Technology differentiation

The remaining lists of technologies are differentiated into the specific stages along the value chain. Using future projections of these stages (IEA ETP, 2008), an evaluation of a particular stage's future projection can be made. In addition, these stages also allow the identified Dutch companies and institutions to be analyzed in their own niche stage along the value chain, and their prospects for future growth analyzed. For example, research institutes conducting research in a certain niche aspect of a technology but with a large future potential, can be analysed concerning their respective growth in that area.

2.5 Evaluation of current global positions and specialisations

Using the above mentioned differentiation, selected companies and institutes are analysed per technology to determine at which stage along the value chain their current specialisations pertains. This could be specific components of a system, or knowledge related to the deployment and diffusion of the technology. If a technology is in a novel stage of development the position

[10] This has been done using their relative size and growth in relation to other European manufacturers in the EurObserv'ER 2008.

of the respective company/institution is compared to the worldwide developments and efforts (e.g. technology share in R&D portfolio, expectation management).

2.6 Future projections and assumptions

Using the roadmaps in the ETP 2008 for each technology and its future elements, the historic and expected growth and projections in increased production and investments are analysed for both ACT and BLUE scenario. In addition, the assumptions surrounding these outlooks are discussed to provide insight into the consequences for the Dutch export market. The regional deployment projection, for example, could be of great significance to establish the chances for Dutch industry in that market.

2.7 Assessment of future potential

Each selected company or institutes' specialisation in a particular stage of the value chain for a technology is matched to the projections in the ETP 2008. This identifies areas of current strength and weakness, and allows further analysis and recommendations to be carried out. As each technology has different production chains, the opportunities for the Netherlands may not be proportional to global projections. For example, increased deployment of a technology may mean that even though the Netherlands has existing manufacturing facilities, its future role may be more focused towards manufacturing optimisation.

2.8 Scenario output

The influence of the four scenarios for possible international agreements on the Dutch export potential for a certain technology is assessed. Special attention is paid to the assumptions and considerations made regarding future projections made for both diffusion of a technology and research, development and deployment (RD&D). This includes potential growth opportunities for selected sub-technologies, or individual components in the value chain. Another possibility is that the opportunities do not reside in the value chain of the technology itself, but are integrated vertically.

2.9 Policy recommendations

The final result of the study will be a set of recommendations how to strengthen the export potential for each technology. The policy recommendations will also summarize the current strengths of the Dutch technologies and the areas that could be influenced by policies affecting deployment levels, or research activity.

3. Selection of eligible technologies

Using the assessment criteria mentioned in 3.2., the initial list of energy technologies provided in the ETP 2008 was cross-checked with the respective technologies in the Netherlands, 3.3. The resulting list of technologies is the basis for the further analysis in this study and establishes the technologies position in the value chain, to be able to link these to either R & D or diffusion investments.

3.1 Assessment of sustainable energy technologies

Only a number of technologies will fulfil the requirements to be in the focus of this study due to their expected export potential. The overview list of technologies is based on an encompassing list derived from the IEA ETP 2008 and structured according to end-use sectors. Some technologies can have several fields of application, e.g. biomass. This study will treat these technologies as a single entity and not separate per industry sector. Below, a short summary of the assessment can be found, together with an overview of all technologies in the ETP 2008.

3.1.1 Carbon Capture and sequestration

As Carbon Capture and sequestration (CCS) is a technology that is still in a pre-demonstration phase specialisations have not been formed. However, it can be said that the Netherlands is extremely active in the field of CCS. Due to the existing gas infrastructure and the availability of storage sites, both on- and offshore, the Netherlands wishes to place itself as a strategic location for CCS activities for neighbouring countries. Rotterdam harbour, which is also an area of highly concentrated CO_2 emitters, positions itself as the Dutch centre of CCS-activity, and would be a mainland access point for CO_2 transport to offshore sites in the North Sea. In addition, Dutch companies' and institutions' vast experience in offshore engineering and oil and gas exploration provide the knowledge needed to be a frontrunner in CCS-development. The export opportunities can be found in a possible CO_2 network providing both Germany and Belgium with storage opportunities. In addition, the experience gathered can be used to implement and deploy projects abroad. The technology is not undisputed, especially local objections seem to arise.

3.1.2 Nuclear power plants

Nuclear power is a technology that is heavily dependent on political circumstances. The full deployment of nuclear power, especially in developing countries, is rather difficult to assess as it depends primarily on both domestic and international will. Apart from this, the Netherlands will not be a logical choice for countries wishing to seek services or products for the fabrication of a nuclear power plant. France, for example, derives almost 80% of its base load from nuclear power, and has been a front runner in the deployment of nuclear power.

3.1.3 Onshore/Offshore wind

The Dutch wind industry includes a number of small, niche manufacturers of onshore wind turbines. The onshore wind turbine market is already quite developed and the world market is dominated by a number of established players in Denmark, Germany and the US. Future advancements in these areas will be mostly done in bringing down cost through mass manufacturing. But the Netherlands are well positioned in specialized applications for offshore wind. This sector has only recently started and major investments are expected over the next years. It is assumed that the offshore wind industry offers large opportunities for the Netherlands.

3.1.4 Biomass for Energy (2nd generation biofuels)

Due to a favourable location (entry point to Europe) and existing harbour facilities, the Netherlands have already gained a strong market foothold as a biofuel (1st generation mainly) trading hub. Rotterdam offers excellent blending opportunities through the proximity to the oil refining sector. As a next step, 2nd generation biofuels will be produced in biorefineries that will have multiple end-products such as biofuel, materials and heat, thus becoming more efficient. Because of its limited availability of arable land most industry opportunities exist in sophisticated process technologies such as Fischer-Tropsch and biomass-to-liquid (BTL) that could open up export potential.

3.1.5 Solar photovoltaic (PV) systems and concentrated solar power (CSP)

The Netherlands has research centres that are globally renowned for their achievements in the field of solar (e.g. ECN, Technical University of Delft). Research is being conducted on several advanced technologies, ranging in their maturity and time span of deployment, and often involves both private and public partners in a research consortium. The consortia members are not always based in the Netherlands and strong ties exist with German and Spanish research institutes and industry partners. The Netherlands also has companies producing solar modules, solar cells, manufacturing machines and companies that deliver turn-key installations.

Concentrated solar power can be broken down in two elements: large scale power generation plants and household solar water heating systems. Currently several research institutes are studying the possibilities of power generation through CSP, but as the technology mainly relies on conventional technologies (e.g. steam turbines) Dutch efforts will be restricted to heat capture and storage. Deployment is highly unlikely in the Netherlands, as these installations are large in size requiring available (cheap) land, and are often only cost efficient in high solar radiated areas. Solar water heaters have a high deployment potential in the netherlands, but the manufacturing possibilities in the Netherlands are limited. Again, the technology is rather does not require high levels of technology research, and is characterised mainly by the ability to offer low prices. Almost all of the production of solar water heaters is in China, and it is highly likely that this sector will remain in lower income countries.

3.1.6 Energy efficiency

Energy efficiency is typically a service oriented service in the Netherlands. Although suppliers of energy efficient apparatus exist, large manufacturing or industrial components often come from abroad. In the service sector, however, many engineering consultancies exist (Royal Haskoning, Tebodin) that offer energy efficiency services and energy audits abroad. However, when looking at the total investments in these technologies, investments in services are not of equal magnitude of investments in improved boilers, pumps or other industrial components. The export market would be affected by increased attention to energy efficiency, but the gross of these investments would not be in services.

3.1.7 Heat pumps

Much research and attention is paid to heat pumps in the Netherlands. The use of geothermal energy to generate and conserve heat has large energy saving possibilities in the Netherlands. However, the export opportunity of this technology is limited. As the largest markets exist in large countries in Asia, such as China, India and Indonesia, the conservation of heat does not play the vital role that it plays in the Netherlands. The export opportunities would be limited to countries with similar temperate climates, such as the Unites states and other European countries. However, due to the fact that the Netherlands has a gas infrastructure primarily used for heat, the use of heat pumps and geothermal energy has been further developed in Scandinavian countries. Without a gas infrastructure their heat resources would otherwise be limited to fire-wood, or electricity, so using geothermal energy is an off-grid solution for heat generation and conservation.

3.1.8 Electric vehicles

The Netherlands are involved in demonstration projects utilizing electric vehicles, e.g. in Amsterdam (*Elektrisch Vervoer Amsterdam*) and with electricity distribution company Alliander or Essent/Enexis in different communities across the country. The government has recently announced to deploy 200 000 electric vehicles by 2020. Nevertheless, the deployed electric vehicles are not produced in the Netherlands neither is there currently a substantial supply of equipment. Due to the large investments necessary to establish large scale car production facilities and given the international situation that already suffers from overcapacities of conventional cars it seems not likely that the sector provides significant export opportunities.

3.1.9 Hydrogen fuel cells

Hydrogen fuel cells can be used in the transport sector or for combined heat and power production (CHP). Vehicles driving on electricity produced from hydrogen in a fuel cell can be a way of sustainable transport. Some demonstrations of this took place in the Netherlands, e.g. hydrogen busses and a fuel cell boat in Amsterdam. Around Arnhem, companies such as HyGear or Nedstack produce key components for fuel cell applications and are also involved in system integration. Nevertheless, due to the uncertainties concerning a large-scale application of hydrogen in transport/CHP and the current position of the Netherlands it is not expected that this sector will be involved in substantial export activities in the future.

Table 3.1 *List of energy technologies adapted from ETP 2008*

Technology	Current industry and R&D status in NL	Expected future export potential	Follow-up in this study
Power generation sector			
CO_2 capture and sequestration	Strong R&D activities, many available storage locations	Process engineering and CO_2 infrastructure hub	Yes
Nuclear power plans	Research on nuclear technology being carried out but no equipment production	Not expected, highly susceptive to political decisions	No
Onshore/offshore wind	Onshore: production of small turbines and parts. Offshore: Highly specialized companies in process technology	Focus on offshore: Strong position in process technology expected to benefit from large-scale introduction of offshore in North-Sea and international water.	Yes
Biomass	Biofuels: R&D concentrated on 2nd generation, industry 1st generation production, trade & blending	Netherlands becoming the European trading and blending hub for biofuels	Yes

Technology	Current industry and R&D status in NL	Expected future export potential	Follow-up in this study
Photovoltaic	R&D into next generation solar cells (e.g.thin-film), Production locations for high-end equipment in NL	Supplier for production equipment of next generation solar cells	Yes
Coal IGCC/USCSC	No major components produced in the Netherlands	Unlikely provided the current market and competitive situation	No
Built Environment			
Energy Efficiency	High level of component and system design	Not significantly given the current industry situation	No
Heat Pumps	Component manufacturing and high R&D	Not significantly given the current industry situation	No
Solar space and water heating	Mainly R&D for building integrated appliances, solar water heaters have little industry involvement	Possible high end building integrated exports, water heating will be too cost sensitive for specialised industry.	Partially[11]
Transport sector			
Biofuels	see Biomass		Yes
Electric vehicles	Involved in vehicle testing and grid integration but no major production of components	Not expected given the current industry situation	No
Hydrogen fuel cells	Small-scale component manufacturing	Not expected given the current industry situation and international competitive environment (players e.g. Canada, Germany, US)	No

Source: IEA ETP, 2008.

3.2 Technology differentiation and future projections.

After selecting the technologies, they will be divided into specific components that contribute to the whole system along the value chain. This structure allows for easier allocation of the strengths of the current Dutch industry and research and development activities. The value chain aims to describe all major components, including R&D and process engineering to arrive at an operable turn-key solution such as offshore wind parks or a pv installation.

In addition, a better picture is necessary to understand future shifts within each of the technologies that will have an influence on the Dutch industry. An example of these shifts is the relative decrease of one production technology against another one (PV) or a specific technology component in the value chain that will gain more importance in the future.

[11] In this report high-end building integrated space heating and photovoltaics will be handled under solar PV.

A further indication is necessary regarding the geographical distribution of future R&D and deployment investments. Figures are available for each of the technologies, based on the ACT and BLUE maps of the IEA.

3.2.1 Offshore Wind

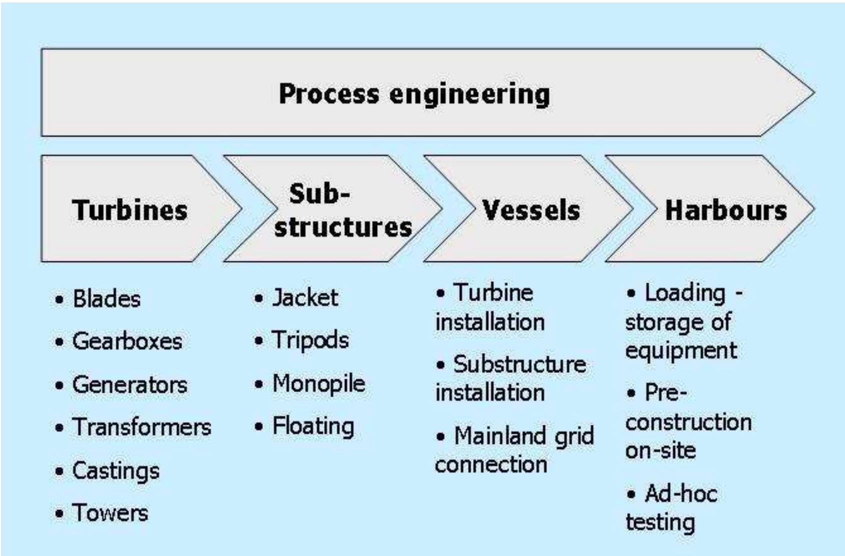

Figure 3.1 *Value chain for offshore wind*
Based on EWEA, 2008.

Wind energy investment scenarios

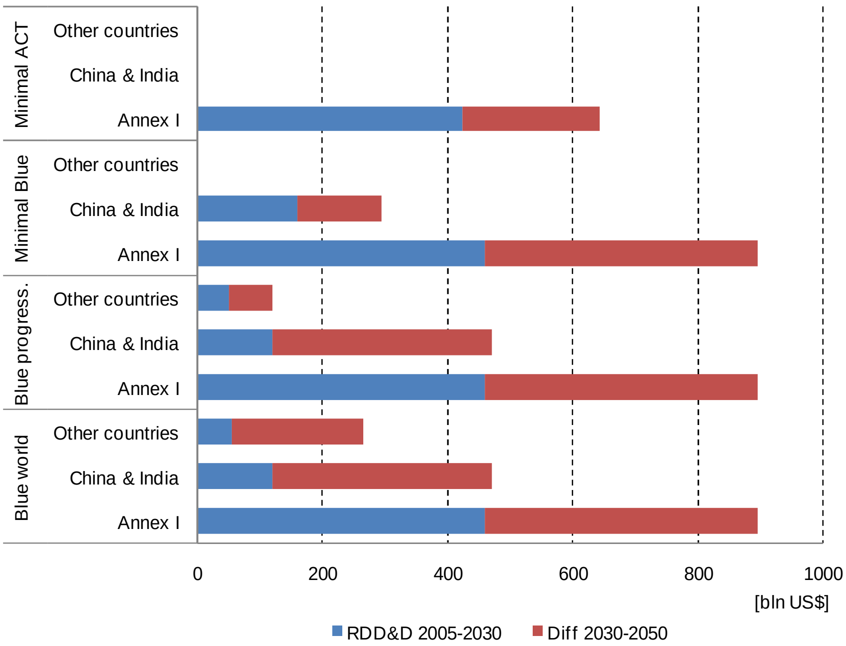

Figure 3.2 *Investment figures for wind (combined onshore/offshore)*
Based on IEA ETP, 2008.

Future projections and assumptions

To increase the operability of offshore wind parks, all technology components need to be further strengthened for resistance against heavy weather influences. High turbine downtimes result in longer maintenance periods were no electricity is produced, thus reducing revenues. This requires novel offshore wind turbine foundations for deeper waters, as well as secure and stable connections to the mainland electricity grid. These are the main necessities to be fulfilled for the

ACT map to make offshore wind cost competitive by 2035. Further R&D in floating platforms could lead to higher deployment and therefore a faster break-even point with traditional forms of electricity by 2030 in the BLUE map. From a geographical perspective, onshore wind energy will enjoy increased deployment worldwide, while Annex I countries will benefit most from offshore developments under the ACT map. This is due to Annex I countries having already occupied the most suitable plots for onshore wind. In the BLUE map, additional deployment of offshore wind in developing countries is assumed.

3.2.2 Photovoltaics

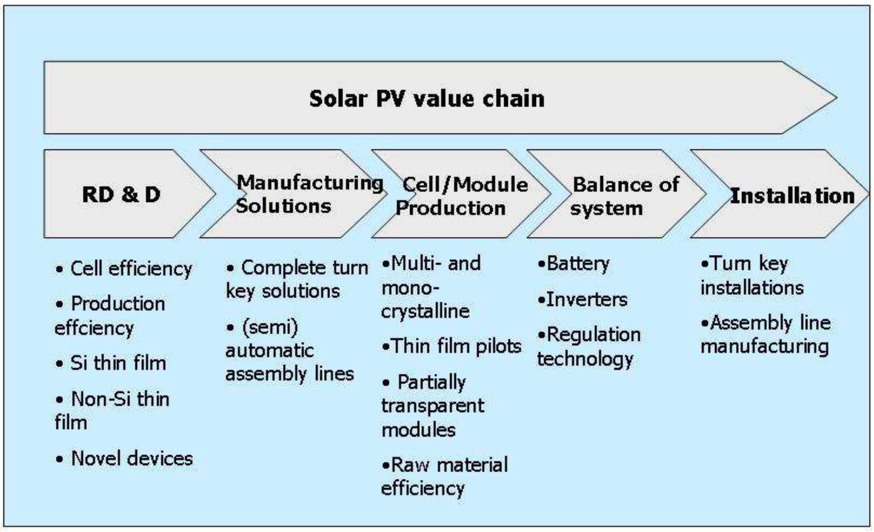

Figure 3.3 *Value chain for photovoltaics*

Photovoltaics investment scenarios

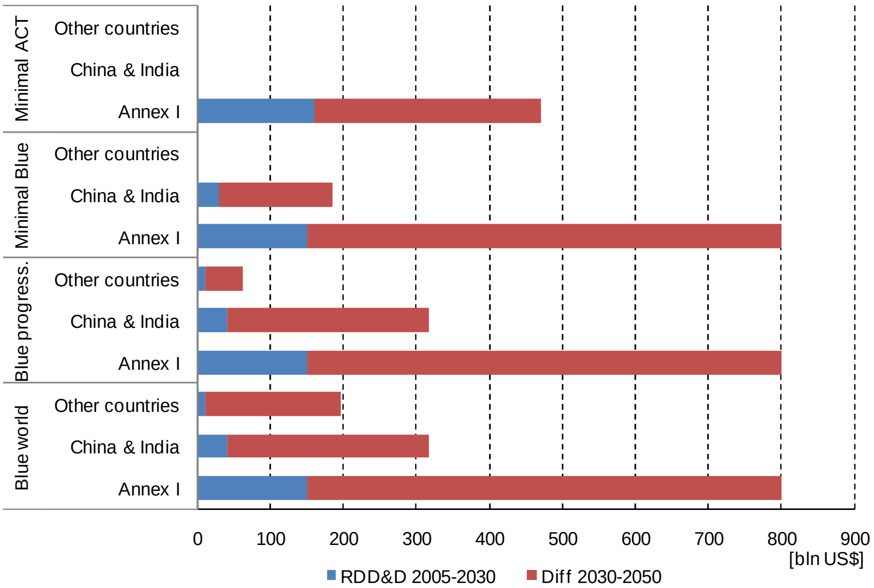

Figure 3.4 *Investment figures for pv energy*
Note: Based on: IEA ETP, 2008.

Future projections and assumptions
The ETP regards a shift in Solar PV technology market shares is necessary to realise the high output, as shown below, where the transition of non-silicon thin films to novel generation devices, such as dye-sensitised nano-crystalline cells and organic solar cells, will be necessary to guarantee lower prices. For example, the dramatic increase in solar PV, mainly due to increased

deployment in Germany and Spain, raised the price of silicon in 2007 (New Energy Finance, 2008). The economic crisis and a shift to thin film solar panels has resulted in current lower prices for silicon, but further mass deployment is likely to exert unsustainable pressure on the silicon market.

Expected distribution of PV technologies in the future

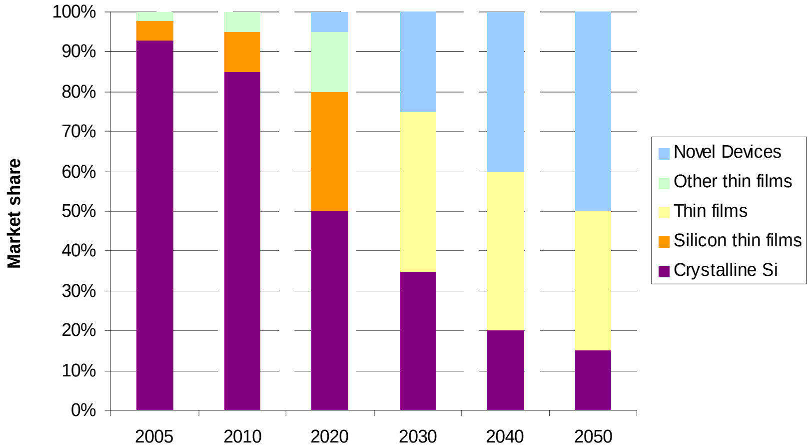

Figure 3.5 *Shift of PV technologies till 2050*
Source: IEA ETP, 2008.

3.2.3 Carbon Capture and sequestration

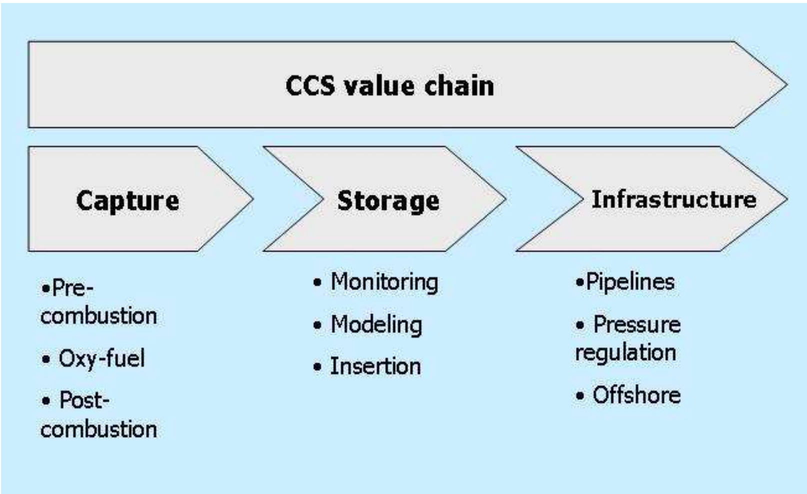

Figure 3.6 *Value chain for CCS*

CCS Investment Scenarios

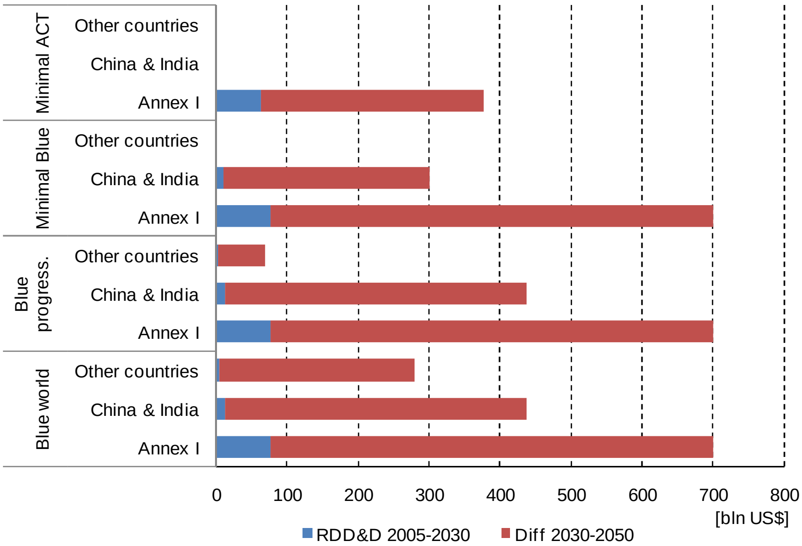

Figure 3.7 *Investment figures for CCS*
Note: Based on IEA ETP, 2008.

Future projections and assumptions
CCS is currently in a deployment stage and tacit knowledge, acquired by doing, is the main barrier to further deployment. This demands numerous demonstration sites, and the investment figures above reflect 30 large-scale demo plants with a range of CCS options by 2020. To enable this both the public *and* private sector will need to address the existing financial gap. An enabling regulatory environment is vital to achieving this.

3.2.4 Biomass for Energy (2nd generation biofuels)

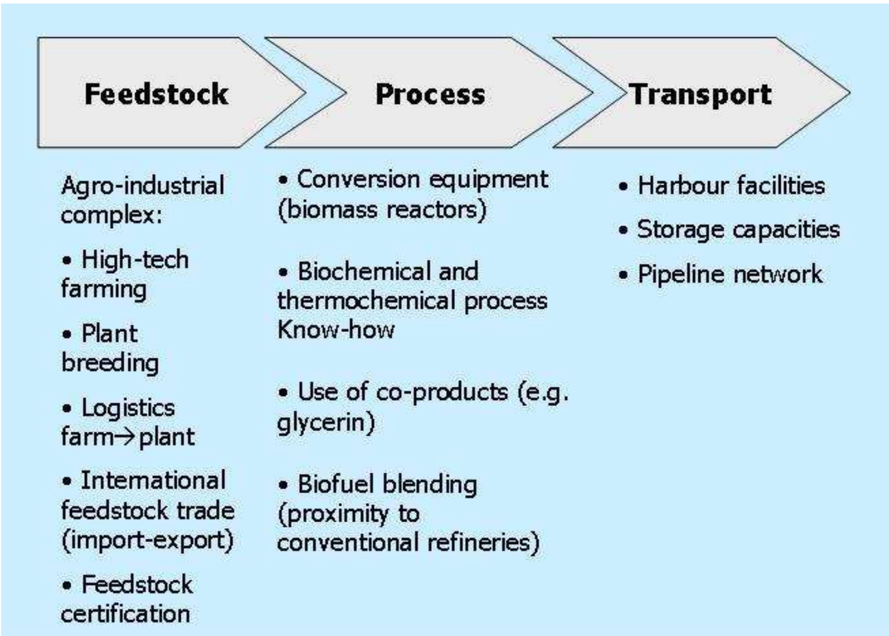

Figure 3.8 *Value chain for biofuels*

2nd Generation biofuel investment scenarios

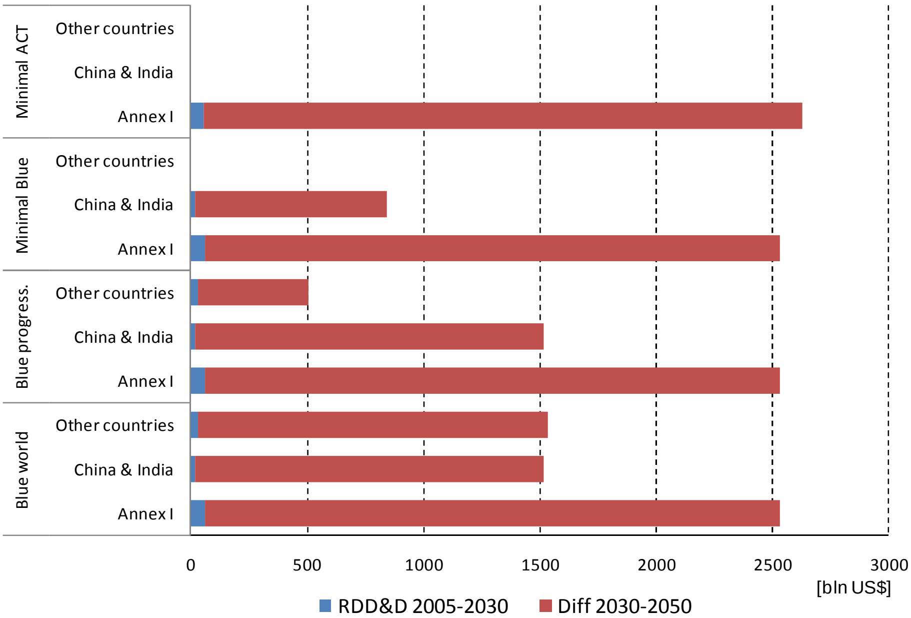

Figure 3.9 *Investment figures for 2nd generation biofuels*
Note: Based on IEA ETP, 2008.

Future projections and assumptions
2nd generation biofuel process technology, such as ethanol from ligno-cellulosic sources and Fischer-Tropsch bio diesel, need to go from demonstration to deployment phase requiring further investments in R&D. Additional work on the concept of biorefineries and the various co-products such as materials, chemicals, fuels and heat & power is expected to increase efficiency of feedstocks. First demonstration plants are being built currently, e.g. in Europe and North America. The cost balance between the size of a biofuel plant and its required feedstock logistics need to be considered, as demand and supply of feedstocks diverge geographically. Large-scale deployment for lingo-cellulosic ethanol and Fischer-Tropsch diesel needs to start in 2015 to reach full commercialization by 2035 in the ACT map, while the BLUE map requires initial deployment for both biofuel technologies by 2012, reaching full commercialization by 2030.

4. Identified Dutch technology suppliers and R&D centres

4.1 Photovoltaics

4.1.1 Assessment of the Dutch industry and research status

National specialisation
The solar PV industry in the Netherlands can be considered a substantial global player. However, along the value chain we notice different levels of involvement and specialisation. The main areas of focus are:
1. Research and development.
2. Solar manufacturing apparatus.
3. Balance of system production.
4. Module and panel production.

Research and development centres
The Netherlands has research centres that are globally renowned for their achievements in the field of solar- the most recent example being a new world record for a Silicon Crystalline (c-Si) module efficiency. Research is being conducted on several advanced technologies, ranging in their maturity and time span of deployment, and often involves both private and public partners in a research consortium. The consortia members are not always based in the Netherlands and strong ties exist with German and Spanish research institutes. The sources of funding vary, but the main contributors are the European Commission and Dutch national innovation programs.

Research in silicon crystalline PV cells currently has been undertaken for decades and it is believed that the largest gains in efficiencies have been obtained. In addition to efficiency, institutes are now looking at improved production efficiency for cell and module fabrication to reach grid parity in the next 5-10 years. As many substantial private partners exist in this market, companies often have their own R&D programmes supplemented by institutes. OTB, for example, is a large supplier of turnkey solar cell production solutions and collaborates with ECN and TU Eindhoven in researching possibilities to further bring down the costs of fabrication processes.

As stated in the ETP thin-film solar panels are crucial to realise an increased global deployment of solar PV technology. The technology requires up to 100 times less material than c-Si panels and is more lightweight and flexible. ECN, TU Delft, TU Eindhoven, University of Utrecht and TNO all have dedicated research groups that focus on the development of this technology. Although no natural market partner exits, Helianthos, a wholly-owned subsidiary of Nuon since 2006, started off as a research initiative of the above mentioned institutes but is now moving towards optimizing the technology for the market.

The Dutch Polymer Institute together with ECN are also researching the possibility of using semi-transparent polymers to be integrated in, for example, buildings. In combination with other organic based PV technology, such as dye-sensitized solar cells, the above mentioned institutes all have research programs in this field. In addition, research on novel devices such as quantum dot solar cells or semiconductor solar cells are being carried out at TU Delft and TU Eindhoven.

Key companies and research institutions

Table 4.1 *A list of key companies and research institutions.*

Companies	Focus
NUON Helianthos	Thin film production pilot
OTB Solar	Turn key fabrication solutions
Eurotron	Turn key fabrication solutions
Solar/glass Scheuten	Solar cell, module and panel fabrication, full turn-key solar installations
Solland Solar Energy	Solar cell, module and panel fabrication
Ubbink Solar Modules	Solar module fabrication
Mastervolt	Balance of system components
Victron	Balance of system components
Institutions	**Focus**
ECN	Silicon and thin film PV, PV module technology
TU Delft, TU Eindhoven University of Utrecht	Thin film PV, CIGS technology
Dutch Polymer Institute	Material science
Holst Centre	Innovative technologies

Solar manufacturing apparatus

The Netherlands focuses on the development of efficient fabrication techniques and processes and several companies have become international players in this market. As mentioned before, OTB, in partnership with other research institutes, has created a line of products to optimise the production of solar cells. Eurotron is another example of a company that focuses on creating complete (semi)automatic assembly lines for solar module production for both multi- and mono-crystalline cells. These products are not only used by national producers but are currently also exported to Chinese manufacturers. The comparative advantage of this technology does not only lie in the technology itself, but can also be attributed to the position of the Netherlands as an international trading partner.

Balance of system production

The additional components necessary to create a solar PV system, apart from the panel are very responsive to the level of implementation of solar PV systems. Two large companies in the Netherlands exist, Mastervolt and Victron that produce these components. Initially these companies started off as suppliers of inverters for boats, trucks and a small off-grid market, but since the mass deployment of solar PV in countries such as Germany and Spain, they have moved their production to cater for this market to. In the past these companies had a substantial national market but as the subsidy scheme for solar decreased, they concentrated on foreign markets. Victron established itself as a supplier of 'heavy duty' components meant for harsh off grid solutions in the developing world.

Module and panel production

The two largest solar module manufacturers in the Netherlands are Scheuten Solar and Solland Solar. These companies experienced extreme growth up until the financial crisis, when orders were reduced and planned expansion was cancelled. In combination with a diminishing national market (of the 35 MWp module produced in 2007 34 MWp was used for export), the trans-boundary Limburg based industry is now slowly on a rise again. Solland solar realised the highest growth of all small and medium enterprises in the country in 2008 and has planned a production expansion of 500 MWp in 2010. Scheuten solar also realises complete turn-key solar PV projects including maintenance and operation worldwide to its portfolio and has offices in, amongst others, California, Spain and Dubai. The most noticeable feature of these companies is their attention to export markets, which is not only visible in their business philosophies, but also in European solar PV statistics.

4.1.2 Evaluation of future potential based on current status

As a whole the Netherlands has both profited and experienced losses due to the failings of its national market for solar PV. Companies and research institutions have been forced to enter the international market to survive and have partnered with some of the largest players in the world. Its position in Europe is strong, but increased ties to the Far East has also materialized for certain products and services.

The research and development segment of the Netherlands for c-Si has been especially successful. Records in efficiency receive international attention and institutions such as ECN and TU Delft have industrial partners in Germany and the Netherlands, in the field of c-Si efficiency in energy production and fabrication. The Netherlands has a comparative advantage in the fabrication of turnkey solar module fabrication solutions that is currently exported to manufacturers in China as well. It is believed that it is especially this sector that will withstand the lower costs of production in the Far East, due to intensive research and development in this sector and the high knowledge need. In addition, the production of these machines is not labour intensive reducing the comparative advantage of low labour costs elsewhere.

Thin-film and novel devices are expected to become dominant technologies around 2030 and the Netherlands has substantial research initiatives and institutes that focus on these areas. Apart from Helianthos no national production capacity exists, but it is believed that the low complexity and easy manufacturing process of these technologies will be most beneficial to Asian manufacturers. Again, the production technology and knowledge will be a valuable asset for the Dutch market. Much potential exists in building integrated technology, especially in urban European areas for retro-fitting and the Netherlands has a strong basis to build upon. The European partners in Spain and Germany have a larger manufacturing capacity while the Netherlands can supply knowledge acquired through research.

Balance of system components are more complex as their prices are more susceptible to deployment levels. As most leading solar industries in the US, Japan, China and Germany have large additional producers of these components, it is increasingly difficult for Dutch manufacturers to compete. For off-grid solutions the size and bulk of batteries may provide incentives to choose suppliers in the Netherlands due to reduced transportation costs, but without the guarantee of a Dutch market competing internationally, this is often difficult. Currently solar module production is not experiencing this phenomenon as much. Although 97% of all production in this sector is exported, unfinished products also get shipped abroad to be completed in countries with lower labour costs. This has kept the companies competitive in offering higher quality modules than most Asian competitors at a comparable price. There is more demand in the European market for these products as lack of available space and sunlight demands higher efficiencies. Developments in the US are also monitored closely, as some Dutch manufacturers have offices in the US already, to profit from increased demand through newly introduced policies.

4.2 Offshore wind

4.2.1 Assessment of Dutch industry and research status

The industry in the Netherlands currently focuses on process technology and not on the core technology, namely wind turbines. There are no manufacturers for offshore wind turbines or substantial parts such as blades. Previously, wind turbines with a 2 two-blade design have been manufactured in the Netherlands but this design did not prove successful. However, the value chain of offshore wind is to a large extent determined by the process technology that is necessary to actually construct, operate and maintain the offshore wind turbine or wind parks.

Through mass production of wind turbines it is expected that the cost ratio between hardware (turbines) and operating and maintenance costs will shift from 50% in 2010 to 66% by 2025 for the latter. That implies that in the future, a higher cost burden will fall on operation and maintenance. Efficient solutions are therefore highly sought after and foundations are key components herein.

The conditions where the technology is deployed demand specialized knowledge. The Netherlands possesses the necessary preconditions for setting up and maintaining wind turbines. For wind parks located in deep waters the construction of foundations is often a problem. Companies such as Heerema and Ballast Nedam are active in the development of novel foundations that are easier to install and include lower maintenance. Other issues are the operability and connection of the wind parks with the electricity distribution grid onshore.

The following parts of the offshore value chain have been identified of having future potential:
- Construction of foundations for wind turbines.
- Setting up wind farms.
- Ensuring operability and connection with onshore distribution grid.

The Dutch offshore wind energy sector can benefit, to a certain extent, from its experiences in offshore oil & gas explorations. Some of the problems connected to oil & gas exploration such as setting up platforms and deep water drilling have created specialized knowledge that can be applied in the set up of offshore wind farms. However, although similarities exist between the two sectors a lot of issues still remain unsolved. The offshore wind sector therefore still depends on further development of know-how that can only be achieved through tacit knowledge, or ‘learning by doing’.

Offshore wind energy in the North Sea has a high potential. Several offshore wind parks are currently developed as the technology moves from demonstration to market maturity. Currently the Netherlands have 228MW of offshore wind capacity installed in the North Sea. Up to 6000 MW is planned for the coming years (until 2020)

Many barriers are unique to offshore wind. The Netherlands can increase its comparative advantage by increasing efforts in this field. However, the knowledge from previous offshore exploration is also somewhat limited. The offshore wind industry is an iterative process; learning by doing. That also means that it is easier for other countries to catch up as there is less of a technological hurdle. The focus of the Netherlands should therefore be to foster specialized small to medium-sized business that are active in the process sector of wind technology.

Novel and innovative research can also contribute to remain ahead of the competition. Research in new foundations is something that arose from independent research, while industry is too often focused on pure cost reduction. However, this is usually the first step of mass production at low cost that is normally not done in Europe.

The following is a list of the main players in the Dutch offshore wind market, in both the R&D and diffusion phase:

Table 4.2 *Companies in the offshore wind sector*

Company	Specialization
Gusto	Specialized ships, jack-ups
IHC Merwede	Specialized ships, jack-ups
Herema Fabrication Group (HFG)	Construction and installation of wind turbines and transformer stations
Smulders Project B.V.	Construction of foundations, setting up towers, 80% share in foundations of offshore-wind parks
Ballast Nedam	Setting up and fabrication of foundations and wind turbines
Van Oord	Dredging and construction
Royal Haskonig	Project management
Fugro	Site preparation, foundation preparation

Around the larger companies, a cluster of specialized suppliers and research institutes have evolved that contribute to the success of the Dutch offshore industry. Research in the offshore wind sector is well established in the Netherlands. Through the ECN Wind Energy Unit and DU Wind, two experienced institutes work on the continuous improvement of technology and support industry. Some of the functions are testing of equipment, simulation and aerodynamic testing, research into novel foundations and software to optimize wind park operation. ECN is involved in the wind turbine test park Wieringermeer which provides unique conditions to test the technology under real-life conditions.

As independent institutes, they have the ability to provide tailor-made solutions for industry to help improve the entire process. Close links to industry exists through involvement in international research projects. Because of their involvement in setting up wind parks they can benefit from first-hand experiences that feed back into the learning process.

The institutes also participate in a number of EU and international development bodies such as the European Academy for Wind Energy, the European Technology Platform Wind and the IEA. With two highly experienced institutes in the Netherlands, Dutch industry benefits from this contribution to the whole sector and positions the industry as a front runner.

Table 4.3 *Overview of offshore wind R&D institutes*

Research institute	Specialization
ECN Wind Energy	Aerodynamic testing, improvement of operation and maintenance of offshore wind parks
TU Delft (DU Wind)	Design of wind turbines, novel foundations, industry support
Knowledge Centre WMC (Wind turbines, materials and constructions)	Experimental simulations, standardization, international project management

4.2.2 Evaluation of future potential based on current status

From a development perspective, offshore wind technology is still in its demonstration phase and has not yet reached full market maturity. First wind parks are being set up at the moment and a substantial number is currently in the permit or planning stage, especially in Denmark, UK, Germany and Norway. Insufficient experiences exist in setting up and operation of wind parks. The long-term impacts of the harsh climate conditions on the hardware can also not yet be fully predicted. The Netherlands can play a strong role in the future given their current expertise, both in their home market and abroad, but above all in the North Sea.

By 2020, some 30,000 MW of offshore wind power could be installed in the North Sea which represents about 38% of the worldwide capacity in IEA's Blue scenario for both on, and offshore. The North Sea area represents an attractive location for offshore wind deployment as water depths are generally not a barrier, despite some deep water areas in the North of the UK and Norway. In addition, most economies located around the North Sea already fully utilized their onshore capacities or decided to focus on offshore wind. Other, less developed world regions as Annex I countries will first develop their onshore potential due to favourable costs.

Costs of offshore wind installations nevertheless are generally higher due to the required foundations. Next to the turbine, the highest cost items for a wind park are the foundations, transformer and the connecting cable to the mainland, see Figure 4.1. In the future, the turbine cost are expected to decrease due to mass manufacturing however all process cost will remain roughly the same. It is therefore in the interest of every wind park operator to involve experienced partners. Novel foundations can also lead to cost reductions. As the Netherlands are currently in a good position given their experience in the wind farm process technology (planning, construction, maintenance and operation) and also some of the key components, such as foundations, they could become a substantial player in the offshore wind energy market. The strong position in the process technology around the setting-up, planning, operation and maintenance and possession of specialized equipment such as ships and harbours to prepare e.g. platforms makes a strong case for its industry.

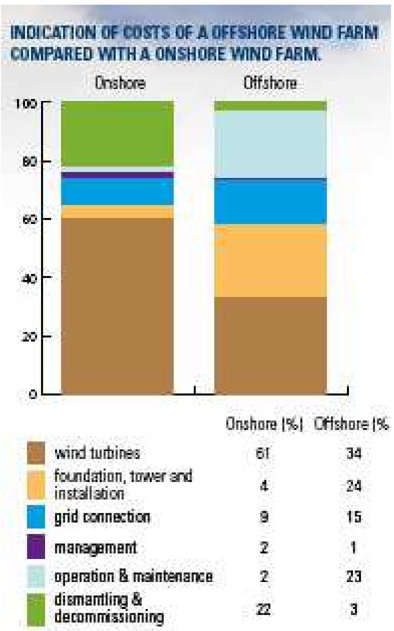

Figure 4.1 *Cost comparison onshore and offshore wind*
Source: We@Sea.

It is not expected that the Netherlands will move in other directions along the offshore wind energy chain and e.g. become a major producer of wind turbines. Those parts are already covered by the established companies for onshore wind turbines and a late market entry would be very costly and difficult to establish a foothold in the market. Standardized hardware such as turbines will be produced at locations with low cost of production that, on the long run, will not take place in Europe anymore. Similar to the Netherlands benefiting from their experience in oil & gas exploration, other countries with similar backgrounds could enter the market in process technology. In particular Norway and the UK have to be mentioned, both having a similar history in North Sea fossil fuel exploration.

Large parts of wind power will be installed in the North Sea by 2020. This means that the expansion of offshore wind is less influenced by the outcomes of an international climate agreement, as demand will mostly come from countries intent to invest in any case. Nevertheless, technology development does not take place on a national level, but spreads across borders.

Dutch technology is already used and deployed in offshore wind farms around the North Sea. The national government should also demonstrate their long-term interest in the technology to the national industry through target setting.

4.3 Carbon capture and sequestration (CCS)

4.3.1 Assessment of the Dutch industry and research status

National specialisation

As Carbon Capture and sequestration (CCS) is a technology that is still in a pre-demonstration phase specialisations have not been formed. However, it can be said that the Netherlands is extremely active in the field of CCS. Due to the existing gas infrastructure and the availability of storage sites, both on- and offshore, the Netherlands wishes to place itself as a strategic location for CCS activities. Rotterdam harbour, which is also an area of highly concentrated CO_2 emitters, positions itself as the Dutch centre of CCS-activity, and would be a mainland access point for CO_2 transport to offshore sites in the North Sea. In addition, Dutch companies' and institutions' vast experience in offshore engineering and oil and gas exploration provide the knowledge needed to be a frontrunner in CCS-development. The main areas of research are the following:

1. Underground (storage) technology.
2. Capture technology.
3. Transport of $CO_{2.}$

Underground (storage) technology

Although the technologies associated with CCS are similar to those used with oil and gas exploration, there is still a large knowledge gap. Without the introduction of demo sites the knowledge about CO_2 plume behaviour in varying geological conditions is now mostly limited to modelling. This is being carried out by several institutes including TU Delft and TNO. These institutes often cooperate with industry partners in large FP7 research projects, or the Dutch national program on CCS, CATO, and since this year CATO-2. The research projects commissioned by the European Commission have allowed Dutch institutes to play a larger role in existing demonstration sites, in Ketzin (Germany), Sleipner (Norway) and In Salah (Algeria). TNO, for example, is actively involved in the monitoring process at Sleipner. The additional experience acquired through the large Dutch oil and gas sector, is another comparative advantage in this field. Much data has been collected regarding offshore gas fields in the North Sea, and can largely reduce uncertainties regarding ground composition.

CO_2 capturing processes

Due to the large availability of sites, Dutch parties involved in CCS are cooperating to reduce the costs of the capture process, the most expensive part in the CCS chain. The aim is to reduce both capital and fuel costs associated with the capture process. ECN, for example, works on improving and simplifying this process. Although the focus is on pre-combustion CO_2 capture, it also has activities in post-combustion and oxyfuel. Royal Dutch Shell is another company investing heavily in the capture process, although its focus lies in post-combustion. Due to the 'European' nature of most of these research projects, international partnerships are key to advance the technology.

Transport technology

Due to the existing experience of the Netherlands with CO_2 transport through the OCAP pipeline, its access to offshore and onshore sites and concentrated emission locations lends itself perfectly as a CO_2 hub for neighbouring countries. Rotterdam, again, plays a vital role as both a harbour location of concentrated emitters. An existing pipeline currently transports CO_2 to greenhouses in the Westland area, and plans exist to extend this to Ijmuiden to allow CO_2 produced by the steel industry to be processed. Through feasibility studies[12] it has however been proven that this can only be economically viable at high quantities of CO_2 and high CO_2 prices.

Table 4.4 *Key companies and research institutions*

Institutions	Focus
ECN/ Air Products	Process technology
TU Delft	Underground storage technology
TNO/Siemens	Underground storage technology, monitoring
Companies:	*Focus*
Shell	Underground storage technology
NUON	Underground storage technology, capture technology
Wintershall Noordzee B.V	Underground storage technology
NAM	Underground storage technology
GasUnie	Transport technology

4.3.2 Evaluation of future potential based on current status.

The opportunities for the Dutch CCS industry are divided in two options:

1. The creation of a CO_2 transboundary network providing Germany, Belgium and possibly the UK with access to on- and offshore storage sites.
2. The export of knowledge on underground technology and capturing processes.

A main barrier so far has been the implementation of Dutch demonstration sites. Storage of CO_2 in two depleted gas fields largely located in Barendrecht, a town close to the industrial area of Rotterdam, was to be the first CCS-activity in the country lead by Shell/NAM. However, due to large objections by local politicians it is currently being delayed, and it is still unsure whether the storage will take place. Institutions and companies feel that this barrier of local resistance needs to be overcome to enable practical experience and recognition. The coordination and development of domestic sites is especially important to position itself as an international leader. A second site is being planned by NUON in the north of the Netherlands, to be combined with a new coal-fired power station.

Both options rely heavily on domestic activity. To warrant the creation of a transboundary CO_2 network, the costs of CCS will have to be reduced to a level that will stimulate CCS and allow it to be an attractive option when regarding the European Emissions Trading Scheme (ETS). The amount of CO_2 captured between the Netherlands and its neighbouring countries will have to be substantial enough to interest pipeline and storage operators to invest in high volume installations[13]. These plans have also been drafted by the Rotterdam Climate Initiative (RCI) which is currently using CO_2 emitted by local industry to be fed to the OCAP CO_2 pipeline to greenhouses in the 'Westland' area. This pipeline is to be expanded to allow the inclusion of the Corus steel plant in Ijmuiden, one of the largest point emitters of CO_2 in the Netherlands.

To create the possibility of exporting and operating sites beyond this network the Netherlands needs to establish itself as a pioneer in CCS which requires a solid domestic infrastructure. Most companies, such as Shell, NAM and Wintershall, already have vast international networks and much experience with possible depleted gas fields abroad. Shell is currently arguing that including CCS in the Clean Development Mechanism (CDM) is another step that can attract developing countries to implement CCS. However, this has attracted much controversy[14] and is still being debated by the UNFCCC.

[12] 'Haalbaarheidsstudie CO2 infrastructuur in Nederland', Machteld vd Broek, 2009.
[13] 'Feasibility study of a transboundary CO2 network', Groenenberg et al, 2009.
[14] 'Trojan horse or horn of plenty? Reflections on allowing CCS in the CDM' H.C. de Coninck 2008.

Summarizing, it is evident that the Netherlands could play a substantial global role in the development of CCS, but it is competing with several other nations. Norway also has a strong basis, with a very large offshore capacity, a similar oil and gas experience, but with the added value of having a domestic CCS demonstration site in Sleipner, which has been operational since 1996. France has started to develop its CCS network and Total has announced its first site at Lacq, near its headquarters in Pau. It has also partnered with research institutes such as Institute Français de Pétrole (IFP), which has conducted much research on BP's In Salah site, to conduct geological research. The UK also has several CCS initiatives with BP's In Salah site and several on- and offshore sites. As the European Commission has released its directive on CCS, and acknowledged the need for several demo sites by 2015 action is slowly being undertaken.

4.4 Biomass for energy (2nd generation biofuels)

4.4.1 Assessment of Dutch industry and research status

The production and use of biofuel in the transport industry in the Netherlands experienced a relatively slow start due to lack of experiences and the absence of a national policy framework to trigger developments. Local initiatives were the first to produce biodiesel. In 2006, two plants for biofuel blending were opened and in the same year also a tax exemption for biofuels was introduced with a duration of one year. The government consecutively introduced a 2% fuel quota for producers that helped increase investments in biodiesel production. The 5,75% EU target on biofuel blending for 2010 is now the main driver for developments in this sector, although it has been lowered to 4.5% due to concerns over sustainability of feedstock. For the same reasons the government has also shifted their R&D focus towards 2nd generation biofuels that involve non-food e.g. purpose grown energy crops and utilization of waste streams for chipped wood.

Currently, several biofuel production facilities exist or are being built, mostly in the harbour areas of Rotterdam, Amsterdam and Eemshaven. These investments are made by international players such as Abengoa and Neste Oil, but also by some Dutch companies. The harbour areas are a strategic location for the Netherlands as they represent market places for biofuels trading. That means that biofuels arrive as final product or feedstock by vessel, then being processed to the final product and then immediately traded further, using shipping or rail connections. Due to the long experience in the handling of fuels, Rotterdam and other harbours also benefit from proximity to refinery locations and an extensive pipeline network. Biofuels can be directly blended with conventional fuels and then traded further without large delay. By-products from biodiesel production such as glycerine can hence be supplied back to the chemical industry. The production locations in the Netherlands possess excellent inland shipping and rail connections to serve other markets in Europe, keeping transport cost low.

First generation biofuel production depends to a large extend on feedstocks from the Ukraine, Brazil and Latin America (Argentina, Costa Rica, Venezuela). US soy-based biodiesel is imported directly and outcompetes domestic production due to export subsidies. The related production processes to make those fuels are well-known, main improvement option are cost reduction by scale increase and to a lower extend process innovation.

Second generation biofuels rely to a greater extent on more sophisticated processes such as bioethanol from cellulosic feedstocks or biodiesel production from lignocellulosis sources, converted via Fischer Tropsch or biomass-to-liquid processes. A number of Dutch companies are investing in the creation of 2nd generation biofuel production facilities, such as Nedalco (bioethanol), N2 Energie (bio-ethanol) and Shell. In Table 4.5, several companies are listed indicated their specialization.

Table 4.5 *Companies in the biomass sector*

Company	Specialization
Shell	Process technology for gasification
Nedalco	Bioethanol production via fermentation (2nd gen.)
Nidera	Trade of biomass feedstocks
Biomass Technology Group	Gasification, pyrolysis
Biopetrol	Biodiesel production
B2G	Biodiesel production (NExBTL)

Several research institutes work in the biomass energy sector in the Netherlands. At ECN, the unit biomass, coal and environment researches novel fermentation/gasification processes for 2nd generation biofuels. At the TU Delft, research is conducted into the gasification of biomass, especially agricultural waste.

A consortium of researchers from Wageningen University and the companies AkzoNobel, Essent and Ingepro have joined a four-year project to study the large-scale production opportunities of biofuels from algae sources. Currently, a demonstration plant is being built to investigate the growth and building blocks of algae. Researchers at the Twente University are involved in a governmental sponsored project on biofuel production processes and facilities for 2nd generation biofuels in Indonesia.

Table 4.6 *Overview of biomass R&D institutes*

Research institute	Specialization
ECN (BKM unit)	Fermentation, Gasification process of 2nd generation biofuels
TU Delft	Fermentation, Gasification process of 2nd generation biofuels
Wageningen University	Biorefinery concepts, Biomass-to-materials, Algae based biofuels
Twente University	Gasification process of 2nd generation biofuels, Algae based biofuels, biorefinery concepts

4.4.2 Evaluation of future potential based on current status

Due to limited availability of agricultural land and resources, the opportunities for biofuel production from domestic sources in the Netherlands are constrained. Nevertheless, there are good opportunities for biofuels trading and exploitation of process know-how on 2nd generation biofuels, especially into co-producing chemical feedstocks. Due to the strong presence of the refinery sector for conventional fuels a stronger link will evolve between the agricultural sector to develop feedstocks suitable for bio-refinery processes.

Currently, the Netherlands is establishing itself as a worldwide trading hub for 1st/2nd generation biofuels. With production facilities close to major harbours and the possibility to trade or directly blend fuels due to the proximity of conventional fuel refineries attractive locations can be offered. Due to ambitious EU targets on the blending of biofuels and the limited domestic resources in the EU the importance of a trade hub will grow. Although the current trade and production of biofuels is mainly within the 1st generation, this is expected to shift within the next years.

The European Biofuels Roadmap REFUEL[15] foresees the gradual introduction of advanced, 2nd generation biofuels starting around 2015. After that, 2nd generation biofuels such as bioethanol from lignocelluloses sources and biodiesel from Fischer Tropsch processes become more important. From a trade perspective, feedstocks for 2nd generation biofuels will still be coming to a great extent from Canada, Russia, Asia and Latin America. Intro-European shipping of sources

[15] Refuel - European Biofuels Roadmap, http://www.refuel.eu.

(e.g. from Spain, France) is also expected to increase. Through their strong position on 1st generation trading and blending, it is expected that the Netherlands will also benefit from the shift to 2nd generation. Trading and blending will remain important areas and extended with a good perspective for application and export of process technology for second generation biofuels.

The Netherlands had an early focus on more sophisticated process technologies (gasification, fermentation) for 2nd generation biofuels such as biodiesel from lignocellulosis sources. Companies have set up first plants and processes are developed further with strong contribution from R&D institutions. The establishment of large production capacities in the Netherlands requires high investments and is not expected that the country will become a major player. However, process technology expertise represents a suitable asset with high export potential, depending on the efforts that other countries (US, Germany, Sweden) are undertaking.

5. Step 4: Evaluation of the four scenarios

Through the expectations for market share, export potential and growth factors for each technology, the investment figures in the ETP will be used to obtain results for each of the four scenarios. Our assessment is based on the current situation of the respective technology in the Netherlands and the expected changes abroad. Each of the tables provides an overview what changes can be expected and how the Dutch industry would be influenced by that.

5.1 Photovoltaics

Table 5.1 *Photovoltaic deployment scenarios*

	Annex-I Countries	China and India (major emitting emerging economies)	Remaining countries
1. Blue worldwide	- High R & D efforts in collaboration with EU partners - High export levels of knowledge to US and Japan - Increased effort on building integrated technology and novel devices (long term) - Broader multi-nationalisation of industries, broader collaboration R&D institutes.(Trans-continental)	- High export of machinery - High export levels of knowledge for thin-film device fabrication - High levels of knowledge for c-Si fabrication techniques (short term)	- High increase in sales of balance of system components through ODA. - Large exports of modules to LDC's through increased ODA.
2. Blue progressive	- High R & D efforts in collaboration with EU partners - High export levels of knowledge to US and Japan - Increased effort on building integrated technology and novel devices (long term) - Broader multi-nationalisation of industries, broader collaboration R&D institutes.(Trans-continental)	- High export of machinery - High export levels of knowledge for thin-film device fabrication - High levels of knowledge for c-Si fabrication techniques (short term)	- High sales of balance of system components through ODA. - Large exports of modules to LDC's through increased ODA.
3. Minimal Blue	- High R & D efforts in collaboration with EU partners - High export levels of knowledge to US and Japan - Increased effort on building integrated technology and novel devices (long term) - Only trans-atlantic multi-nationalisation of industries and collaborating R & D institutes.	- Medium export of machinery to China - Medium export levels of knowledge for thin-film device fabrication - Medium levels of knowledge for c-Si fabrication techniques (short term)	-
4. Minimal ACT	- High R & D efforts in collaboration with EU partners - Medium export levels of knowledge to US and Japan, through industrial partners	-	-

5.2 Wind[16]

Table 5.2 *Off-shore wind deployment scenarios*

	R&D	Deployment
Blue Worldwide	Dutch industry continues to built-up competences in process engineering, but worldwide competition increases	High investment demand Annex I and from China/India as well as from other countries China and India play a strong role as technology supplier
Blue Progressive	Dutch industry continues to build-up competences, but also China and India ramp up R&D investments	High investment demand in Annex I and China/India Demand from other countries arises China and India emerge as technology supplier
Blue Minimal	Dutch industry continues to built-up competences in process engineering Increased R&D investments from other Annex I countries	Increased demand in Annex I countries and emerging demand from China/India
Minimal Act	Dutch industry continues to built-up competences in process engineering	Investment demand from Annex I countries

5.3 Carbon Capture and sequestration

Table 5.3 *CCS deployment scenarios*

	R&D	Deployment
Blue Worldwide	Dutch industry increases efforts in capture and storage research to create opportunities for efficient	High investment demand Annex I and from China/India as well as from other countries China and India play a strong role as technology supplier
Blue Progressive	Dutch industry continues with high investments in research and development due to high demand in neighbouring countries	High investment demand in Annex I and China/India China and India emerge as technology supplier
Blue Minimal	European demand continues to fuel Dutch investment opportunities in research.	Increased demand in Annex I countries and emerging demand from China/India
Minimal Act:	Transport infrastructure research is dropped, capture and storage technology is continued.	Focuses on domestic demand, and neighbouring countries. Transport infrastructure is not developed.

16 Currently there are no separate investment figures available for onshore/offshore wind. It is assumed that the investments will be divided equally between the two applications.

5.4 2nd generation Biofuels

Table 5.4 *Biofuel deployment scenarios*

	R&D	Deployment
Blue Worldwide	Continued R&D towards Fischer-Tropsch and BTL process technologies	Large deployment opportunities in Annex I countries, China and India and other countries
	Increased R&D competiton with China/India	Competition with China/India as technology supplier
Blue Progressive	Continued R&D towards Fischer-Tropsch and BTL process technologies	Large deployment opportunities in Annex I countries and China and India, Demand from other countries arises
	Increased R&D competition with China/India	Competition with China/India as technology supplier
Blue Minimal	Continued R&D towards Fischer-Tropsch and BTL process technologies	Large deployment opportunities in Annex I countries and China/India
	Research collaboration within Annex I countries	
Minimal Act	Continued R&D towards Fischer-Tropsch and BTL process technologies, strong position within Annex I	Large deployment opportunities in Annex I countries
	Research collaboration within Annex I countries	

5.5 International collaboration

The role of international collaboration has been frequently mentioned during the interviews with technology experts. In their opinion, already now and even more so over the next years, R&D efforts are going to be shared and conducted at international level. Especially for technologies that require high up-front capital investments for RDD&D such as CCS and offshore wind, no developments will happen autonomously anymore at national level or only to a limited extend. This can also prevent the market introduction as no country by itself is able to achieve a ‘critical mass’ of deployment and learning effects that could trigger broader roll-out. Joint efforts are the only option to bring those technologies faster to the market. Research cooperations are usually initiated on a bi-lateral level between research institutes and through participation in international research consortia funded by international bodies or the EU framework programmes for research. Within the Strategic Energy Technology plan (SET-plan), the European Commission has also started efforts to streamline research on European level.

The European Commission has set up the European Energy Research Alliance[17] (EERA) with the aim to strengthen, expand and optimise European energy research through facility and knowledge sharing. The background to this is that technology development on national level is often hampered by a sub-level of critical mass. National and EU Energy research R&D programmes will be streamlined and coordinated. All this should contribute to the aim of bringing technologies faster to the market and make Europe a world leader in sustainable energy tech-

17 http://www.eera-set.eu/.

nologies. 10 energy research institutes from all over Europe make up the funding partners of EERA.

One of the aims of EERA is the selection of energy technologies that have priorities within the SET-plan and to stimulate cooperation and funding schemes for the selected technologies. This also means that there will be a stronger focus of single research institutes into specific technologies while others may receive less attention in the future. A further aim of the EERA is to work upon a partnership with industry to ensure that technologies are timely taken to the market, also benefiting from possibilities to include feedback how to improve the technology further.

Future energy policy on R&D should therefore incorporate the necessary instruments that allow research facilities to work together.

6. Conclusions and recommendations

This report analyzed the potential influences of a new, post-2012 climate framework regarding the export of low-carbon technology from Dutch manufacturers. Four technologies have been selected as the study focus as they possess the necessary potential to be interesting for the export market in the future. The four selected technologies are: photovoltaic (PV), Carbon Capture and sequestration (CCS), biomass (specifically 2nd generation biofuels) and offshore wind. Expected export potential has been measured based on the forecasts within the ACT and BLUE scenarios of the Energy Technology Perspectives 2008 of the IEA. For four plausible scenarios, the opportunities and risks for the Dutch industry have been outlined.

Each of the four studied technologies underlies specific framework conditions concerning the current market position of the Dutch industry and its future perspectives. The export potential is linked with the expectation of the contribution of this particular technology to reduction of GHG emissions.

Most low-carbon technologies occupy each level of a product development value chain (i.e. RD & D, diffusion and deployment), meaning that varying competitive advantages exist for the selected technologies, e.g. operation & maintenance of offshore wind. By nurturing these specific competences the Netherlands could establish a strong market position that could be beneficial for its position as a technology exporter. In this increasingly global market it is arguable if other parts of the value chain, where the Netherlands may have less established competences, will 'catch up' in the future, if larger, more competent firms, or entire sectors, exist abroad. However, if the technology is globally still in a very early stage of development, and the surrounding conditions exist (i.e. established R&D institutes) the opportunity exists for the Netherlands to occupy market niches that can provide technology and knowledge exports in the future. As global RDD&D competition grows (e.g. US becoming more active in low-carbon technologies), governmental support for proven and promising technological opportunities in the Netherlands is needed . The type of policy instrument that can be used to further stimulate each sectors' international presence varies greatly, and requires a specific, tailor-made policy framework.

The role of international collaboration in bringing technologies to the market needs to be understood. It will not be possible from a national perspective to bring certain technologies (e.g. CCS) to the market due to the high investment cost necessary in the demonstration phase. International research collaboration benefits the Dutch industry sector as they will have access to larger financial resources from international funding bodies to demonstrate their technology, while at the same time strengthening the domestic industry players. In the following, more detailed policy advice is provided for each technology. The diagram below also shows the investment in the most likely, yet still ambitious, 'Blue minimal' scenario for each of the chosen sectors.

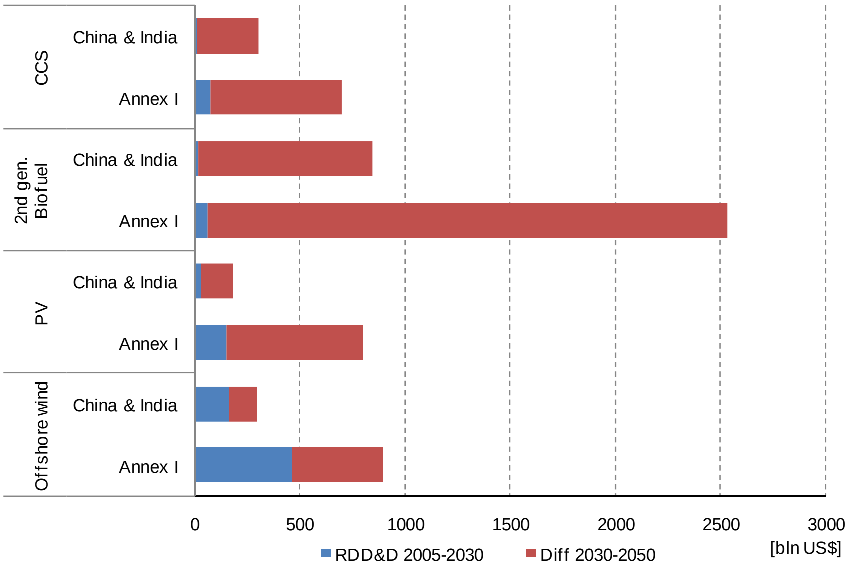

Figure 6.1 *Expected investments in a blue minimal scenario*

CCS

The Netherlands has two main strategic advantages in the CCS sector:

- Its vast (domestic) experience with offshore engineering and gas and oil exploration, provides the necessary knowledge and experience for the realisation of CCS demonstration sites.
- Its location provides both the advantages of suitable and nearby on and offshore sites, and the proximity of countries like Germany and Belgium, may lead to a transboundary CO_2 pipeline network.

However, there are still several uncertainties surrounding CCS that hinder development in the Netherlands.

There has been much controversy regarding onshore CCS in Barendrecht, as nearby inhabitants have purposefully proven at this demonstration site, near the industrial region of Rotterdam. This, combined with the population density of the Netherlands, will most likely force future projects to offshore sites increasing both transport and storage costs. In addition, CCS is highly dependent on EU or international agreements regarding CO_2 prices, to support the financial feasibility of a project. As it does not generate electricity, but instead reduces the efficiency of coal fired power stations, the private sector needs strong and clear indications that the public sector regards this as a necessary future technology.

These two features- the favourability of offshore sites and the reliance on high (international) volumes and CO_2 prices to validate these investments- create uncertainty for the Dutch CCS sector. On the other hand, the IEA states that to reach acceptable CO_2 emissions by 2030 and 2050 CCS is absolutely necessary and the associated investments are very large (see fig. 3.7). To leverage private sector investments in CCS, the Dutch government will have to invest heavily in demonstration sites at this phase, either through transboundary network support with neighbouring countries or direct investments in sites. In addition, research will need to be carried out to improve the current efficiency loss due to CCS, requiring dedicated subsidies to programs related to capture processes and CO_2 storage behaviour. It's strategic advantages coupled with increased research focus at scientific institutions and universities, are both factors that could lead to successful offshore demonstration sites, and may lead to a position as global front-runner in the field.

PV

The Dutch PV sector has suffered from low domestic demand but has, however, made the industry resilient to fluctuations in domestic demand and has forced it to search opportunities abroad. With the increased deployment in Spain and Germany exports have been able to rise slowly, especially from companies like Solland Solar. The increased development of high end manufacturing technology has also increased export flows to China, and has allowed for further diversification in the industry.

Policies needed to strengthen this are still based on an increasing local demand. The balance of system industry depends on this, and costs of entire systems can be reduced this way. Germany and Spain, for example, have implemented policies that have expanded their domestic industry, and allowed all components of the PV industry to flourish. This could be done by adopting subsidies that are related to the electricity generation such as feed-in-tariffs, instead of the conventional subsidies that leverage the investment costs. This spurs the industry to produce more efficient modules, increasing private R&D investments.

On the other hand research in solar cells is currently very strong and this needs to be maintained. The Netherlands does not enjoy a traditional semi-conductor industry, but it performs fairly well in niche products for this sector. The same could be said for PV. To remain a future player, research in novel devices and manufacturing techniques must be continued. Building integrated devices, offer large potentials for industrialised countries, and the technology efforts needed are more concerned by manufacturing techniques, than material research. Strong industry cooperation is needed to be able to exploit foreign markets, especially within the EU.

Offshore Wind

The Dutch offshore wind industry is well-positioned within the process engineering sector. This includes e.g. planning, development of foundations, setting-up and operation and maintenance of offshore wind farms. Dedicated harbours for equipment loading and storage are also an advantage. The relative strength in process engineering has benefited from previous experience in the oil & gas sector, however it should be clarified that both sectors have different characteristics and still a lot of experience is gained through learning by doing. Process engineering know-how has the advantage that it cannot be easily replicated elsewhere and is more resistant to external threats such as simple cost reductions for hardware parts (e.g. turbines). Independent research institutes in the Netherland contribute to the competitive situation of the Dutch industry through important research on wind park testing and development of key components such as novel foundations that need to be able to cope with the various degrees of water depth in the North Sea. Research also depends on international collaboration to a large extent as R&D is a global issue, not confined only to EU. Research results contribute to the competitive edge of the Dutch industry.

To keep and strengthen the Dutch position a policy framework for offshore wind should serve both deployment and R&D objectives. To trigger the domestic market for offshore wind a clear and long-term policy is necessary to serve industry with the perspectives for investment security. Besides, learning effects are important for the industry. The current national target of 6,000MW installed offshore wind until 2020 is surely ambitious. It also depends how hard the government is really pursuing the target and which timing to reach the target is applied. R&D support should foster independent research for the institutes, collaborations with industry and international cooperation in research consortia.

Biomass (2nd generation biofuels)

The Dutch biomass sector has established a strong foothold in the biofuel trading and blending of currently mainly 1st generation biofuels. The Netherlands benefit from their strategic location as a large number of biofuel feedstocks enter Europe via one of the Dutch ports. Rotterdam’s importance as a trading hub is growing not only because of its importance in Europe, but also due to available blending opportunities. Currently, the R&D focus is on novel production processes such as Fischer-Tropsch or biomass-to-liquid (BTL). This process technology can be utilized through integrated biorefineries that have multiple outcomes, besides biofuels also chemicals, materials or by-products creating an overall higher value. Biorefineries have the potential to replace traditional oil-based refinery concepts in the future.

It is expected that the Netherlands will further develop to become a major biofuel trading hub in Europe as domestic sources are scarce. Sophisticated biorefinery process technology could emerge as a second industry pilar with opportunities for export. Countries such as Brazil, Sweden, Germany and the US are strong competitors, although some of these countries are still more focussed on feedstocks/production processes for 1st generation biofuels.

The shift towards 2nd generation integrated biorefinery processes requires significant initial investments to realize this new opportunity and gain lessons learned from the operation of demonstration facilities. The Dutch government should foster the investment climate for biorefinery concepts by providing a clear and stable policy framework as a signal of long-term interest towards the industry. Policies related to the initial deployment of biorefinery demonstration plants can help to overcome high investment cost as this technology is in an early stage of development. In addition, continued R&D support is necessary to further improve the effectiveness of processes and enhance efficient use of feedstock for multiple purposes (e.g. fuel, materials, heat)

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Appendix A Overview of interviews

During the project, several personal interviews have been performed with experts from within the Energy research Centre of the Netherlands. For a complete overview see Table A.1 below.

Table A.1 *Expert interviews*

ECN expert	Expertise area
Wim Sinke, program manager pv	PV
Daan Janssen, program manager CCS	CCS
Chris Westra, general manager We@Sea	Offshore Wind
Karina Veum, senior researcher	Offshore Wind
Marc de Wit, researcher	Biofuels
Marc Londo, group leader	Biofuels