

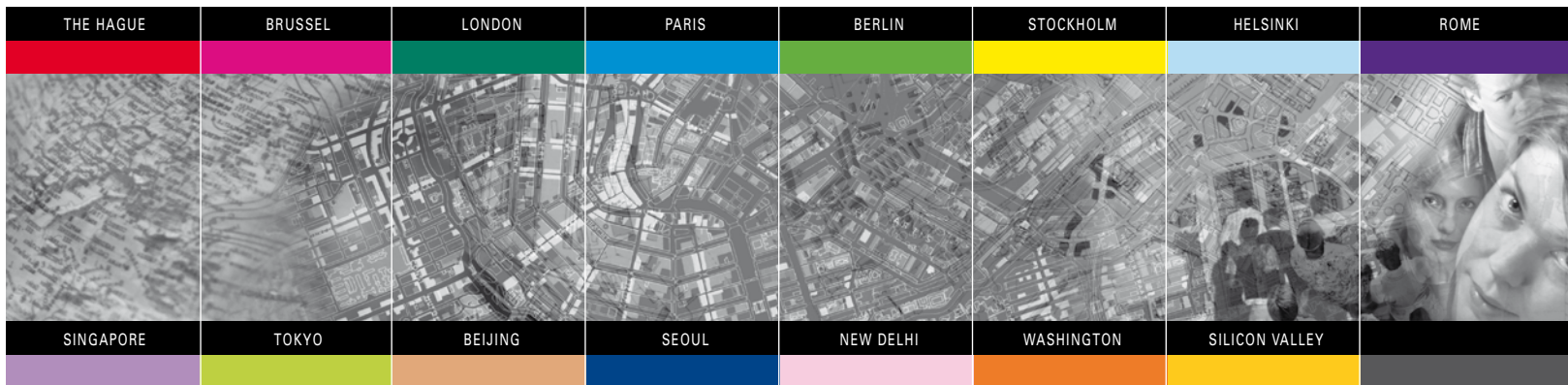


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The Biobased Economy: The state of the art in The Netherlands

Introduction

Like many advanced industrialized economies, the Dutch economy and society face some interesting challenges in the field of sustainable and economically competitive energy, fuels and materials. It is therefore no surprise that the Dutch government has developed a vision for the future around the well known concept of a bio based economy. This vision demonstrates awareness of the potential of international and Dutch R&D efforts to address some of the technological issues surrounding the adoption of bio based technologies, notably in the areas mentioned.

The Netherlands does not pretend to have the technology solution for all advancements in a bio based economy. Yet with our knowledge and experience in related fields, such as agricultural and plant sciences, biotechnology, biochemistry, energy research it is achievable to play a role in some of the breakthroughs which are to be expected in the areas of fuels, energy and materials.

In order to provide a stimulating push in this field of R&D and innovation an international conference by the Netherlands Network of Science and Technology Officers was agreed on the topic of "Innovative Technologies for a bio based economy". The Netherlands Network of Science and Technology Officers (Technisch-wetenschappelijke Attachés) are able to quickly establish contact with the various experts in the field of relevant R&D activities in the Netherlands. These S&T officers are stationed in a large number of countries around the world to foster cooperation between researchers and entrepreneurs.

As part of this conference we aim to provide international relevant contacts in the field of science and technology with an overview of the Dutch R&D and innovation efforts in the fields mentioned earlier.

This publication will provide you with a non-exhaustive overview of some of the novelties of Dutch bio based entrepreneurship in the field of fuels, materials, chemicals and energy. The Netherlands Network of Science and Technology Officers (Technisch-wetenschappelijke Attachés) sincerely hopes that you are inspired by this publication to work together with all Dutch organizations active in the field of bio based innovations and technologies.

Enjoy,

The Netherlands Network of Science and Technology Officers.

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The Biobased Economy: The State of Affairs in The Netherlands

Corry van Driel, SenterNovem

Summary

The biobased economy, an economy based on renewable biological sources, demands the sustainable cultivation of biomass plus the technology to convert biomass more effectively into food, products and energy. The food processing industry, the pharmaceuticals and the paper manufacturing industries, have for many years now been making use of biobased raw materials and biotechnology. The Dutch agricultural sector has a good reputation in the field of processing and producing starch, sugar and lactic acid. Furthermore, a small number of Dutch chemical companies are manufacturing biopolymers and biobased chemicals for niche markets. Initiatives for the large-scale manufacture of biofuels and bio-refining are still either in the preparatory or research stage. Nevertheless, the Netherlands does hold a prominent position in terms of knowledge in the field of cultivation technologies and industrial (white) biotechnology. This knowledge plays a significant role in the development of new technology for the sustainable co-manufacturing of food, chemicals, materials and fuel from biomass. Especially the use of algae to produce carbohydrates and chemicals is a highly promising technology for the Netherlands.

Introduction

In the biobased economy businesses manufacture foodstuffs, chemicals, materials and energy from biomass. Making use of biobased raw materials reduces the amount of fossil raw materials required. Opportunities are presenting themselves for the chemicals and agricultural sectors, two important pillars of the Dutch economy. Moreover, the Dutch chemicals sector hopes to reduce the use of fossil raw materials by 50% in the year 2030. This can be achieved, for instance, through the sustainable production of chemicals and plastics from biomass. The Netherlands Government presented its vision on the biobased economy in the energy transition (1) in October 2007.

The cultivation of biomass

A total of 820,000 of the two million hectare of Dutch agricultural land is in use as arable land (2, Table 1):

The Dutch arable farming chains for cultivation, trade and the processing of agricultural products comprises more than 24,000 businesses. The turnover of this sector is upwards of € 16 billion per annum and exports are in the region of € 6 billion. Dutch production per hectare is the highest in Europe and the Netherlands is leading in potato cultivation.

Crop	Hectare
Potatoes for the retail market	66,000
Industrial potatoes	51,000
Seed-potatoes	39,000
Wheat	137,000
Barley	51,000
Other grains	8,000
Sugar beet	84,000
Field vegetables	53,000
Oilseed	7,000
Other crops	72,000
(Green) maize	230,000

Table 1. Area of land used for agriculture in the Netherlands. NB (green) maize is not counted as specialist arable farming (Source: CBS)

Green Genetics

The Netherlands is one of the world leaders in the cultivation of new plant varieties for ornamental plant cultivation, seed for sowing and young plants for potatoes and vegetables. The sector is worth an annual turnover of van € 2.5 billion. The breeding companies, consisting of several large-scale and many small and medium sized enterprises, is a highly R&D intensive sector which spends some 15% of its turnover on R&D. Umbrella organisation, Plantum-NL, represents the majority (95%) of these businesses.

Technological Top Institute, Groene Genetica in Wageningen, was founded in order to bridge trade and industry's fundamental genetics research and applied research. The research programme, with a budget of € 40 million (half of which is being financed by the knowledge institutes and half by industry) will take four years to complete.

Another research programme in the field of genetics at Wageningen University aims to reduce the use of herbicides and amount of energy consumed in the cultivation of potatoes. Today, of all the herbicides used in arable farming 50% is used to combat Phytophthora.

Biopolymers

Because of the substantial potato sector and starch processing industry a relatively large amount of starch-based polymers is manufactured in the Netherlands. Dutch company, Paragon, a spin-off of the starch processing company, Aveba, manufactures illea and dog chews. Rodenburg Biopolymers manufactures Solanyl, which is used for flower pots and plant ties. While the price/performance ratio of these polymers has improved over the years the low price of competitive bulk polymers, such as polyethylene and polypropylene, means that the market share of these green thermoplastics remains limited: less than 0.1%. The manufacturers have to take advantage of the technical benefits of biopolymers such as biodegradability and the high oxygen barrier. The latter in particular makes them highly suitable for food packaging. The Dutch company, PaperFoam, makes plastic packaging and CD sleeves from a fibre-reinforced starch-based polymer (Table 2, next page).

Hycail in Nordhorn, a spin-off of the University of Groningen, produces several hundred tonnes of polylactide (PLA) annually on a semi-commercial basis. CSM subsidiary, Purac, in Gorinchem produces lactic acid for the food processing industry.

Innovative biobased SMEs in the Netherlands

- Tech-Wood Nederland in Rijssen manufactures composites from wood and plastic:
- As the first company in Europe, NPSP Compositen in Haarlem is developing a fully biobased composite: fibre and resin. ANWB and NS have shown interest in this material.
- Holland Novochem in Nieuwegein discovered a new synthesis route for the production of a spongy adsorption material from fatty acids. This material is particularly suitable for separating oleaginous compounds from water. The purification efficiency is also extremely high for low concentrations of oil in water.
- Greengran, a spin-off of Wageningen University and Research Centre, processes short agro-fibres in polymers suitable for injection moulding. In association with Anome, Greengran developed a plastic ground consolidator. This is a hook-shaped product which, when applied in bulk, can be used to counteract soil erosion and dike protection.



Figure 1. ANWB road markers

Group	Type	Structure/production method
1. starch-based polymers	polysaccharide	modified natural polymer
2. polylactide (PLA)	polyester	bio-monomer (lactic acid) by fermentation, followed by polymerisation
3. Other polyesters from bio raw materials a. polytrimethylene terephthalate (PTT) b. polybuteneterephthalate (PBT) c. polybutylene succinate (PBS)	polyester	bio-based 1,3-propanediol by fermentation + petrochemical terephthalic acid bio-based 1,4 butanediol by fermentation + petrochemical terephthalic acid bio-based succinate acid by fermentation, plus petrochemical terephthalic acid
4. polyhydroxyalkanoate (PHA)	polyester	direct production of polymer by fermentation or as a plant (both usually genetically modified)
5. polyurethane	polyurethane	bio-polyol by fermentation or chemical purification, plus petrochemical isocyanate
6. polyamide a. polyamide 6 b. polyamide 66 c. polyamide 69	polyamide	bio-based caprolactam by fermentation bio-adipic acid by fermentation bio-monomer obtained by conventional chemical conversion from oleic acid via azelaine acid
7. cellulose polymers	polysaccharide	a. modified natural polymer b. bacterial cellulose by fermentation

Table 2. List of the main groups and types of biopolymers (Source: 3) (NB. Natural rubber consists of polymerised methyl butadiene, or isoprene)

One of the major advantages of using agro-fibres in polymers is the weight-saving aspect. The use of agro-fibre reinforced composites and polymers leads to a substantial saving of energy in the transport sector.

Some 40 SME entrepreneurs and research institutes are united in the Biobased Business Platform. The Netherlands Ministry of Agriculture, Nature and Food Quality gives support to SME entrepreneurs through the SBIR Biobased Economy programme.

The Dutch Polymer Institute in Eindhoven, Wageningen ASFG and the University of Groningen are developing a joint research programme called Biobased Performance Materials. This programme, that combines research into biopolymers and additives in the Netherlands, has a budget of € 20 million and will run for four years.

Biodiesel

The present market share of biobased car fuels in the Netherlands is approximately 0.4%. In conformity with the European Directive this market share should increase up to 5.75% in 2010. The current, first generation of biofuels are manufactured from high oil-content or high sugar-content agricultural crops. Biodiesel, for instance, is derived from rapeseed oil by means of extraction. The rapeseed used for this purpose is cultivated outside the Netherlands.

The manufacture of biodiesel in the Netherlands

Production at the end of 2006 : 5.5 million litres per annum

- Coöperatie Carnola in Oirlo: 2 million litres per annum;
- Noord-Nederlandse Oliemolen BV in Boijl: 3.5 million litres Puur Plantaardige Olie (PPO) from imported rapeseed.

Plans and objectives:

- Biopetrol Rotterdam: 400 million litres biodiesel
- Biovalue in Eemshaven: 85 million litres from vegetable and

animal oils and fats

- Sunoil Biodiesel in Emmen: 30 million litres
- Ten Kate in Ter Apelkanaal: 10 million litres biodiesel from animal fat
- Ecoson in Son: 5 million litres biodiesel and 1 MWh electricity from slaughter by-products.

Source: (2)

Two Dutch companies manufacture biodiesel from frying-fat which is collected from the catering industry. Fatty acids are converted into diesel fuel by means of a transesterification reaction. A third plant is under construction.

New method for manufacturing biodiesel from algae

One promising development for the Netherlands is a new method for manufacturing biodiesel from algae. Under the influence of light and nutrients, algae converts CO₂ into carbohydrates and chemicals. Algae, under the right conditions, produce 50 to 100 times more vegetable oil per hectare than other plants. Wouter van Winden of Delft University of Technology and Leo Vleugels of the chemicals company, DSM, were awarded the Leo-Petrus-Innovation-Trophy in 2007 for their research into a revolutionary manufacturing method to obtain biodiesel from algae. This new method increases the economic feasibility of the process. The award includes a monetary sum of one hundred thousand Euros to further develop the method.

Bio-alcohol

Sugars from biobased raw materials are converted into ethanol by means of fermentation. BER, a company located in the Rijnmond area,

produces 100 million litres of bio-ethanol annually from wheat. At Amsterdam, Harvest Fuels BV produces 110 million litres of bio-ethanol from corn. Nedalco in Bergen op Zoom intends to scale up the manufacture of bio-ethanol from starchy residue flows to 200 million litres. Metanor is manufacturing biomethanol in Delfzijl. ECN and Wageningen University and Research Centre are conducting research into the production of biobutanol by fermenting biomass. Maatschap Bosma in Zuidvelde is manufacturing bio-ethanol from potatoes, approximately 4,600 tonnes on an annual basis.

Alcohol from wood and straw

Nedalco is developing a new production process to obtain bio-ethanol from wood chippings and straw. This has become possible since researchers at Radboud University Nijmegen isolated an enzyme in elephant droppings which researchers of Delft University of Technology have incorporated in yeast to ferment ligneous materials and straw. This enzyme converts the sugars (xylose) present in ligneous fibres into ethanol. This discovery means that the production of ethanol no longer competes with the production of food.

Several scenarios for the European market share of biofuels in 2020 have been computed by the Agricultural Economics Research Institute. A market share of 2.2% for example already implies that more than half the required biomass originates from non-European countries. The price of corn increased by 32% in 2006 due to the economic growth in Asia, disappointing crops in North America, and the demand for biofuels. In other words, the precondition for the biobased economy is that it does not compete with the production of food, nor does it lead to the loss of biodiversity.

Bio-refining

A total of 600 petajoule (PJ) of biomass and 600 PJ of fossil fuel is required (1) for the production of food in the Netherlands. For the consumer this yields an energetic value of 59 PJ. This could be considerably more efficient. Bio-refining; the smart co-manufacturing of food, pharmaceuticals, fibre, materials and fuel from biomass plays a key role in this respect. Residual products, wood chippings, roadside grass, straw and the inedible components of agricultural crops are directly converted into energy.

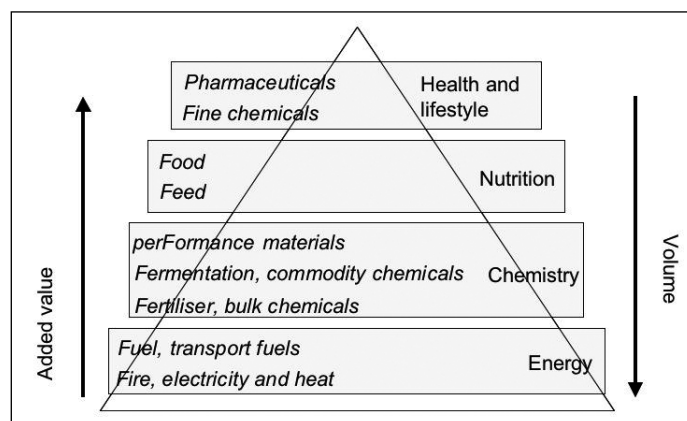


Figure 2. Added value of agricultural produce (1)

Bio-refining is in actual fact a generic term that covers several key technologies:

- biochemical or biotechnological synthesis: fermentation by using enzymes, ferment, fungi, bacteria and algae production
- thermochemical synthesis: gasification, hydrothermal upgrading,

torrefaction and pyrolysis

- separation technology: extraction, compression, filtration, centrifugation, pervaporation, etc.

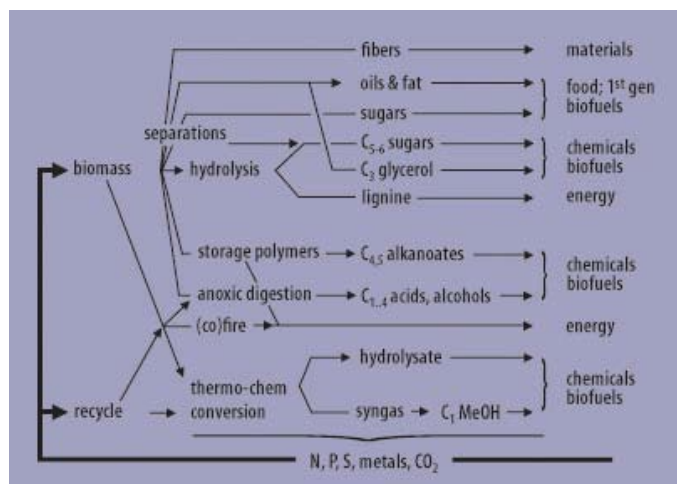


Figure 3 Diagram of bio-refining (4)

Different branches of industry; foodstuffs, medicines, paper, paint and floor covering, have all applied biotechnological processes for many years now. Aquamarijn, a business established in IJmuiden, manufactures natural linseed oil-based paint systems. Forbo in Krommenie manufactures for instance Linoleum from linseed oil.

Knowledge of key technologies for more advanced and more energy efficient bio-refining in the Netherlands is concentrated in research institutes: cultivation and production (Wageningen University and Research Centre /ASFG), biotechnology and catalysis (Delft University of Technology, Wageningen University and Research Centre, Energy Research Centre of the Netherlands ECN, Utrecht University) and separation technology (NIZO Food Research, Dutch Separation Technology Institute DSTI, Wageningen University and Research Centre, Delft University of Technology). The joint R&D investment made in green chemistry and materials is approximately €130 million per annum. About half of this amount is funded by knowledge institutes and industry.

Nevertheless, the Dutch knowledge infrastructure is fragmented. On the initiative of the Netherlands Ministry of Agriculture, Nature and Food Quality a roadmap of bio-refining is being drawn up. The government plans to invest €80 million over the next few years in R&D in the field of sustainable and efficient production of biobased products.

Chemicals and 'white biotechnology'

Dutch manufacturers of bio-ethanol and chemicals currently opt for wheat as the raw material because the extraction of chemicals from the inedible residual flows is even more difficult. The B-BASIC research programme focuses on the synthesis of chemicals from biomass which is difficult to access, such as the inedible parts of agricultural produce. This programme examines the biosynthesis of bulk chemicals, fine chemicals, pharmaceutical products and new materials, including alternatives for the production of biofuels.

Industrial (white) biotechnology has the focus of attention. Micro-organisms and enzymes are the catalysts in production processes. The manufacture of antibiotics using this new biotechnology, for example, saves 50% more energy. Researchers Luuk van der Wielen and Gerda Lourens of Delft University of Technology are the managers of this programme. The consortium comprises Delft University of Technology, Leiden University and the University of Groningen, TNO-Institute of Environmental Sciences, Energy Research and

Process Innovation, Wageningen University and Research Centre, DSM, Akzo Nobel and Shell. A budget of €50 million has been set aside for this research programme which will run for five years. Half the budget is funded by those companies and knowledge institutes involved in the programme. The remaining 50% is funded from Dutch revenues from natural gas (FES).

The Kluyver Centre for Genomics of Industrial Fermentation, affiliated to B-BASIC, focuses its research on the genomics of micro-organisms for industrial production. Delft University of Technology is responsible for coordinating this research that falls under the Nederlands Regieorgaan voor Genomics.

Catchbio

Catalytic processes (both homogenous and heterogeneous) for converting biomass into inexpensive and sustainable biofuels, chemicals and pharmaceuticals are being developed in the Catchbio research programme. This programme runs from 2007 to 2015 and has a budget of €9.2 million, €6.6 million of which is made available by the Ministry of Economic Affairs and the Ministry of Education, Culture and Science. The motor behind this programme is the Nederlands Instituut voor Onderzoek naar Katalyse (NIOK) (Dutch Institute for Catalysis Research) with twenty-two research and industrial partners.

Catchbio consortium

Companies: Shell, DSM, Dow, Sabic, Albemarle, Avantium, BASF, Organon, BIOeCON, Sasol, VibSpec, Hybrid Catalysis.

Universities: Utrecht, Wageningen, Twente, Groningen, Delft, Eindhoven, Leiden, Nijmegen and Amsterdam.

Institutes: NIOK and ECN

Paper and agro-fibres

Bio-refining is essential for the paper manufacturing industry. The price of wood and scrap paper has more than doubled over the past eighteen months due to the demand for these raw materials to make green energy. The association of paper and cardboard manufacturers (VNP) and the Kenniscentrum Papier en Karton (Knowledge Centre for Paper and Cardboard) work in association with Avebe, Cosun, HPA and Meneba on bio-refining. At present the paper manufacturing industry is mainly dependent on Finnish technology for knowledge on bio-refining.

A Finnish company, Chempolis, developed a smart process for the production of paper fibres from agricultural waste. This is a process that converts straw and ligneous material into paper fibres and the chemicals acetic acid and furfural.

Algae Production of energy and chemicals

Under the influence of sunlight, and with nutrients, algae convert CO₂ and water into carbohydrates and chemicals, including colouring agents, fatty acids and pharmaceuticals. The combination of generating energy from carbohydrates and biomass makes this technology highly interesting. The main advantage of using algae is that there is then no need to import biomass. Significant research questions are the chemicals output and harvesting techniques.

LGem, a company located in Brabant, cultivates algae for the production of omega-3 fatty acids for the food processing industry. Algae Production can be combined with waste-water purification and manure processing. Fertiliser results from converting manure and CO₂ into nitrogen compounds by using algae. These ideas are still in the research stage.

Energy

In 2005 the Dutch private sector invested €220 million in energy research and development, 54% of which was on energy saving (5). €11 million (5%) was spent on research into generating electricity from biomass. The ambition of the Biobased Raw Materials Platform (Groene Grondstoffen platform) is to generate 25% of the total demand for electricity from biomass by 2030. At the assignment of this platform the Utrecht University Innovation Studies Group is conducting a scan into promising technological transition paths to realise this ambition.

Farmers as the producers of energy

All the waste from agriculture, the food processing industry and the catering industry is enough to generate some 10% of our current energy consumption. The current share of green power in the Dutch power supply is in the region of 2.5%. This is generated mainly by fermenting manure and burning wood waste and scrap paper in power stations.

Eighteen farms in the Netherlands are equipped with a manure fermentation unit. The biogas produced is converted into electricity and heat in a cogeneration unit. The residue from (manure) fermentation units is used as fertilizer and contains fibres that might possibly be of use to the paper manufacturing industry. The expertise and technology for manure fermentation is mainly from Germany and Denmark. Wageningen University and Research Centre is conducting research into the biorefining of grass for Courage, a foundation set up on the initiative of LTO Nederland and the Dutch Dairy Produce Industrial Organisation NZO. Agricultural contractor Gjalt de Haan of Friesland carried out experiments with refining grass towards the end of 2006. This first, simple refinery process using two presses produces a protein concentrate for cattle feed, fibres and a residual sap with a high sugar and mineral content. Research is underway to find out whether these fibres are suitable for the paper manufacturing industry. For the time being, the sap is left on the land but it is quite possible that it may be suitable for use as raw material for the chemicals and pharmaceuticals industries.

Ports and import

The Port of Rotterdam has a key position in the supply of biofuels and cattle feed. The location of Eemshaven is favourable for all initiatives for bio-refining and the production of arable crops and green energy in the northern part of the Netherlands.

The Biobased Raw Materials Platform estimates that in 2030 approximately 60% of the biomass or biobased raw materials will be imported in order to realise the ambition in which the biobased economy will provide 30% of the demand for energy and raw materials in the Netherlands. To prevent this from being at the expense of the production of food and biodiversity, the government has drawn up sustainability criteria for biomass production. It is likely that a certificate will be introduced for sustainably-produced biomass. This is one of the few systems that complies with the set of rules drawn up for international trade by the WTO.

Corry van Driel is programme adviser for Chemistry at SenterNovem. I would like to extend my thanks to dr. ir. Marco Schwegler, ir. Edith Engelen and ir. Geert van Grootveld.

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This publication is edited by Bruno van Wayenburg, science journalist.

TWA DEN HAAG

EVD
TWA Netwerk

Postbus 20105
2500 EC Den Haag

Servaas Duterloo
Alice Rauch
Lies Timorason
Sabra Boedhoe (secretariaat)
telefoon +31 (0)70-778 82 37
telefax: +31 (0)70- 778 88 89
e-mail: twa.thuisbasis@info.evd.nl

TWA BRUSSEL

Embassy of the Kingdom of the Netherlands (EU-Brussel)
Herrmann Debrouxlaan 48
1160 Brussel

Marloes Telgenhof
telefoon: +32 2 679 1665
telefax: +32 2 679 1777
e-mail: Brussel@twanetwerk.nl

TWA LONDEN

🕒 1 uur vroeger

Embassy of the Kingdom of the Netherlands
Office for Science & Technology
38, Hyde Park Gate
London SW7 5DP

Henk Hoefdraad
Vanessa van Mildert (Office manager)
telefoon: +44 20 75903295/
+ 44 20 7590 3239
telefax: +44 20 7584 3396
e-mail: londen@twanetwerk.nl

TWA PARIJS

Ambassade du Royaume des Pays-Bas
Service pour la Science et la Technologie
7 Rue Eblé
F-75007, Paris

Carolien van Hemel
Joannette Polo-Leemreis
Saskia van der Wiel (Office manager)
telefoon : + 33 1 40 62 33 33
telefax: + 33 1 40 62 34 56
e-mail: Parijs@twanetwerk.nl

TWA BERLIJN

Botschaft des Königreichs der Niederlande
Büro für Wissenschaft und Technologie
Klosterstrasse 50
D-10179 Berlin

Thijs Spigt
Nabila Chehab - van den Assem
Sonja Schwirkmann (Office manager)
telefoon: + 49 30 20956219
telefax : + 49 30 20956471
e-mail: Berlijn@twanetwerk.nl

TWA STOCKHOLM

Kungliga Nederländska Ambassad
Götgatan 16A
SE-104 65 Stockholm

Antoine Wittebols
telefoon: +46 8 556 933 20
telefax: +46 8 556 933 11
e-mail: stockholm@twanetwerk.nl

TWA HELSINKI

🕒 1 uur later

Ambassade van het Koninkrijk der Nederlanden in Helsinki (Helsingfors)
Erottajankatu 19 B, 5e verdieping
(Skillnadsgatan 19 B)
00130 Helsinki

Johan Hendriks
telefoon: +358-(0)9-228920
telefax: +358-(0)9-22892228
e-mail: Helsinki@twanetwerk.nl

TWA ROME

Ambasciata del Regno dei Paesi Bassi
Addetto Tecnico-Scientifico
Via Michele Mercati 8
00197 ROMA ITALIA

Karel van Gorp
telefoon: +39-06-32286 205
telefax : +39-06-32286 249
e-mail : Rome@twanetwerk.nl

TWA SINGAPORE

🕒 6 uur later

Embassy of the Kingdom of the Netherlands
Office for Science and Technology
541 Orchard Road, 13-01
Liat Towers Singapore 238881

Annoek van den Wijngaart
Margreet Mennes
(TWA assistente)
telefoon : +65 67 39 11 11
telefax: +65 67 37 24 31
e-mail: Singapore@twanetwerk.nl

TWA TOKIO

🕒 7 uur later

Embassy of the Kingdom of the Netherlands
Office for Science and Technology
3-6-3 Shibakoen
Minato-ku, Tokio 105-0011

Thomas Bleeker
Daan Archer
Rob Stroeks
Kikuo Hayakawa
Mihoko Ishii (Office manager)
telefoon +81 3 5776 5510
telefax +81 3 5776 5534
e-mail: Tokio@twanetwerk.nl

TWA PEKING

🕒 7 uur later

Embassy of the Kingdom of the Netherlands
4, Liangmahe Nanlu
Beijing 100600, China

Eric van Kooij
Jaap van Etten
telefoon: +86-10-853 20259
telefax: +86-1085320302
e-mail: peking@twanetwerk.nl
Freek Jan Frerichs (Shanghai)
telefoon: + 86 21 6209 9076 ext 223
telefax: + 86 21 6209 9079
e-mail: shanghai@nost.org.cn

TWA SEOEL

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Embassy of the Kingdom of the Netherlands
Netherlands Office of Science and Technology
14th Fl. Kyobo Building
1 Jongro 1-ga, Jongro-go,
Seoul 110-714 Korea

Peter Wijlhuizen
telefoon: +82 2 737 9514 (ext. 209)
telefax: +82 2 735 1321
e-mail: seoel@twanetwerk.nl

TWA NEW DELHI

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Embassy of the Kingdom of the Netherlands
Department for Science & Technology
6/50-F, Shantipath, Chnakyapuri,
New Delhi- 110 021
India

Theo Groothuizen
Rushi Bakshi
telefoon: +91 11 24197625 direct of
algemeen +91 11 24197675
+91 9873076764 (mobiel)
telefax: +91 11 24197710
e-mail: newdelhi@twanetwerk.nl

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Embassy of the Kingdom of the Netherlands
Office for Science & Technology
4200 Linnean Avenue N.W.
Washington DC 20008-3896, USA

Paul op den Brouw
Bart Sattler
Gerda Camara (Office manager)
Barbara Staals
telefoon: +1 202 274 27 27
telefax: +1 202 966 07 28
e-mail : Washington@twanetwerk.nl

TWA SILICON VALLEY

🕒 9 uur vroeger

Netherlands Office for Science and Technology
901 Mariner's Island Boulevard
Suite 595
San Mateo, CA 94404

Bianca Oudshoff
Marc Nellen
Cees van der Zon
Anushka Koeldiep (Office manager)
telefoon: +1 650 403 02 22
telefax: +1 650 349 82 01
e-mail: Siliconvalley@twanetwerk.nl