Lopend en gepland NWO-energieonderzoek 2008 - 2012: een inhoudelijke beschrijving

Een overzicht gemaakt naar aanleiding van het NWO-thema 'Funderend Energieonderzoek'

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Voor nadere informatie kunt u zich wenden tot
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1. Inleiding

Het energievraagstuk wordt met de dag urgenter. De vraag naar energie neemt gestaag toe, terwijl de productie van energie met steeds grotere problemen wordt geconfronteerd. De regering is zich de urgentie van het energievraagstuk bewust[1].

Naast maatregelen gericht op zuiniger omgaan met energie is er op allerlei fronten innovatie, toegepast onderzoek en funderend (lange termijn) onderzoek nodig. Meer onderzoek naar bronnen van duurzame energie is hard nodig. De uiteindelijke invulling van de transitiepaden die leiden tot een duurzame energievoorziening vraagt daarbij om een goed samenspel tussen overheid, industrie en kennisinstellingen.

In de publieke sector zijn vele organisaties betrokken bij funderend energieonderzoek, als financier dan wel als uitvoerende. Met deze notitie wil NWO helder maken wat op dit moment de inhoud is van het geplande en lopende NWO-onderzoek 2008-2012. De programmatische aansturing van dit onderzoek vindt vooral plaats in het kader van het NWO-thema 'Funderend energieonderzoek' (kortheidshalve aangeduid met NWO-thema Energie).

Deze notitie c.q. inhoudelijke beschrijving heeft twee functies:

- **startpunt voor interne NWO-besprekingen over nieuwe inhoudelijke accenten voor toekomstige onderzoekprogrammering bij de NWO-gebieden/instituten en**
- **startpunt voor mogelijke nationale samenwerking en afstemming met andere nationale partijen die actief zijn op het gebied van funderend energieonderzoek, met name ECN, TNO, SenterNovem (EOS) en het Regieorgaan Energietransitie.**

Deze notitie is als volgt opgebouwd:
In hoofdstuk 2 wordt de scope van het NWO-thema Energie beschreven. Hier wordt, ingedeeld naar onderzoekslijn, het aan energie gerelateerd onderzoek van NWO beschreven en wordt duidelijk gemaakt hoe het thema Energie zich verhoudt tot andere onderzoekthema's van NWO. Verder wordt een schematisch overzicht gegeven van alle energiegerelateerde onderzoeksprogramma's 2008-2012 van NWO. In hoofdstuk 3 wordt een korte inhoudelijke beschrijving gegeven van elk van de betrokken onderzoeksprogramma's.

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[1] Op 16 juni 2008 is door de ministers Van der Hoeven (EZ), Verhagen (BuZa) en Cramer (VROM) het Energierapport 2008 aan de Kamer aangeboden. Het Energierapport 2008 gaat over de vraag hoe er gezorgd wordt voor een betrouwbare, betaalbare en schone energievoorziening op de korte en lange termijn. Daarbij wordt ook ingegaan op de betekenis van energiebesparing en duurzame energie voor de betrouwbaarheid en de betaalbaarheid van de energievoorziening.
Op 3 juli 2008 is door de ministers Van der Hoeven (EZ) en Cramer (VROM) de Innovatieagenda Energie aan de kamer aangeboden. De agenda is gebaseerd op pijler 2 (een innovatieve, concurrerende en ondernemende economie) en pijler 3 (duurzame leefomgeving) van het Regeerakkoord en wordt aangekondigd in de werkprogramma's Schoon en Zuinig en Nederland Ondernemend Innovatieland uit het Beleidsplan van het Kabinet. Met de Innovatieagenda Energie wordt in deze kabinetsperiode o.a. een extra bedrag beschikbaar gesteld van € 438 miljoen om aan de innovatie een extra impuls en meer focus te geven. Met deze impuls wil het Kabinet programma's en projecten opzetten waaraan het bedrijfsleven en onderzoekinstituten een zeer belangrijke bijdrage leveren.

2. De scope van het NWO-thema Energie

2.1 Primaire invalshoek van het NWO-thema Energie

Deze notitie beschrijft het geplande en lopende energieonderzoek voor de periode 2008-2012 in het NWO-circuit. Daarbij gaat het om onderzoek dat programmatisch wordt aangestuurd. Hierbij moet een onderscheid worden gemaakt tussen:

- enerzijds onderzoek dat primair vanuit de invalshoek Energie wordt aangestuurd en
- anderzijds onderzoek dat primair vanuit een andere invalshoek, bijvoorbeeld Milieu, wordt aangestuurd maar dat óók een duidelijk energiecomponent - bijvoorbeeld energieproductie/besparing - in zich heeft.

Van beide categorieën worden in deze notitie de energiegerelateerde onderzoeksprogramma's beschreven. Uit een oogpunt van efficiënte aansturing en transparante governance zal aansturing van het thema Energie vooral gericht zijn op het onderzoek met primaire invalshoek Energie.

2.2 Onderzoekslijnen binnen het NWO-thema Energie

De komende jaren zullen in het teken staan van de energietransitie: de structurele verandering naar een duurzame energiehuishouding. Gericht wetenschappelijk onderzoek zal een bijdrage moeten leveren om deze transitie mogelijk te maken. Maatschappelijke vragen waar men hoopt dat wetenschappelijk onderzoek voor doorbraken gaat zorgen zijn:

- verduurzaming van het energieverbruik, ofwel het efficiënter omgaan met energie;
- tot ontwikkeling brengen van nieuwe energiebronnen die gedurende lange tijd aan de energievoorziening kunnen bijdragen, o.a. door minder belastend te zijn voor het milieu;
- vergroten van de toegankelijkheid tot energie (i.e. opslag, transport en distributie).

Concreet betekent dit dat de focus zal liggen op onderzoek in de volgende drie programmatische onderzoekslijnen: Energiebesparing, Energiebronnen en als derde Energieopslag, -transport en -distributie. Met het thema Energie wil NWO het funderend onderzoek op bovengenoemde gebieden versterken. Het accent zal liggen op onderzoeks-terreinen waar Nederland een sterke internationale positie heeft of het potentieel bezit om deze te verkrijgen.

<u>Energiebesparing</u>

Energiebesparing is een speerpunt in het Nederlandse energiebeleid. Het kabinet heeft de ambitie uitgesproken om in 2020 te komen op een besparingstempo van 2% per jaar.

Bestaande technieken hebben voor de komende decennia een verbeteringspotentieel van 25 – 40 procent op de energie-efficiëntie: voorlopig voldoende om de bovengenoemde besparing van 2 procent per jaar te realiseren. Ontwikkeling van nieuwe technieken is nodig om het bestaande potentieel tegen lagere kosten te kunnen realiseren en om op termijn een doorgaand tempo van verbetering van de energie-efficiëntie te realiseren. Een ambitieuze inzet op onderzoek en ontwikkeling kan op den duur leiden tot een verbetering van de energie-efficiëntie van 3 – 4 procent per jaar (Bron KNAW Verkenning 'Duurzaamheid duurt het langst', 2007).

Typische voorbeelden van NWO onderzoeksprogramma's binnen deze onderzoekslijn Energiebesparing zijn het Clean Combustion Concepts programma naar schonere en efficiëntere verbranding van fossiele brandstoffen en het onderzoekprogramma naar de invloed van turbulentie bij energieconversie.

Energiebronnen: Zonnecellen
Zonnecellen worden algemeen beschouwd als een onmisbare hoofdingrediënt van een duurzame energiehuishouding. Zonnecellen vormen een typische lange-termijn optie, in de zin dat het zelfs in ambitieuze scenario's nog enkele tientallen jaren duurt voordat een significante bijdrage aan de totale mondiale energievoorziening mag worden verwacht.

In deze onderzoekslijn wordt langs twee wegen gewerkt: 1) zonnecellen voor elektriciteits-productie (fotovoltaïsche zonnecellen) en 2) zonnecellen voor brandstofproductie, zoals koolwaterstoffen uit CO_2 en water (fotosynthetische zonnecellen).

Fotovoltaïsche conversie verkeert nog steeds in een vroeg stadium van wetenschappelijke en technologische ontwikkeling. Het theoretische maximum rendement voor pv-conversie is ongeveer 85 procent. Rendementen voor kleine laboratoriumcellen halen de 40 procent, terwijl commercieel verkrijgbare panelen rendementen tussen 5 en 20 procent halen. Er valt dus nog veel winst te behalen in zowel de verbetering van het rendement als in het verlagen van de productiekosten van de zonnecel.

Fotosynthetische zonnecellen staan nog aan het begin van hun ontwikkeling. Nu de fundamentele mechanismen in cyanobacteriën en planten grotendeels in kaart gebracht zijn, is het mogelijk soortgelijke, voor brandstoffen geoptimaliseerde processen te realiseren in kunstmatige (nano)-structuren of aangepaste biosystemen. Dit is een zeer interessante optie voor schone en efficiënte, door zonlicht gedreven, (chemische) energie-productie in de vorm van waterstof of koolwaterstoffen als methanol of glyceride.

Typische voorbeelden van NWO onderzoeksprogramma's binnen deze onderzoekslijn zijn het 'Joint Solar Program' en het programma 'Thin-film nanomanufacturing of high efficient solar cells'.

Energiebronnen: Fusie
Bij kernfusie wordt energie opgewekt volgens het principe van de zon, zonder uitputting van grondstoffen, en met beperkte, laag-radioactieve afvalstromen. Het werkt op basis van de samensmelting of fusie van twee zware soorten waterstof. Na vele decennia onderzoek heeft het internationale JET-project tot het resultaat geleid dat nu gedurende één seconde 10 Megawatt aan kernfusie-energie kan worden geproduceerd. Het wereldwijde ITER-project heeft als doel om in het jaar 2018 in staat te zijn 500 Megawatt op te wekken gedurende meer dan 400 seconden. Een aantal partners van ITER verwacht dat in 2035 de eerste demonstratiereactor zal draaien en dat in 2050 een betrouwbare kernfusiereactor beschikbaar komt.

Belangrijke wetenschappelijke en technologische uitdagingen waar Nederland in ITER-verband aan meewerkt zijn:
- het stabiel en efficiënt opsluiten van een energieproducerend plasma, en de geavanceerde regeling van dit complexe systeem;
- de ontwikkeling van materialen die het intense neutronenbombardement kunnen doorstaan;
- de afvoer van het gedissipeerd vermogen uit de wanden van de fusiereactor.

Het FOM-Instituut Rijnhuizen is de thuisbasis voor de Nederlandse inbreng in het ITER fusieprogramma. Onderzoek aan fusierelevante materialen vindt plaats bij NRG in Petten. De Nederlandse industrie wordt in het werk voor ITER betrokken via ITER-NL, een

project van TNO, FOM en NRG. Het is de bedoeling universitaire onderzoekgroepen meer bij het werk van FOM-Rijnhuizen te betrekken.

Energiebronnen: Bio-brandstof
Recent wetenschappelijk onderzoek claimt dat biomassa het technische potentieel bezit om een significante bijdrage aan duurzame energie kan geven. Het onderzoek beoogt het ontwikkelen en integreren van nieuwe concepten voor de duurzame productie van biobrandstoffen uit laagwaardige, non-food biomassastromen door het inzetten van micro-organismen en/of enzymen als biokatalysatoren. De nadruk ligt op het optimaliseren van energetische rendementen en het minimaliseren van netto kooldioxide-uitstoot, teneinde een economisch en maatschappelijk haalbare transitie van petrochemie naar 'bio-based' productie mogelijk te maken.

Een typisch voorbeeld van een NWO onderzoeksprogramma binnen deze onderzoekslijn is het programma 'Biomass en bio-based production' dat nu ontwikkeld wordt.

Opslag, transport en distributie
Nieuwe energiebronnen als windenergie en zonne-energie kenmerken zich door een groot aantal opwekeenheden met een sterk variërende bijdrage in de energievoorziening. Daardoor ontstaan soms sterke verschillen in vraag en aanbod, zowel op locatie als in tijd. Dit maakt de komst van een veel geavanceerder energieopslag en -distributienetwerk noodzakelijk. Waterstof, als drager van energie, zal zowel bij opslag als transport een belangrijke rol gaan spelen.

Opslag van energie uit nieuwe energiebronnen is op grote schaal, met uitzondering van stuwmeren in hooggebergten, nog nauwelijks mogelijk. Men hoopt nieuwe doorbraken te realiseren voor chemische, mechanische en elektrische energieopslag.

Transport en distributie van energie, in de vorm van elektriciteit, gas en warmte, maakt een ontwikkeling door van een centraal naar een meer decentraal geconfigureerde infrastructuur. Zo ontstaat door massale locale elektriciteitopwekking met levering aan het landelijke elektriciteitsnet een heel nieuwe problematiek. Met behulp van slimme energiemeters en ICT-voorzieningen – smart grids - kan op een nieuwe manier verrekening van elektriciteitsverbruik en stroomlevering plaatsvinden. Dit schept ook nieuwe eisen aan de infrastructuur, waaronder stabiliteit en belastbaarheid van netwerkvoorzieningen en intelligente plan-, meet-, regel- en verrekeningssystemen.

Een hoofdlijn in het onderzoek naar energieopslag betreft materiaalontwikkeling voor elektrochemische opslagtechnologieën zoals geavanceerde batterijen en supercondensatoren. Andere voorbeelden van NWO onderzoeksprogramma's binnen deze onderzoekslijn zijn 'Sustainable Hydrogen' en 'New technologies for fuel cells and hydrogen storage'.

2.3 Energie gerelateerde onderzoekslijnen binnen NWO-thema's anders dan thema Energie

Maatschappelijke transitieprocessen
Verduurzaming van de energievoorziening vraagt om het ontwikkelen van nieuwe hoogwaardige energietechnologie. Dit heeft o.a. tot gevolg dat de maatschappij op een andere manier met natuurlijke hulpbronnen moet omgaan. Voordat deze nieuwe vormen van energiegebruik kunnen worden doorgevoerd zijn dan ook ingrijpende veranderingen van bestaande maatschappelijke processen (transitie) nodig. Hierbij gaat het om

veranderingen in instituties, organisatiestructuren, markten en menselijk gedrag en variëren van lokaal tot globaal niveau. De energietransitie is dus een proces dat effecten heeft in het gehele maatschappelijk systeem.

Voor een optimale overgang naar een duurzame energiehuishouding zijn analyses en modellen nodig van mogelijke toekomstige transitieprocessen, bekeken vanuit verschillende tijds- en ruimte-niveaus en voor verschillende energiesystemen. Daarnaast is kennis over de manier waarop nieuwe energietechnologieën van invloed zijn op het gebruik (bv. productie en consumptie) van natuurlijke hulpbronnen belangrijk. Ook is onderzoek naar de (overheidssturing) governance van transitie nodig.

Een typisch voorbeeld van een NWO onderzoeksprogramma binnen deze lijn is Energy & Resources dat nu ontwikkeld wordt.

2.4 Overzicht NWO-energieonderzoek voor de periode 2008-2012

Tabel 1 geeft een overzicht van lopend en gepland energieonderzoek 2008-2012 dat deel uitmaakt het NWO-thema Energie.

Tabel 1: Overzicht lopende en geplande NWO-programma's binnen het thema Energie *)

Programma	Financier(s)	Looptijd	Budget [M€]				
			Totaal	2008	2009	2010	2011	2012
Energiebesparing								
Clean Combustion Concepts (CCC)	STW Industrie	09 - 13	**9,7**	-	2	2	2	2
Magneticaloric materials for cooling applications	STW BASF	05 - 10	**1,1**	0,2	0,2	0,2	0,2	0,2
Magneticaloric materials not only for cooling appl.	FOM BASF	08 - 12	**1,4**	0,3	0,3	0,3	0,3	0,3
Turbulence and its role in energy conversion	FOM	02 - 10	**3,6**	0,4	0,4	0,4	-	-
Process intensification	STW Industrie	08 - 12	**2,8**	0,6	0,6	0,6	0,6	0,6
Intelligent omgaan met Energie **)	EW, ICTregie	08 - 12	**2,0**	0,4	0,4	0,4	0,4	0,4
Energiebronnen: Zonnecellen								
Joint Solar Program	FOM, CW Shell, Nuon	05 - 13	**7,2**	0,6	0,8	0,9	0,9	0,9
Thin film nanomanufacturing of high efficient solar cells	STW Industrie	06 - 14	**3,5**	0,4	0,4	0,4	0,4	0,4
Fotosynthetische zonnecellen **)	FOM, ALW	09 - 13	**2,5**	-	0,5	0,5	0,5	0,5
Nano-photovoltaics	FOM	09 - 13	**2,1**	-	0,3	0,6	0,5	0,5
Energiebronnen: Fusie								
Manipulation of meso-scale structures in plasmas	FOM Euratom	04 - 08	**4,5**	0,4	-	-	-	-
Laboratory on plasma-surface interaction	FOM Euratom	04 - 15	**18,7**	1,6	1,6	1,6	1,6	1,6
ITER-NL	TNO/OCW	07 - 09	**4,5**	1,5	1,5	-	-	-
Energiebronnen: Bio-brandstof								
Biomass en bio-based productie **)	NGI Industrie	08 - 12	**4,0**	0,8	0,8	0,8	0,8	0,8
Bio-based Sust.Industrial Chemistry (B-Basic)	ACTS, Univ. Industrie	01 - 09	**15*****)**	1,7	1,7	-	-	-
Opslag, transport en distributie								
Sustainable Hydrogen	ACTS, FOM, WOTRO, AB, OCW, VROM, EZ, Industrie	03 - 12	**18,0**	1,7	1,7	1,7	1,7	1,7
New techn. for fuel cells and hydrogen storage	STW Industrie	05 - 10	**1,6**	0,3	0,3	0,3	-	-
Innovative physics for oil and gas (iPOG)	FOM Shell	08 - 14	**4,5**	0,3	0,8	0,9	0,9	0,9
Geothermie *)	ALW	08 - 12	**0,5**	0,1	0,1	0,1	0,1	0,1

*) Gereserveerd budget voor nieuw te ontwikkelen programma's die niet in dit overzicht zijn opgenomen: FOM: M€ 1, STW: M€ 3, CW: M€ 2.

**) Programma in voorbereiding, het NWO-deel van het budget is gealloceerd.

***) Ongeveer een derde van het B-Basic programma (totaal budget 50 M€) is direct gerelateerd aan bio-brandstof.

Tabel 2 beschrijft het NWO onderzoek dat sterk aan energie verwant is maar niet onder de governance van het NWO-thema Energie gerekend mag worden.

Tabel 2: Overzicht energie-gerelateerde NWO-programma's die niet tot NWO-thema Energie behoren

Programma	Financier(s)	Looptijd	Budget [M€]					
			Totaal	2008	2009	2010	2011	2012
Maatschappelijke transitieprocessen								
Stimuleringsprogramma Energieonderzoek	MaGW, STW EZ/SenterNovem OCW	98 - 09	**6,0**	0,5	0,5	-	-	-
Energy Transitions *)	MaGW EZ/SenterNovem	09 - 13	**3,0**	-	0,5	0,5	0,5	0,5

*) Het NWO-budget, afkomstig uit het themabudget van Duurzame Aarde, is gealloceerd. De jaarlijkse verdeling van de middelen is een schatting.

3. Factsheets lopende NWO-programma's op het thema Energie

NWO-thema: Energie
Onderzoekslijn: Energiebesparing
Programma: Clean Combustion Concepts (CCC)

a. Objectives
This STW Perspectief Program aims to fill crucial knowledge gaps in applications using Clean Combustion Concepts (CCC's). CCC's are a set of new revolutionary combustion methods which combine very high efficiency with extremely low emissions of unwanted pollutants. Further development and application is considered to be essential to create a society with a sustainable energy supply. This research program is unique in the sense that bridges between different methods and institutes are created by carrying out a set of interconnected projects and by emphasizing knowledge exchange.
The focus of this program is on new Clean Combustion Concepts (CCC's), revolutionary methods to produce energy from current and future fuels, with substantially enhanced efficiency and significantly reduced pollutant emissions. Examples of emerging technologies for ultra-clean combustion are Premixed Charge Compression Ignition (PCCI) in engines, and High Efficiency Combustion (HEC) in gas turbines, furnaces and boilers. These concepts and similar ones such as 'Controlled Auto-Ignition' (CAI), 'Low-Temperature Combustion (LTC)' with high Exhaust Gas Recirculation (EGR) in engines, 'High Temperature Air Combustion' (HiTAC), or 'FLameless OXidation' (FLOX) in furnaces that have already been proposed should be brought to widespread application via the results of this program. On the other hand, proposals for other CCC's are invited for investigation in the program.

b. Background, relevance and implementation
More than 80% of our current energy is generated by combustion of fossil fuels and it is well recognized that combustion of fossil and future (bio)-fuels will remain the primary energy source in the 21st century.
The sectors in the Dutch industry that will benefit from and intend to contribute to the research program are: petrochemical industry, metals industry, transport sector and electricity producers, boilers and furnace industry, gas industry, consumer electronics and SME. Besides the Dutch industry also research institutes such as TNO and ECN will benefit from the knowledge that is generated in this research program. To increase the impact of the new program current research projects on CCC's will be incorporated.

c. Facts

Program period	2009 - 2013
Universities/Institutes	Open call for all Dutch universities Call for proposals ends: 25 August 2008
Partners	Industry and Technological Institutes. Current partners are DAF Trucks, Corus, Shell, Electrabel, TNO, Wärtsilä, Fluent Europe, WS-Wärmeprozesstechnik, ECO Ceramics
Program management	Prof.dr. L.P.H. de Goey, TU/e (program leader) Dr. L.J. Korstanje, STW (secretary)
Budget NWO	STW: M€ 7,6
Budget others	Industrial partners: M€ 2,1

NWO-thema: Energie
Onderzoekslijn: Energiebesparing
Programma: Magnetocaloric materials for cooling applications

a. Objectives

In the framework of earlier STW projects a new class of magnetic refrigerant-materials was discovered for room-temperature applications. New promising materials are manganese-iron-phosphorus-arsenic (MnFe(P,As)) compounds. These new materials have important advantages over existing magnetic coolants: They exhibit a large magnetocaloric effect (MCE), larger than that of Gd metal, which is used in existing high performance refrigerators, and the operating temperature can be tuned from about 150 K to about 335 K by adjusting the P/As ratio. Aim of the program is to further develop the new material from scientific level to industrial applicable and fundamental research to explore other materials with high potential for magnetic refrigeration.

b. Background, relevance and implementation

Magnetic refrigeration has three prominent advantages compared to compressor-based refrigeration. First there are no harmful gasses involved, second it may be built more compact as the working material is a solid and third magnetic refrigerators generate much less noise. Modern society relies very much on readily available cooling. The world market for small units is currently about 140 million units per year. Nowadays, 90% of the household and light commercial refrigeration applications use the vapor-compression cycle. Alternatives for this technology are needed due to environmental concerns (ozone depletion, greenhouse effects, flammability). The ideal cooling machine would be a compact, solid-state, silent, energyefficient heat pump, which does not require maintenance. Magnetic refrigeration based on the MCE may be the solution.

c. Facts

Program period	2005-2010
Universities/Institutes	UvA/TUD
Industrial partner(s)	BASF; Unilever; Climate Colntrol Technologies; Cooltech Applications, Liebherr; Ingersoll Rand
Program management	Prof.dr. E.H. Brück
Budget NWO	STW: M€ 0,9
Budget others	Industrial partner(s): M€ 0,2

NWO-thema: Energie
Onderzoekslijn: Energiebesparing
Programma: Magnetocaloric materials not only for cooling applications (MCM)

a. Objectives

This program aims at better understanding and improved properties of novel magnetocaloric materials. The relation between structure and magnetic properties and the kinetics of magnetocaloric effects are to be studied. The program includes the search for new materials with yet better performance. Additionally the optimal route of large-scale production will be investigated. Finally the design and composition of composite magnetic regenerators will be modeled and tested.

b. Background, relevance and implementation

Magnetocaloric refrigeration is a totally new technology, which employ the very efficient coupling between spin degrees of freedom in a solid with the vibrational states of the atoms. In combination with the field generated by a permanent magnet this opens the way to very energy efficient heat pumps. It is expected that magnetocaloric heat pumps need 50% less energy. As additional environmental advantage of this technology one should consider that these heat pumps do not use gases, but employ a solid as working material, which brings along ease of recycling. Until recently, the bottleneck of this technology was the limited availability of suitable magnetic materials.

To accelerate the lab to market process, BASF and the academic research group, team up and join forces. In this way we expect to further improve the performance and enable the availability on an industrial scale, in the near future. The later is a prerequisite to market introduction of any magnetocaloric device.

c. Facts

Program period	2008-2012
Universities/Institutes	TUD
Industrial partner(s)	BASF
Program management	Prof.dr. E.H. Brück
Budget NWO	FOM: M€ 0.7
Budget others	Industrial partner(s): M€ 0.7

NWO-thema: Energie
Onderzoekslijn: Energiebesparing
Programma: Turbulence and its role in energy conversion processes

a. Objectives

To perform fundamental research in turbulence, in order to better understand turbulence phenomena relevant in energy conversion. Fundamental questions to solve are e.g.:
- How does laminar flow become turbulent?
- The role of anisotropy and inhomogeneity in turbulent flow
- Influence of body forces
- Coherent structures and turbulence control
- Turbulence and chemical reactions
- Sound prediction

Knowledge in these fields of research will lead to advances in our understanding of turbulence phenomena relevant to energy conversion, such as the transition to turbulence, noise production, reactivity and heat transfer.

b. Background, relevance and implementation

Despite century long research, fluid turbulence remains still the major challenge in non-linear physics. The phenomenon is ubiquitous, unavoidable and omnipresent in almost every branch of natural science and technology where the matter flows as fluid. Besides being an intriguing scientific challenge, the understanding of turbulence and the ability to predict its manifestation is a necessity and a prerequisite for resolving many technological and environmental problems. Moreover, the research in turbulence has always had an important role in the research in physics in general, stimulating and generating progress in other branches of physics, particularly non-linear mechanics, astro- and geophysics, atmospheric and ocean sciences.

Turbulence research addresses traditionally the following questions: what are the physical processes and interactions governing turbulence, how can they be quantified and described mathematically, how to predict turbulence and turbulent flow in unknown situations and how to control and manipulate turbulence. This research program in particular focuses on laminar-to-turbulent and reverse transition, effects of thermal buoyancy, unsteadiness, compressibility and rotation, and on the interaction with chemical reactions. As an intriguing and coherent application field the energy conversion processes are regarded.

The first call for proposals (2001) was completed in January 2002, the second in 2004 and the third and last call for proposals has been concluded in February 2006.

c. Facts

Program period	2002-2010
Universities/Institutes	TUD, TU/e, RU, UT
Industrial partner(s)	-
Program management	Prof.dr.ir. A.A. van Steenhoven
Budget NWO	FOM: M€ 3.6
Budget others	Matching univ.: 91 k€

NWO-thema: Energie
Onderzoekslijn: Energiebesparing
Programma: Process intensification (Green & Smart Process Technologies)

a. Objectives
This STW Program aims at:
• generating new leads for industry to radically improve chemical processes and plants in terms of energy use and cost/benefit ratio
• drastic changes in reactor engineering technologies, comprising step-outs outdating familiar concepts such as unit operations and scale-up rules
• contributing to the developments of a more sustainable and competitive process industry in the Netherlands and Europe
• encouraging the process technology groups at the Dutch (technical) universities to explore new leads and ideas in the core field of reactor engineering
Research topics for new energy saving technologies are heat recovery, catalysis engineering, molecular modelling, reaction modelling, process synthesis, waste based processes, biomass conversion. Examples are: new reactor systems for Fisher Tropsch synthesis based on raw materials (biomass); bio-oil produced by pyrolysis of biomass; efficient conversion of alkanes by oxidative dehydrogenation.

b. Background, relevance and implementation
The chemical sector plays an essential role in the Dutch economy. The annual turnover amounts to some 40 billion euros and makes up about 3% of the gross national product.
For several decades, chemical process industry was dominated by the 'economy of scale' paradigm. Nowadays, it becomes clear that achieving the goals of sustainability not only requires new chemistries and new products, but also requires fundamental changes in the chemical routes and processing methods for manufacturing those products. To mitigate the negative effects of the current manufacturing processes on our Earth, its atmosphere and climate, and its finite resources of clean air, clean water, forests, fossil fuels and ores, big steps are needed in developing more sustainable manufacturing processes.
The technology developed at the universities will be transferred to industry or alternatively offer opportunities for new companies. Knowledge exchange between industry and academia is stimulated from the start of the research projects.

c. Facts

Program period	2008 - 2012
Universities/Institutes	TUD, UT, RUG
Partners (onder voorbehoud)	Shell Global Solutions, DSM, Yara, Corus, TNO, Micronit Microfluidics, BuNoVa, ILA GmbH, Kiwa Water Research, Petrobras, Albemarle Catalysts Company, BIOeCON, CB&I
Program management	Program leader: Prof. Schouten (TU/e) ; Dr. M. Wiegel, STW
Budget NWO	STW: M€ 2,0
Budget others	Industrial partners: M€ 0,8

NWO-thema: Energie
Onderzoekslijn: Energiebesparing
Programma: Intelligent omgaan met Energie

a. Objectives
The research challenge is to achieve significant energy savings (in some cases up to 50%) by employing intelligent ICT to the field of energy consumption.

b. *Background and implementation*
The programme will be established jointly with ICT-regie. ICT-regie has established the Sustainable ICT-platform which is addressing this theme. Members of the platform are the technical universities and a number of commercial organisations (TNO, Philips, HP e.a.). Based on proven strength in relevant Dutch research areas a choice has been made for the following lines of research:

- **Smart solutions for traffic management**
  These research topics cover the area of communication technology (for example ad-hoc and sensor networks), privacy and security, visualisation, control algorithms, prediction techniques, queuing theory, and modelling and simulating traffic - and transport systems.
- **Smart methods for energy saving in buildings**.
  The research challenge is how to reach a minimum in energy consumption in offices and homes using sensor networks for the computer monitoring and control. For this new intelligent software needs to be developed.
- **Smart control systems for flexible electricity networks**.
  The generation of energy on a small scale and in a decentralized manner results in increasingly complex electricity networks. This development is facing big challenges, amongst others: modelling and simulating these complex networks, visualisation techniques, developing agent technology for negotiating energy supply and demand, developing smart control systems, guaranteeing correctness, safety and stability of the control systems.
- **Energy reduction within ICT systems**
  Computer science will be required to minimize the energy consumption of ICT systems whilst their performance remains acceptable. One of the challenges is to program future parallel architectures with hundreds of programmable cores in an energy efficient way.

c. Facts

Program period	2008-2012
Universities/Institutes	Call in preparation
Industrial partner(s)	TNO e.a. in ICT Platform
Program management	Programme Committee, secretary dr. L. Zandee
Budget NWO	EW: M€ 1
Budget others	ICT-regie: M€ 1 Industrial partners: to be specified

NWO-thema: Energie
Onderzoekslijn: Energiebronnen: Zonnecellen
Programma: Joint Solar Program (JSP)

a. Objectives

The main objectives are:

1. Creating prospects for new generations of PV cells with substantially improved characteristics, by exploring new conversion principles, device concepts, and processing methods;
2. Achieving synergy and acceleration by involving new groups and disciplines in PV related research.

b. Background, relevance and implementation

Energy is of vital importance to mankind. It is consumed in huge and still growing quantities, mainly from finite fossil sources and with increasing environmental damage. The development of renewable energy technologies and the transition to a sustainable energy system are therefore major challenges. Photovoltaic conversion of solar energy is generally considered one of the key candidates for future large-scale use.

Reliable PV systems are already commercially available and in use, but large-scale application is severely hindered by current prices. To improve the economy of PV systems it is crucial to develop low-cost manufacturing technologies and to increase production volumes, but also to enhance the performance of PV modules. Today's commercial modules have an efficiency of 5-15%, while laboratory cells achieve 35%. These numbers are in sharp contrast with the theoretical maximum for photovoltaic conversion, which is roughly 85%.

The program aims to create breakthroughs in photovoltaic conversion, by enabling full use of the solar spectrum and of the generated charge carriers in super-high efficiency devices, or by developing materials, processing methods and device structures which are very promising for future low-cost manufacturing. Researchers are challenged to cross current boundaries, via high-risk, high potential ideas, since the program should be complementary to existing ones.

c. Facts

Program period	2005-2010
Universities/Institutes	TUD, TU/e, UU, RUG, AMOLF
Industrial partner(s)	Shell
Program management	JSP Program Committee: chairman Prof.dr. W.C. Sinke (ECN, Universiteit Utrecht)
Budget NWO	FOM: M€ 1.1 CW: k€ 675
Budget others	Industrial partner(s): M€ 2.0

NWO-thema: Energie
Onderzoekslijn: Energiebronnen: Zonnecellen
Programma: Thin film nanomanufacturing of high efficiency solar cells

a. Objectives
The main objective are:

1. Fundamental understanding and development of atomic layer deposition and i-CVD techniques for manufacturing thin film solar cell structures.
2. Fundamental knowledge with respect to surface roughness and etching mechanisms of III-V materials for multi-junction solar cell designs.
3. Coating of quantum dots for solar cell application.
4. Energy conversion and efficiency in nanostructured solar cells

b. Background, relevance and implementation
Major challenges in solar cell research are efficiency increase and cost reduction. At this moment there is a wide gap between the energy efficiencies of commercial and experimental solar cells. Manufacturing techniques are a known bottleneck in commercial production of new designs. In this program there is a strong focus on understanding of what is happening in existing production processes on a fundamental level – i.e. how to circumvent a trial and error approach to reproduce laboratory achievements under industrial conditions? - and to develop new techniques and equipment for practical application. Also new concepts of highly efficient solar cells with various materials and various designs are investigated.
Atomic layer deposition (ALD), epitaxy (MOVPE) and catalytic initiated chemical vapor deposition (i-CVD) are powerful techniques for the manufacture of new industrial products. In the mean time it is a challenge to shorten the time to market for new high efficiency solar cell designs, e.g. how do we make, under industrial and controllable conditions, high efficiency cells using quantum dot technology?, how to prevent moisture problems in devices fabricated on flexible substrates?, how to control surface roughness in making multi-junction structures?

c. Facts

Program period	2006 – 2014
Universities/Institutes	TUE, TUD, RU, UU, UvA
Partners	Oxford Instruments, MKS Instruments, NXP semiconductors, Philips Research, AdvanceSis Ltd., Azur Space Solar Power, Dutch space BV, ECN, ESA,Advanced Surface Technology, Nuon Helianthos, Holst Centre, VHP Security Papermill, OTB, MEMC Electronic Materials SpA.
Program management	TFN Program committee: chairman Prof.dr. R. van de Sanden (TU/e), secretary: dr.ing. Y. Roman (STW)
Budget NWO	STW: M€ 2,3
Budget others	Industrial partners: M€ 1,15

NWO-thema: Energie
Onderzoekslijn: Energiebronnen: Zonnecellen
Programma: Nano-photovoltaics

a. Objectives
The objective of this programme is to exploit recent advances in nanoscience and nanotechnology to realize solar cells with increased efficiency and/or lower materials costs. The programme is based on exploiting enhanced light absorption and carrier collection in ultrathin film, nanowire and quantum dot solar cells. The programme has four key focal points:
1. Enhanced light coupling into ultra-thin film and low-dimensional inorganic semiconductor absorber layers using plasmonic and photonic nanostructures;
2. Design and synthesis of quantum dot multijunction and multispectral absorber layers with enhanced carrier collection efficiency;
3. Enhanced light coupling using nanowire graded-index surfaces;
4. Integration of these concepts in novel nanoscale solar cell geometries.

The programme focuses on achieving fundamental understanding of light-matter interaction in novel solar cell geometries at sub-wavelength length scales and will lead to entirely new design concepts in photovoltaics.

b. Background, relevance and implementation
The development of renewable energy sources is of great importance to achieve a society with a sustainable energy supply. Photovoltaics has the promise of a clean and practical technology that can be applied at large scale. However, the costs of photovoltaic energy conversion presently exceeds significantly the costs of 'conventional' electricity. To solve this problem, breakthrough developments are required. The goal of this programme is to investigate such possible breakthroughs, focussing on the development of novel solar cell geometries with increased efficiency or with reduced fabrication costs.

The programme brings together three research groups that combine a unique complementary expertise in nanophotonics, plasmonics, semiconductor nanowire opto-electronics, and ultrafast and THz spectroscopy in low-dimensional systems. It is carried out within an international network of collaborators at the California Institute of Technology, Stanford University, and the Australian National University. While the program will focus on fundamental concepts, prototype devices will be fabricated as well. This will facilitate transfer of knowledge to the photovoltaics industry.

c. Facts

Program period	2009 – 2013
Universities/Institutes	AMOLF
Partners	-
Program management	Prof.Dr. A. Polman
Budget NWO	FOM: M€ 2,1
Budget others	-

NWO-thema: Energie
Onderzoekslijn: Energiebronnen: Fusie
Programma: Manipulation of meso-scale structures in hot, magnetised plasmas (M3P)

a. Objectives

The main objectives are:

- to explore and develop the concept that hot, magnetised plasmas have a rich structure on the meso-scale: in between the system size and the Larmor radius of the particles.
- to manipulate this structure and thus control the macroscopic plasma properties.

These objectives are to be achieved through the combination of these plasma manipulation and diagnostic tools, along with numerical magneto-fluid simulations and the advancement of relevant theoretical models.

b. Background, relevance and implementation

This proposal is inspired by the results obtained in the course of FOM Program 18, 'High temperature plasma physics', which ran until end of 2003. In this program, it was demonstrated that the turbulence in tokamak plasmas organises itself in such a way that alternating layers of good and bad thermal conduction are produced. There is a strong relation between this structure of the turbulence and the topological properties of the confining magnetic field. This layering, and more generically, the meso-scale structure of the turbulent plasma, gives a new angle on the turbulent transport in hot, magnetised plasmas. World-wide, the formation of meso-scale structures in fusion plasmas has become a hot topic over the last 5 years or so.
In order to address the many open physics questions in this field, we need to study the meso-scale structures in plasma turbulence not only as they develop spontaneously in plasmas, but also during precise and localised manipulations of the plasma interior. Experimental tools to manipulate the plasma - a state-of-the-art Electron Cyclotron Heating and Current Drive system, the Dynamic Ergodic Divertor and Neutral Beam injectors - are available at TEXTOR. Also the - FOM built - high-resolution diagnostic equipment that is needed to analyse the response of the plasma to the manipulations has become available in 2003.

The program has tight links with the JET program, in particular with the task forces on 'advanced tokamak scenarios' and on 'MagnetoHydroDynamics'. Rijnhuizen is strongly involved in those programs in JET. Thus, while the main research program will be done at TEXTOR, on the basis of this an active participation of Rijnhuizen in JET is foreseen.

c. Facts

Program period	2004-2008
Universities/Institutes	FOM-Rijnhuizen
Partners	Euratom
Program management	Prof.dr. N.J. Lopes Cardozo
Budget NWO	FOM M€ 3.6
Budget others	Euratom: M€ 0.9

NWO-thema: Energie
Onderzoekslijn: Energiebronnen: Fusie
Programma: An integrated laboratory on plasma-surface interaction (PSI-lab)

a. Objectives

The objective of the program is to study the interaction of intense particle or photon fluxes with a material surface in a fundamental approach. An important aim of the investigation is to access the strongly coupled regime, in which the particles that come of the surface are kept in the system and define the plasma-surface interaction. Concrete research areas include:

- The interaction of plasma with a material surface in conditions comparable to those in a fusion reactor, aiming at the development of dynamically stable surfaces.
- The development of robust reflective optics for XUV light with high power densities of the incident radiation.
- The formation of clusters of particles (dust) in the plasma, and their influence on the plasma-surface interaction.

b. Background, relevance and implementation

A plasma is a unique source of chemical radicals that allow for tuning chemistry at surfaces with opportunities beyond classical chemistry. However, the plasma-surface system is complex, governed by strong non-linearities in particular at high densities. The plasma in front of the surface (composition, temperature, density etc) is strongly influenced by the plasma-surface interaction (PSI). The surface, through radical reactions, erosion and deposition, in particular the deposition of clusters and compounds formed in the plasma, is modified by the plasma. The formation of clusters of molecules and their evolution in the plasma is in itself a process that strongly depends on the PSI conditions, while the clusters in turn strongly influence both the plasma and the surface. Thus, plasma and surface cannot be treated separately. Together they form a strongly coupled physical system in dynamic equilibrium. To study and employ PSI, four experiments will be built, sharing surface analytical equipment. A world-wide unique linear plasma generator, Magnum-PSI, will allow access to the strongly coupled regime of PSI. A smaller, already operational facility (Pilot-PSI) will be used for source development and testing of diagnostics. A novel, versatile thin film deposition machine (Thin-Film PSI) will be employed for the deposition of layered structures for XUV optics.

In addition, the Surface-PSI device will allow basic PSI studies under well-defined low flux conditions. The experiments are complementary, and e.g. layered structures prepared in Thin-Film PSI will be used in erosion studies in Magnum-PSI. Parallel and integrated with the experimental research program is a strong computational effort. The controlled and well-diagnosed experiments in PSI-lab are ideally suited for the benchmarking of computational models, which in turn can guide further experiments.

c. Facts

Program period	2004-2015
Universities/Institutes	FOM-Rijnhuizen
Partners	Euratom
Program management	Prof.dr. A.W. Kleyn and Prof.dr. N.J. Lopes Cardozo
Budget NWO	FOM: M€ 13.3
Budget others	Euratom: M€ 5.4

NWO-thema: Energie
Onderzoekslijn: Energiebronnen: Fusie
Programma: ITER-NL

a. Objectives

Het ITER-NL programma heeft een tweetal doelstellingen voor de periode 2007 – 2009:

- ITER-NL stelt zich ten doel leidend partner te worden in het Europese consortium voor de UPV en een belangrijk (maar niet leidend) partner te worden binnen het UPL-consortium;
- Het bereiken door de industrie en het MKB van een standaard en kwalificatiestatus die hoort bij de kernfusiemarkt en -technologie om zo haar concurrentiepositie voor ITER, maar ook voor andere (Europese) hightech projecten te verbeteren.

b. Background, relevance and implementation

ITER – de internationale proefcentrale voor energieopwekking op basis van kernfusie, bouwkosten 4,7 miljard euro - is een van de meest aansprekende en uitdagende 'big-science' projecten ter wereld. De unieke samenwerking van de zeven partijen (EU, Japan, USA, China, Russische Federatie, Z-Korea, en India) geeft ITER een extreem grote (politieke) zichtbaarheid. Als resultaat van dit programma wordt de Nederlandse betrokkenheid bij ITER bestendigd, waardoor:

- Nederland haar wetenschappelijke toppositie op het gebied van fusie-onderzoek en ontwikkeling verder kan uitbouwen;
- Het Nederlandse bedrijfsleven (incl. MKB) de bij deze markt/technologie horende standaard en kwalificatie bereikt en zo haar concurrentiepositie ook voor andere grote Europese hightech projecten verbetert;
- Er een positieve 'return on investment' voor Nederland wordt gerealiseerd met betrekking tot de Nederlandse bijdrage aan ITER;
- Het potentieel van ITER om een positieve uitstraling op scholieren en studenten te realiseren wordt benut.

Dit doel kan worden bereikt op basis van de internationale toppositie van Nederland voor enkele specialisaties binnen het fusieonderzoek en de aanwezigheid van hightech bedrijven met specifieke kennis en kunde.

c. Facts

Program period	2007-2009
Universities/Institutes	FOM-Rijnhuizen
Partners	TNO, NRG, OCW
Program management	Dr. A.J.H. Donné
Budget NWO	-
Budget others	OCW: M€ 4,5

NWO-thema: Energie
Onderzoekslijn: Energiebronnen: Biobrandstof
Programma: Biomass en bio-based production

a. Objectives

The research aims at the development and integration of new concepts in the sustainable production of transport fuels and bulk chemicals from low-value, non-food biomass flows by means of micro-organisms and/or enzymes as biocatalysts. The emphasis of the research is in the optimizing of energetic efficiencies and the minimisation of carbon dioxide exhaust, to enable an economic and societal transition of petrochemistry to 'bio-based' production. Specific research topics are:

- pre-processing, hydrolysis and refinement of low-value biomass flows (residue flows from agriculture and forestry, biomass waste streams from industrial and household sources) for the release of carbon (and nitrogen) containing compounds that can be used as raw material for microbiological industrial processes
- extension of the potential of raw materials for the industrial biotechnology through the development of new industrial micro-organisms, mixed microbial cultures and biotechnological processes for the optimal exploitation of carbon containing compounds from low-value biomass flows
- extension of the product spectrum of the industrial biotechnology through directed genetic engineering (metabolic engineering, synthetic biology, and inverse metabolic engineering), *in vivo* and *in vitro* evolutionary approaches, and high-throughput screening and selection
- process intensification by the increase in productivity, yield, and robustness of microbial and enzymatic production systems
- development of innovative concepts in the field of biotechnology and bioprocess integration, aimed at the optimisation of energy and carbon yields of industrial biotechnological processes
- integral supply chain analysis of production processes in industrial biotechnology, from raw materials to products, and analysis of societal factors in large-scale introductions.

b. Background, relevance, and implementation

The Kluyver Centre will, in accordance with the NGI business plan phase II (2008-2012), set off important activities in the field of bio-based production in industry. The research in the Kluyver Centre is primarily aimed at genomics in microbial fermentation processes. A large part of the research consists of generic, fundamental aspects of the application of micro-organisms in industrial production. From the 15 M€ that the Kluyver Centre obtained from NGI in phase II, approximately 2 M€ will be used in research directly related to energy (production of bio-fuels). Matching funds from B-Basic, DSM, and EOS make a total amount of 4 M€ available.

c. Facts

Program period	2008 - 2012
Universities/Institutes	TUD (Kluyver Centre)
Partners	B-basic
Program management	Prof. dr. J.T. Pronk
Budget NWO	NGI: 2 M€
Budget others	2 M€ (matching funds van B-basic, DSM, en EOS)

NWO-thema: Energie
Onderzoekslijn: Energiebronnen: Biobrandstof
Programma: B-Basic (Bio-based Sustainable Industrial Chemistry)

a. Objectives

Bio-based industrial production of chemicals, often referred to as Industrial Biotechnology is the controlled use of microbial cell factories such as yeast for the efficient production of desired products, using cheap, renewable feedstocks and advanced biotechnology. Within the field of Industrial Biotechnology, the B-Basic mission is to perform excellent fundamental and applied scientific research in order to provide the chemical industry with an advanced set of tools and concepts by approaching Bio-based Sustainable Industrial Chemistry in a fully integrated manner, combining functional genomics, intensified bioprocess technology and novel feedstock scenarios. With the aim to achieve a sustainable future in the field of bio-based chemicals and energy.

b. Background, relevance and implementation

Within the B-Basic program five sub-programs have been defined:
- Bulk Chemicals
- Fine Chemicals
- Performance Materials
- Novel Feedstocks & Recycling
- Life Science and Technology Training Centre (LST-TC)

Roughly one third of the research activities falls under the category bio-energy.

c. Facts

Program period	2001 - 2009
Universities/Institutes	Delft University of Technology, Groningen University, Leiden University, Wageningen University
Industrial partner(s)	Akzo Nobel, DSM, Shell, TNO, Agrotechnology & Food Sciences Group, Paques
Program management	NWO-ACTS, Prof.dr.ir. Luuk van der Wielen (Director)
Budget NWO	-
Budget others	15 M€ (about 1/3 of the B-Basic budget) B-Basic is financed by: Bsik subsidy of the Ministry of Economic Affairs (M€ 25) Industrial B-Basic partners (M€ 12) Participating universities and research institutes (M€ 13)

NWO-thema: Energie
Onderzoekslijn: Opslag, transport en distributie
Programma: Sustainable Hydrogen (SHY)

a. Objectives

Renewable energy sources (wind, solar, water, biomass, etc.) have in common that they are inhomogenously distributed spatially and strongly fluctuating in time. Therefore there is a strong need for an efficient and reliable way to store and transport energy. There is a growing world-wide consensus that beside electricity, hydrogen will become an important energy carrier in future energy scenarios. The program's aim is to develop the knowledge and technology to enable this transition.

b. Background, relevance and implementation

The program 'Sustainable hydrogen' is intrinsically a multidisciplinary research program, needing the input of a broad class of experts in various disciplines of science, e.g. (bio)chemistry, physics, behavioural sciences, biology and biotechnology. The problems involved cover many different facets of a future based on hydrogen as energy carrier:

- hydrogen storage; the materials science of hydrogen;
- hydrogen storage and its implications for energy systems (and their management);
- the integration of hydrogen into energy supply (for the transition period and after);
- the social acceptance of hydrogen as a part of the energy infrastructure;
- hydrogen production in a broad sense (i.e. fossil and renewable sources);
- separation technologies for clean hydrogen;
- hydrogen activated energy saving devices and sensors.

c. Facts

Program period	2002 - 2012
Universities/Institutes	Several universities and research institutes
Industrial partner(s)	Shell, ECN, Gasunie, NUON, and BTG
Program management	Programme Committee 'Sustainable hydrogen', chairman Prof.dr. A.J.M. Schoot Uiterkamp (RUG)
Budget NWO	M€ 4,5 (AB, CW, FOM, WOTRO)
Budget others	EZ: M€ 4.5 VROM: € 4.5 Industrial partner(s): M€ 4.5

NWO-thema: Energie
Onderzoekslijn: Opslag, transport en distributie
Programma: New technologies for fuel cells and hydrogen storage

a. Objectives
Fuel cells enable conversion of hydrogen into electricity with zero emissions and high efficiency. Improved hydrogen storage materials are needed to realise the hydrogen economy. The primary objective of this program is to develop new technologies and materials for fuel cells and hydrogen storage.
Specific research topics within this program are:
• Explore and develop thermally stable protonconducting electrolytes for solid-acid fuel cells, and to explore the potential for utilizing them in a novel, innovative design of a fuel cell operating at medium temperature (150-250°C).
• Development of new membrane materials for direct methanol fuel cells (DMFC's). DMFC's can convert the chemical energy of a fuel directly into electrical energy with high efficiency and low emission of pollutants. The new membranes will be used in a micro fuel cell device.
• Development of new materials for on board hydrogen storage for automobile transportation. Complex metal hydrides offer promise with regard to hydrogen uptake and release, which is thermodynamically allowed near operating temperatures of PEM fuel cells.

b. Background, relevance and implementation
Local and global environmental issues as well as the consumption and supply of energy are major challenges for the future. Hydrogen, in combination with fuel cells, is likely to play a major role in the future energy supply. Fuel cells technologies offer the prospect of significantly increased energy conversion efficiency coupled with little or even zero emissions of pollutants and greenhouse gases. The technology of using hydrogen as an environmentally clean and efficient fuel is an active area of research worldwide. Improved hydrogen storage materials are needed to realise the hydrogen economy, in which hydrogen is used as a clean fuel.
The technology developed at the universities will be transferred to industry. Knowledge exchange between industry and academia is stimulated from the start of the research projects. By identifying all the relevant factors, the technology can be upscaled or downscaled to meet specific application needs. This could open up huge markets of the assembled devices, ranging from applications in car transportation to use in handheld devices and other consumer electronics.

c. Facts

Program period	2005 - 2010
Universities/Institutes	UT, TUD, UL
Partners	ECN, TNO, Bronkhorst High-Tech, Aquamarijn Microfiltration
Program management	Program leader: Dr. H.J.M. Bouwmeester; Secretary: Dr. L.J. Korstanje, STW
Budget NWO	STW: M€ 1,5
Budget others	Industrial partners: M€ 0,1

NWO-thema: Energie
Onderzoekslijn: Opslag, transport en distributie
Programma: Innovative physics for oil and gas (iPOG)

a. Objectives

The general aim of this Industrial Partnership Program (IPP) is to promote innovative basic research with potential relevance for the exploration and production of oil and gas reservoirs. The program will have two open rounds with a budget of M€ 1.5 each. The research theme of this second round will be identified in 2008.

The research theme of the first round is 'Novel physical techniques to probe structure and transport in granular or heterogeneous media'. The scientific program for this call is:

(i) Probe fundamental aspects of acoustic waves in granular or heterogeneous media, in particular in the strongly scattering and nonlinear regime or where the waves couple to electro-kinetic transport.
(ii) Develop effective theory and model systems to capture these aspects of seismic waves.

b. Background, relevance and implementation

The detection and recovery of fossil-fuel reserves is complicated by the fact that the repertoire of methods to probe such reserves is limited. Direct drilling experiments are expensive and necessarily provide 'local' information. Imaging experiments provide information that is, at best, indirect. These problems are compounded by the fact that, as fossil fuel reserves diminish, exploration increasingly focuses on fields that are difficult to access. This makes it even harder to arrive at reliable assessments of the recoverable reserves. Straightforward optimization of existing exploration methods is yielding diminishing returns. For this reason, it becomes very interesting to look at original, even speculative, physical concepts that might be used to probe subterranean fossil fuel reserves. In addition, there is a great need to use novel computational techniques to arrive at optimal predictions concerning the recoverability of reserves, based on imaging probe data that are necessarily incomplete.
To address these issues, Shell and FOM have initiated a joint Industrial Partnership Program (IPP) to facilitate the exchange between academia and industry of relevant new ideas and to initiate pilot research programs that aim to explore novel, physics-based methods to probe complex media and to develop novel modelling techniques to analyze the resulting data.

Shell has a leading position in the use of seismic techniques for oil and gas recovery, but the present day techniques may no longer be sufficient to uncover and assess the reserves in the class of fields that presently are being targeted for production. Truly innovative approaches, in which fundamental physics can play a key role, are called for. It should be stressed that since an important goal of this IPP is to extend the range of methods available, exploratory research is encouraged, and the program is organized 'bottom-up', i.e. with an open call for proposals in the first round.

c. Facts

Program period	2008-2013
Universities/Institutes	First round call in progress
Industrial partner(s)	Shell
Program management	Prof.dr. D. Frenkel / Prof.dr. M. van Hecke
Budget NWO	FOM: M€ 1.5
Budget others	Industrial partner(s): M€ 1.5

NWO-thema: Systeem Aarde
Onderzoekslijn: Maatschappelijke transitieprocessen
Programma: NWO/SenterNovem Stimuleringsprogramma Energieonderzoek

a. Objectives

The aim of the NWO/SenterNovem Stimuleringsprogramma Energieonderzoek is to generate innovative integral knowledge that is necessary to stimulate the transition of the current energy system into a future sustainable energy supply. Therefore the development of theories and methodologies is needed on :

- the energy chain: sources-conversion-usage and - performance;
- the R&D cycle: development-demonstration- introduction ;
- three different levels of systems: technical system-actor system- societal system, and on the interactions between them;
- three major components of sustainable development: environmentally sustainable, economically appealing and socially just.

b. Background, relevance and implementation:

The programme has been set up in close collaboration between NWO and SenterNovem as requested by the ministries of Education, Culture and Science, and Economic Affairs. The programme is a direct result from one of the conclusions from the 'Verkenningscommissie Energieonderzoek' (1996). The programme was set up to quicken the following processes:

- improving and anchoring of the cohesion in university-based energy research;
- reinforcing the ties between research at universities and applied energy research;
- establishing feedback among diverse fields of social sciences engaged in energy research and between the efforts in those disciplines and the research taking place in the natural sciences.
- the transfer of knowledge within the field of energy and environment. The target group are the societal (including business) and policy.

NWO is responsible for the coordination and execution of the programme. SenterNovem plays an important role in the transfer of knowledge to societal partners in the energy and environmental field.

c. Facts

Programme period	1998 - 2009
Universities/Institutes	TUE, UU (en Copernicus), VU (en IvM), TUD,UT, ECN
Partners	-
Programme management	Steering group: chairman Prof.dr.mr.ir. S.C. Santema Programme committee: chairman: Ir. J.P. van Soest
Budget NWO	MaGW: M€ 0,5 STW: M€ 0,5
Budget others	EZ/ SenterNovem: M€ 2,0 OCW (stimuleringsgelden): M€ 3,0

NWO-thema: Duurzame Aarde / Energie
Onderzoekslijn: Maatschappelijke transitieprocessen
Program: Energy Transitions

a. Objectives:
The Energy Transitions program aims to stimulate innovative multidisciplinary research that results in knowledge, insights and tools that will support the Dutch government in its ambition to promote a sustainable energy transition. Due to the strong policy-driven focus, this programme has been developed together with the Dutch Ministry of Economic Affairs (EZ). The Dutch Cabinet's Energy Innovation Agenda forms the policy framework of the programme.

The program comprises 2 research lines. The aim of research under the first line, *Understanding transitions to sustainable energy*, is to analyse and model socio-technical transition processes at different scales and related to different energy systems.
Research under the second line, *Governing energy transitions* will investigate and make recommendations to resolve problems of incentives, coordination and evaluation associated with transition processes.

b. Background, relevance and implementation:
Energy is fundamental to economic growth and social welfare, but energy production and consumption also lies at the root of the most pressing resources, security and environmental problems. For reasons of resource depletion, climate protection and energy security, a switch away from fossil and towards renewable sources of energy is planned at a global scale. This transition to more sustainable energy systems demands radical shifts in the sources, conversion and uses of energy. Governments worldwide are faced with questions as how to realize this transition in a technological and a social manner. The program Energy Transitions aims to contribute to solving the societal difficulties of a transition. The program is part of the proposed NWO theme Sustainable Earth. Contrary to research carried out elsewhere, the program will not investigate topics within a specific energy technology (in The Netherlands), but will analyse the relationship between energy and other resources in their social, economic, institutional and technological context.

c. Facts

Program period	2009-2013
Universities/Institutes	All relevant universities
Partners	-
Program management	A program committee, consisting of scientific experts and a representative of the Ministry of Economic affairs will direct the program. The assessment of full proposals will be carried out by an ad hoc assessment committee. Apart from the program committee, a steering committee has been set up to coordinate the different programs within the theme Sustainable Earth.
Budget NWO	MaGW: M€ 2
Budget others	EZ: M€ 1