ECN

Energy research Centre of the Netherlands

2005

Annual Report

Contents

Preface

Following a fantastic jubilee year ECN (Energy research Centre of the Netherlands) is focusing all its energies on the next fifty years. As a Major Technological Institution (MTI) in the field of energy research ECN is now in a good position to do so. With the implementation of the Wijffels recommendations it occupies a key position in Dutch energy research. This is not only a challenge for ECN but also a substantial additional responsibility. My hope for the future is that ECN will fulfil this key role in making in the Netherlands (and Europe) sustainable in the field of energy. This involves a sustainable energy supply that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Along this path I see four priorities for ECN, in order of importance: energy saving (more efficient use of energy), renewable energy, clean fossil fuels (capturing the carbon when using fossil fuels), and finally nuclear technology.

An ECN that adopts a profile in line with these priorities will make a worthwhile contribution to the transition to a sustainable energy supply. How successful this is, however, will be determined not only by the success of technology development at ECN itself but above all by how much it assists the efforts of government and industry. The success is also determined by the input of knowledge from the university.

It is a good thing that ECN, as an MTI, has substantial elements of its research linked directly to the Ministry of Economic Affairs' research programme and is not dependent on tendering to SenterNovem for each project. This reduces the time from research to application, in both policy and industry. ECN's position as an MTI means that it needs to aspire to have a major presence at the centre of energy transition efforts. A self-assured ECN needs to offer both the private sector and the government the options required to speed up the switch.

In this era of globalization it is becoming less and less important whether it is Dutch industry that takes on the commercialization of energy technology. If a German or Japanese company wants to develop ECN technology we can support that wholeheartedly. Creating jobs in the Netherlands is not one of ECN's aims: the goal is to speed up the energy transition by developing appropriate technologies. For a Japanese company it will be required to develop the technology in question for the European market as well.

As chairman of the Supervisory Board of ECN and NRG (Nuclear Research & Consultancy Group) I would stress that NRG has an identity of its own, which is justified by the special dimensions of nuclear technology and NRG's activities, some of which are commercial. I do believe, however, that the ties between ECN and NRG should be maintained.

My hope is that Petten will become a Centre of Excellence which communicates openly with similar bodies in Europe and elsewhere, so that ECN and NRG are open to foreign researchers and, conversely, good researchers from Petten can develop their skills during a period abroad. My wish is that the institutions enjoy harmony and mutual respect, in the realization that all the disciplines involved need to make a contribution to achieving a sustainable society. None of the four priorities mentioned is so important that any of the others can be ignored; and each of the priorities contains areas that are all essential: within sustainable energy, for instance, solar, wind and biomass all have a contribution to make. A robust, transparent and honest business must however be prepared to abandon options that are not sufficiently promising.

An institution in this position can play a key role in the energy transition that is so important to the future of the Netherlands and the whole world.

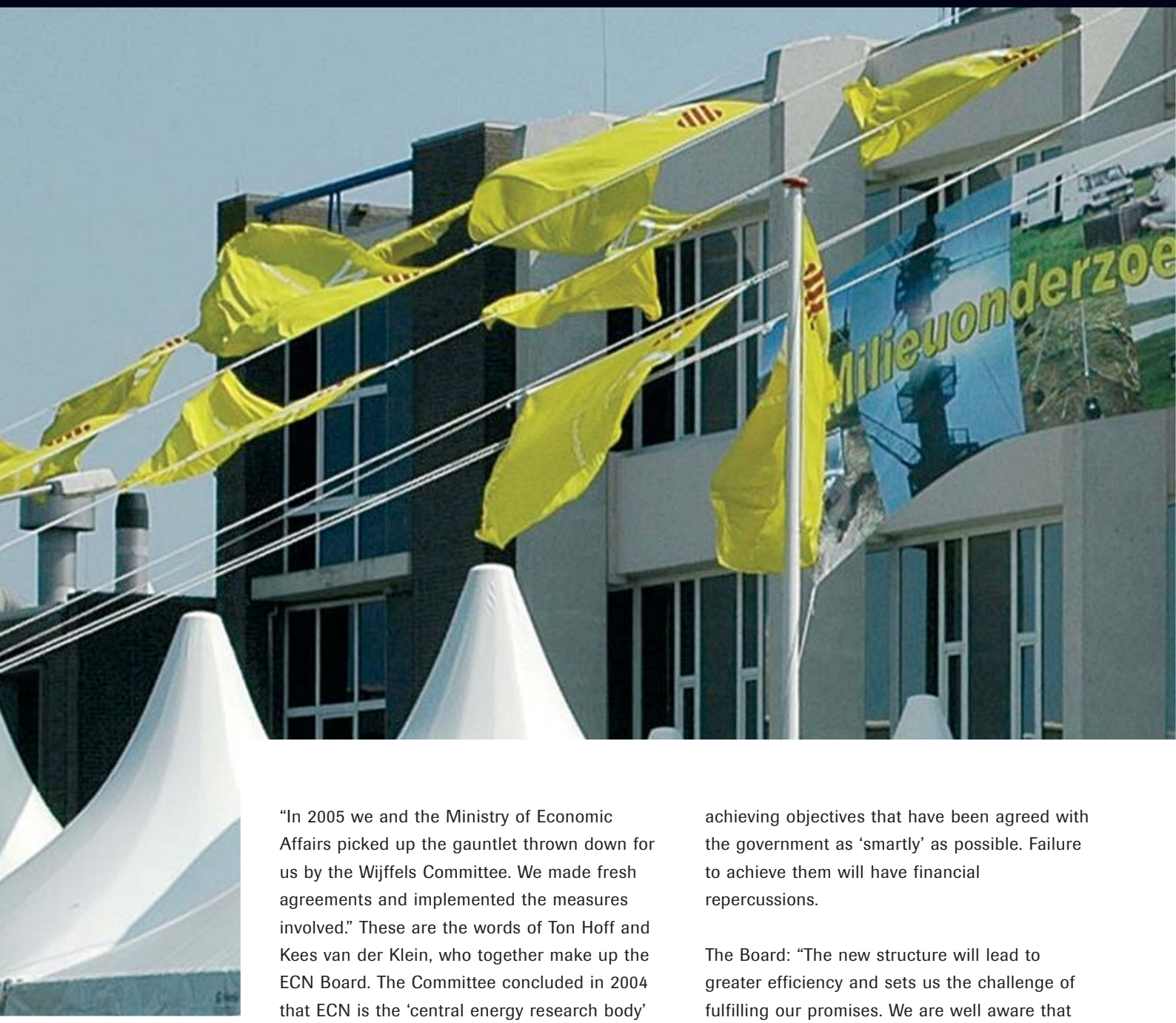
Per June 1st of 2005 Jan Terlouw and Peter Scholten departed from the Supervisory Board of ECN. We would like to express our gratitude on their contributions. Jan Terlouw, (from 1995) as Chairman, and Peter Scholten (from 1996) as a member, both made a significant contribution to the broadening of the research activities for a sustainable society. During their period in the Board, ECN was going through turbulent times. In particular do I think about the transformation of ECN to a market oriented organisation, the budget cuts in 1995, the foundation of NRG and the difficult period 2001-2002. Due to their managerial contributions the problems were solved.

2005 was a good year for ECN, and a special one because of its jubilee. I would like to compliment the Board and all the employees sincerely on the results they have achieved. It is thanks to all the employees that ECN is a trend-setting body.

Dr. Ruud Lubbers
Chairman of the Supervisory Board


Ruud Lubbers

Introduction



"In 2005 we and the Ministry of Economic Affairs picked up the gauntlet thrown down for us by the Wijffels Committee. We made fresh agreements and implemented the measures involved." These are the words of Ton Hoff and Kees van der Klein, who together make up the ECN Board. The Committee concluded in 2004 that ECN is the 'central energy research body' in the Netherlands and needs to be positioned and managed accordingly. The Committee also noted, however, that the flow of knowledge and new technology to the market place is not yet adequate.

The recommendations have far-reaching consequences. While ECN no longer needs to tender in a number of areas where it has a strong position in the EOS (Dutch abbreviation for Energy Research Strategy) programme, it has to adapt its structure and programme to the EOS objectives. It will also be judged much more than before specifically on whether it is achieving objectives that have been agreed with the government as 'smartly' as possible. Failure to achieve them will have financial repercussions.

The Board: "The new structure will lead to greater efficiency and sets us the challenge of fulfilling our promises. We are well aware that this special position gives us an additional responsibility to tackle the subjects concerned in a structural way and take on a central role in these areas in the Netherlands. It is very important here to involve other organizations, so as to achieve national unity, coordination and synergy. We have formulated and launched new five-year structural programmes in line with the EOS programme, including one-year objectives on which we wish to be judged. The aim of the exercise is to improve efficiency, both for our client, the Ministry of Economic Affairs, and in our operations. Above all, however, we wish to achieve cohesive structural programming from

the exploratory stage right up to market implementation. Ultimately we shall be judged by the use to which our research is put in practice."

The implementation of the recommendations has resulted in a limited reorganization of units at ECN. A new structure in line with the ERS programme came into force on 1 January 2006.

"We shall be setting new emphases starting in 2006. First, we shall be adopting a more international focus, on foreign and international clients. We shall also be developing our contribution to innovation processes. From our position as a task-driven organization we want to 'complete' the development of our technology in the market place and thus help to ensure that the things we develop cross the 'technology gap' and are eventually implemented. As regards research and consultancy we aim to focus more on Europe. We shall draw up a new Strategic Business Plan in 2006 that explicitly includes these points. ECN's mission did not change in 2005. The current mission statement is still succinctly worded and reflects the fact that objectives in the area of energy and innovation are intertwined in the context of the transition processes in the Netherlands."

ECN's strategic plans no longer state that ECN is to perform a 'bridging role towards implementation'. Kees van der Klein: "That suggested that technology is developed in an institution and then transferred to the market for implementation; nowadays we regard that as over-simplistic. We now see our role as participating in networks in the field of energy transitions and technology transfer. In a network of this kind industry is involved in the selection of research and development at an early stage on the one hand, and ECN remains involved in implementation processes longer on the other."

"A good example of this new partnership between ECN and industry is solar cell technology. We are working on improving the basic material and production processes, and industry is watching these developments closely. At the same time, though, that same industry is already putting knowledge developed at ECN to commercial use. In this way there is a natural cross-fertilization between industry and research organizations. The same kind of partnership can be seen in fuel cell technology and nowadays particular in wind energy. All the major wind turbine manufacturers use knowledge developed at ECN or the existing infrastructure, but they are also involved in the follow-up research that is needed. The number of licences on ECN patents is still on the up-and-up.

"We are increasingly seeing an international dimension to technology development. We no longer regard it as a problem if the results of our work are taken up abroad. But we make sure in that case that the technology remains available on a preferential basis for achieving sustainability in the Netherlands. We are pleased, for instance, that Enatec's Stirling technology is to be developed (in Japan), and that the Rinnai company will continue to develop Stirling engines for the European market."

ECN's strategic position ties in closely with the energy transition. Ton Hoff: "Yes, we are very active in this area. It seems to us that the transition itself is beginning to speed up, and we can make an important contribution. Personally I'm involved in the energy transition task force (initiated by the Dutch Prime Minister) , but there is ECN is represented in almost every platform. We regard developing the transition idea as a challenge and a good way of getting long-term processes in particular under way. Industry too is beginning to realize that there will have to be changes in the energy supply in view of the many problems: climate and the environment, scarce resources, security of supply, the economy. Realization is dawning that humanity is engaged in a process that entails tremendous risks."

Mission

ECN develops high-level knowledge and technology for the transition to sustainable energy management.

In more detail its mission is as follows:

- **ECN focuses on the knowledge and information the government needs to develop and evaluate policy and achieve policy objectives in the field of energy, the environment and technological innovation.**
- **ECN partners industry in the development and implementation of product, processes and technologies important to the transition to sustainable energy management.**
- **ECN closely works together with Dutch and foreign universities and research institutes and performs a bridging function with implementation by carrying out technological research.**

Day of Open House

Ton Hoff is happy with ECN's role in energy policy. "We play an important role in research and consultancy on energy and environmental policy. The policy challenges when it comes to achieving a more sustainable energy supply are just as great as the technological challenges. What is needed is a good combination of incentives to influence the behaviour of companies and manufacturers positively with a fair distribution of effort." Hoff sees trade in CO2 emissions as a telling example that it is not easy to achieve a balanced policy, pointing to ECN's study of the electricity producers' substantial windfall profits as a result of the emissions trading system, a problem for which ECN is now exploring solutions. He notes that Europe is becoming increasingly important when it comes to policy. "Energy needs a strong European policy. There is a great potential here for synergy in security of supply and innovation."

What role will be set aside for nuclear power in the future? The Board: "ECN takes the view that we need to retain the 'nuclear option', and nuclear fission should therefore remain an important element in the Dutch research programme. It could be a component in the energy transition, if it transpires that not enough sustainable energy is available in time when fossil fuels run out. The ties between ECN and NRG are excellent and should stay that way."

How does the Board judge whether ECN is on track? Hoff and Van der Klein: "We measure our position first of all by the quality of our work and the response from our main partners and clients. We have close contacts with the Ministry of Economic Affairs, SenterNovem and partners in industry, and we try to listen carefully to see whether our position and input still come up to scratch. Last year we did the rounds of the energy companies, and that yielded a whole lot of useful information. We are increasingly seeing government white papers referring to ECN policy studies. We think we are on the right track, but we shall have to carry on checking this with our stakeholders. We also try to benchmark, but the results are not always clear. There are key performance indicators that

Jubilee festivities at the Kurhaus

show your position, for example numbers of publications and patents. More important, though, is the number of strategic partnerships and implementations of technologies or products developed by us."

"Financially the organization is out of the woods. We still haven't managed to solve the pension problem, unfortunately. We are working extremely hard on it, but it's an incredibly complex problem and the financial repercussions are enormous. We had a good year in 2005 and expect to have a stable operation with healthy management in the years to come. Both the new structure and the internal programme are strong enough for us to look to the future with confidence. The main challenge will be to get the things we develop implemented in the market place and, with this in mind, to strengthen our relations with industry and increase the flow of contracts from it."

Lastly, the Board looks back on the jubilee year that has just ended with a great deal of pleasure and, in fact, pride. Ton Hoff: "The various events were highly successful and reinvigorated our relations with our partners. On top of the festivities, though, everyone worked extremely hard, and I should like to re-emphasize that ECN owes its success to the quality of our staff, who are motivated and do their day-to-day work with great enthusiasm. In the final analysis energy research is human work."

Ton Hoff and Kees van der Klein, ECN Board

Ton Hoff

Kees van der Klein

"I'm worried about future energy supplies", says Remko Ybema, head of ECN's Policy Studies unit. "Substantial problems are looming as a result of climate change and threats to security of supply. Technically a great deal is possible, but how can society implement the solutions? Greenpeace, for example, says that CO2 emissions could be reduced by 70-80% by 2050 by using only renewable energy sources and increasing energy savings. Technically this is indeed possible, but enforcing policies to realize this technical potential is now without a chance to succeed. The sense of urgency is not strong enough, and the support for such radical changes is absent. There are other solutions besides energy saving and sustainable energy, too. A balance between the various solutions will make achieving the policy objectives more likely and will lower cost. Also, there is substantial inertia when it comes to making changes. It will take long-term and vigorous application of policy instruments to get this process under way and keep it going. True change in the direction of sustainability will only follow once people have taken the transition idea on board."

An important topic is the transition to a sustainable energy supply, e.g. by introducing hydrogen. The unit is fully involved in a number of European projects in this area. Ybema: "We have a strong position in this area. The HyLights project for the European Union is looking at smart combinations of demo projects for the next ten to fifteen years. It mainly involves stakeholders: the car industry, the gas industry, energy companies and just a handful of consultants." A parallel project is HyWays, which aims to develop a long-term strategy based on hydrogen, and Cascade Mints, which is computing various scenarios for the future of the EU-25.

Ybema: "When it comes to infrastructure we have a 'chicken and egg' problem: sales of hydrogen cars will only take off once there are enough filling stations, and there will only be enough filling stations once there is a demand from the market place. Don't rise expectations that are too high. Demo projects have to be properly organized, supervised and analysed. We don't want uncontrolled growth, as support will be lost if there are a lot of failures."

A major milestone was the publication of a report on four European scenarios and their consequences for policy by Jos Bruggink. This was a groundbreaking document, also internationally, as it took pessimistic hypotheses about the availability of oil and gas seriously, which other studies generally failed to do.

Various transition studies were carried out in 2005, e.g. into a more sustainable transport industry. This is a difficult sector, as influencing it by means of government policy is a politically sensitive matter. There is also a major international aspect here, as the Netherlands has a limited influence on technology development.

The Energy Markets and International Climate Policy cluster of the unit has been anticipating new developments in energy markets: over the years it has developed analytical tools using quantitative models. Among the many studies published by the cluster, the report on the knock-on effects of the CO2 price on the price of electricity deserves special mention. Ybema: "We showed that 30-70% of the CO2 price was being passed on in the price of electricity, while the CO2 rights were free. As a result of our report two emergency debates on this subject took place with the Minister, and EU Commissioner Piebalgs said he appreciated the groundbreaking insights. The increased cost to electricity consumers and the free extra profits to the electricity companies could run into hundreds of millions in the Netherlands alone. This is not a case of 'the polluter pays' but 'the polluter is rewarded'.

"The question, then, is: have the right incentives been introduced in the market to reduce CO2 emissions? Rights have been allocated on the basis of the historical situation: those who used to have lots of coal-fired power stations were given lots of rights. We've achieved a lot, though. Emission trading has got off the ground in Europe and it works, unlike the years of failed attempts to get an energy tax off the ground. The system is still young, and the shortcomings we have identified need to be

Long-term Energy Futures and Climate Change Mitigation Strategies

As part of the 50th jubilee celebration of the Energy research Centre of the Netherlands an international energy symposium was held in November, focusing on long-term climate policy and the relationship with energy policy and energy innovation policy. Robust solutions to the problems of climate change that take other issues such as economic development and security of supply into account were discussed, including both technical solutions and the policy needed to put them into practice.

bron: IEA

Wind-offshore

remedied. It will be more mature in the next trading period, 2008-2012."

Another cluster in the unit is concentrating on policy for renewable energy. A cost-benefit analysis of the sensitive topic of 'offshore wind energy' was generally well received, both as regards methodology and the argument that growth needs to be controlled if we are to gain maximum benefit from learning effects and emissions trading. It was calculated for the Ministry of Economic Affairs that renovating wind turbines would produce a saving on the Environmental Quality of Electricity Production budget (MEP–Milieukwaliteit Elektriciteits-productie). The merits of a compulsory system for sustainable power were also examined. The portfolio analysis method was used to explore the optimum mix of sustainable energy options in the energy supply under changing conditions. The cost and potential to Europe of biofuels were surveyed: in the short term biodiesel will dominate, but in the longer term there are good opportunities for advanced biofuels such as Fischer-Tropsch diesel and biodimethylether.

Careful phasing and a rigorous international climate policy are essential if offshore wind energy is to yield a social benefit.

The social cost of constructing some 30 wind farms in the North Sea with a total capacity of 6,000 megawatts in 2020, covering about 15% of projected electricity consumption in the Netherlands, exceed the benefits in the case of all the variants examined. If construction were to be phased in over time, with the same 6,000 MW installed by 2030, the costs and benefits of offshore wind energy could be balanced reasonably well provided, however, a rigorous international climate policy is enforced.

Day of Open House

Lastly, the financial gap (the difference between production cost and calculated deprival value) when it comes to using bio-oil as a supplementary fuel in power stations was computed, and the Ministry of Economic Affairs revised its incentive scheme as a result.

The Energy Use and Emission Reduction Group completed reference projections on energy and emissions 2005-2020. It had already been reported that the rate of savings was stagnating, at 1% a year, and that the Netherlands would meet its obligations under the Kyoto Protocol. New points are that the monitoring of greenhouse gases has improved substantially and energy consumption will fall as a result of climate change.

An evaluation study of sustainable energy management policy by ECN urged more joined-up policy in areas such as energy saving and sustainability. Economic efficiency, security of supply and clean fossil fuels are undervalued, according to the study, or not properly reflected in policy. There is not enough continuity in the policy instruments, and there is no long-term strategy, said the study.

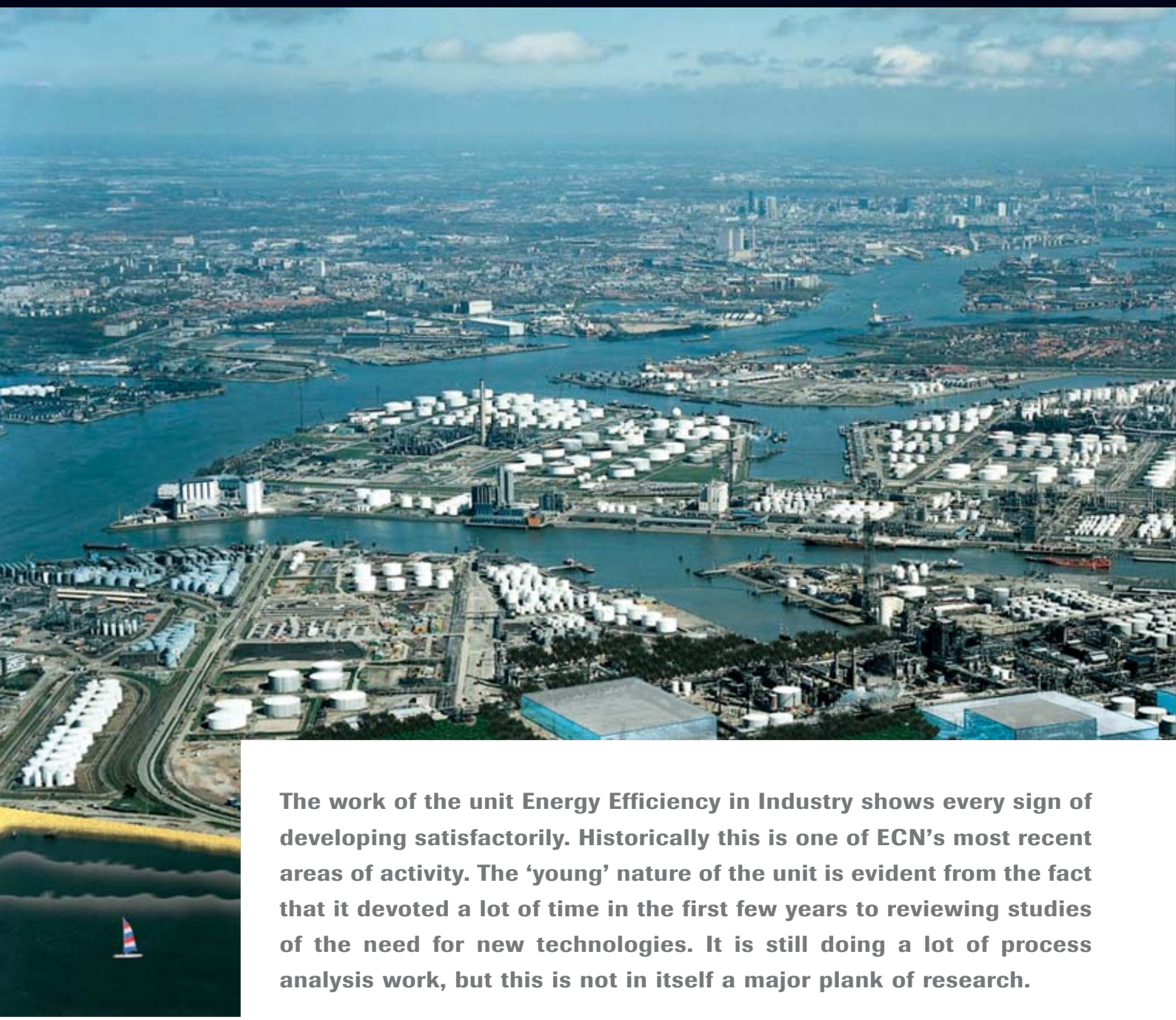
Other studies analysed domestic energy consumption, policy on combined heat and power, and the economic potential for energy saving.

Ybema: “Energy has risen on the agenda during the past two years, with uncertainty about the oil price and security of supply. Energy has been acknowledged as a geopolitical issue. It is taking on increasing importance at the European level too, especially after the recent crisis affecting the Ukraine.

“We have developed into a permanent fixture in the policy-making arena. Ministries are knocking on our door more often. We are being quoted in Dutch government documents twice as often as five years ago.”

Remko Ybema

Energy Efficiency in Industry



The work of the unit Energy Efficiency in Industry shows every sign of developing satisfactorily. Historically this is one of ECN's most recent areas of activity. The 'young' nature of the unit is evident from the fact that it devoted a lot of time in the first few years to reviewing studies of the need for new technologies. It is still doing a lot of process analysis work, but this is not in itself a major plank of research.

Over the years the unit has developed a focus by making clear-cut choices. First, it concentrates on the energy-intensive process industry, where the biggest results can be achieved. Second, it is focusing on break-through technologies, which, if they prove successful, will have a substantial effect at a European level: industrial heat management, molecular separation technology and multifunctional reactors.

Peter Alderliesten, Energy Efficiency in Industry (EEI) unit manager: "Heat management plays an important role throughout industry. Over 80% of industrial energy consumption is in the form of heat, which is ultimately released at a fairly low temperature. We are focusing on the recycling and useful application of waste heat between 50 and 150ºC.

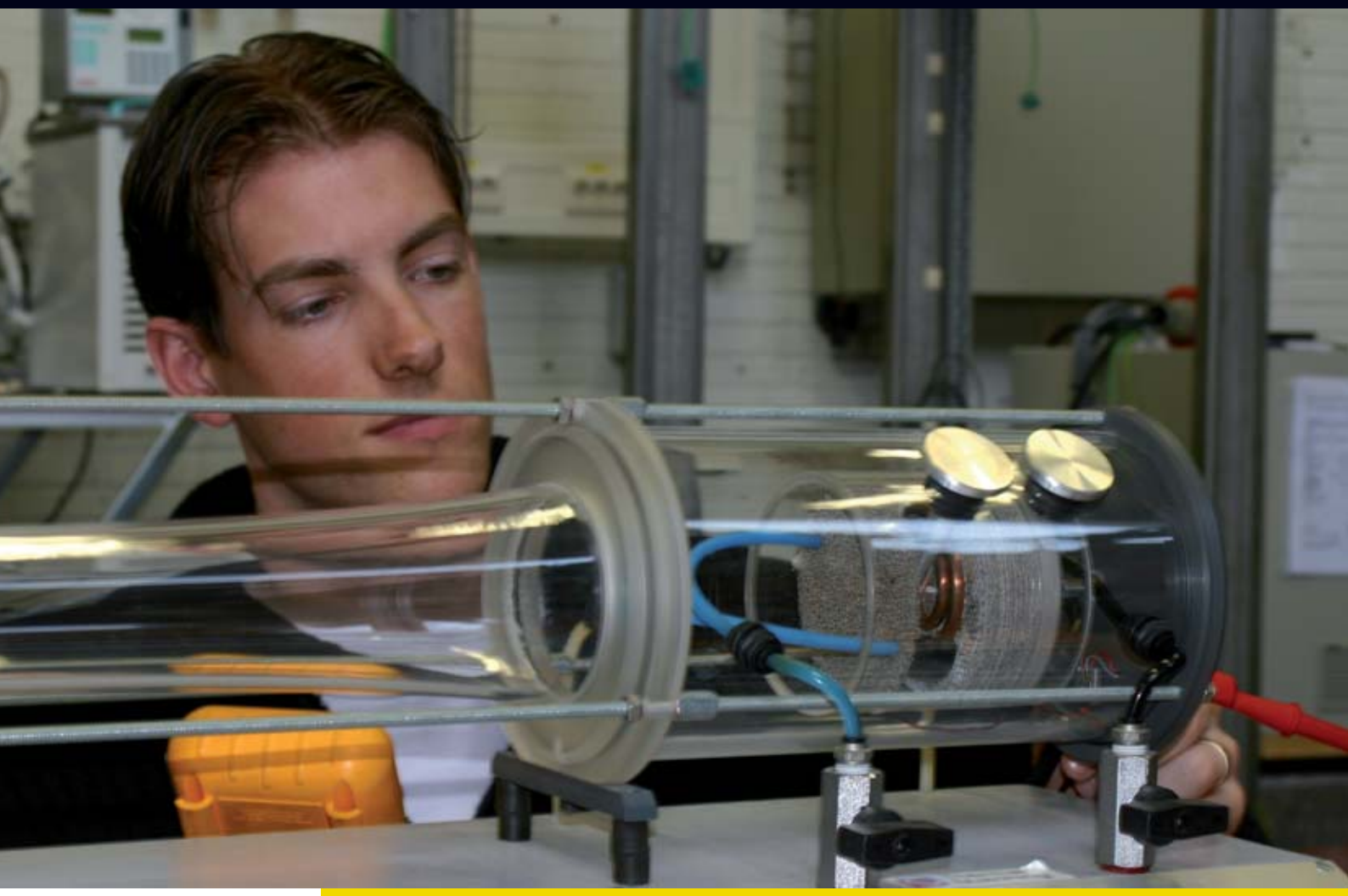
"Our second focus: the separation of substances, for example by means of distillation, is an energy-inefficient process, being no more than 10-15% efficient as a rule. The losses are partly compensated by means of process integration. With our separation technology we aim to take this a step further, thus achieving substantial energy savings.

"Our third focus is improving the core of the process itself. By tackling the chemical reactors that are at the heart of most processes you can achieve intrinsic improvement and greater sustainability, but these are really long-term projects."

"With these priority areas we have been able to hook up with existing ECN core competences. ECN knows a lot about the physico-chemical properties of materials and functional ceramics, for instance. We are taking advantage of this to develop our particular technologies. We also make ample use of ECN's knowledge of systems analysis, modelling, component development and chemical reactions."

"In the first few years we constructed large bench scale industrial heat pump systems. These gave us a proper insight into the necessary technological developments. Now we are taking the development of the technology back one stage: first we want to have devices that work well on a laboratory scale and fulfil the requirements with respect to efficiency. Currently our technology is still at the Proof of Principle stage."

Didn't the unit come up against an unexpected number of setbacks last year? The thermo-chemical heat pump leaked; the thermoacoustic heat pumps suffered from heat losses and lack of power; pervaporation membranes that worked well in themselves turned out not to be sufficiently resistant to high process temperatures. Alderliesten: "Setbacks are inevitable at this stage in technology development.



Unique system producing heat from sound

ECN in Petten made great progress during 2005 in its research into a thermoacoustic heat pump. This system uses high-power sound waves to upgrade industrial waste heat from a low temperature to a higher one. The amount of industrial waste heat above 50°C discharged in the Netherlands is at least 100 PJ a year, comparable to the annual energy consumption of over 1 million households. If this heat is to be put to practical use, a heat pump is needed that can operate in the required temperature range and provide a lift of 50 to 100°C. Heat pumps of this kind are not available at present.
A thermoacoustic heat-pump system is able to cool or heat over a wide temperature range. By using waste heat or a burner to drive the thermoacoustic motor, the demand for heat or cold in the process industry could be met. Based on a specially developed acoustic configuration we have already succeeded in operating the system at a waste-heat temperature of 110°C, which had not hitherto been demonstrated in the project. The thermal efficiency of the system is not yet adequate, however, so we are working hard to improve this.

We develop fundamental knowledge into technologies that are ready to be implemented. We tackle projects that involve risks and uncertainty. If that were not the case, then they would not be within our domain."

The setbacks, however, were more than offset by the good results. The SOCOOL system, which produces cold from waste heat, works well. The follow-up project, TOPMACS, designed for air-conditioning systems in lorries and private cars, is now under way. Specifications have been drawn up for the new system, and a number of ways of integrating the cooling system with the vehicle engine have been devised.

The thermoacoustic systems are being improved year on year: a heat-pump system for use in distillation processes, a waste-heat-driven thermoacoustic heat pump for use in industrial utility networks, and a thermoacoustic cooler. Good results were eventually achieved with the thermochemical heat pump as well. These devices work well, even if the ultimate targets have not yet been reached. Studies show, however, that the devices can be developed to achieve the desired performance.

The Molecular Separation Technology cluster has found alternatives to the pervaporation membrane that look promising. Understanding of how the membranes work is improving. The technology developed at ECN is designed for dewatering and separating organic mixtures. Work is also taking place on membrane technology for specific industrial processes: ammonia production, oxygen separation from air, and hydrocarbon separation. The unit's membrane technology has also led Tokyo Gas to collaborate with ECN in developing their membrane reformer at one of the hydrogen filling stations in the Japanese capital.

An ever-closer partnership with industry —both clients and prospective manufacturers— is evolving. The first true Dutch road map for separation technology has been developed, with the industry and the knowledge infrastructure as partners. The contacts with industry are proving very useful. Alderliesten: "We are able to be increasingly specific. In the case of the thermoacoustic heat pump for distillation applications we initially envisaged a burner-driven device. The industry came up with the suggestion of looking at other drive systems —partly for safety reasons—which might also make the device simpler and cheaper. Now that we have a better understanding of the requirements for each application we can develop more targeted systems, and we can also work on setting up a consortium. Companies are now coming to us with their own technology projects and applications. We expect to have a consortium of end-users and manufacturers in place within a year."

Peter Alderliesten

Renewable Energy in the Built Environment

On 1 January 2006 the unit Renewable Energy in the Built Environment was merged with the Micro-CHP Group, which is developing energy-saving concepts for heating homes or small business premises and supplying hot water based on free-piston Stirling technology. The work of the new unit Energy in the Built Environment and Intelligent Energy Grids focuses on developing smart grids, as well as energy consumption in the built environment.

Marije Lafleur, head of the unit, comments: "There are major long-term developments taking place in the built environment. The demand for heat for homes, especially in newly built houses, is steadily falling, and the remaining demand is mainly for domestic hot water. At the same time there is a growing demand for cooling. One of the possible efficient and renewable ways of meeting the resulting demand for energy is mini-CHP and

micro-CHP. There is a marked trend, for various reasons, towards more local power generation combined with heat production."

One of the aims of the research done by the Ways To Go cluster in 2005 was to develop an energy-neutral built environment, in other words one where total energy consumption over a year is fully covered by renewable energy generated locally. This involves examining a large number of options at the same time: in the built environment there is no single dominant new technology but multiple options, each with its own potential. A good deal of systems research is being done using developments at ECN and elsewhere in the field of new innovative technologies, existing technologies and developments in energy infrastructure. This is also used to do practical research for the market place, e.g. testing a heat pump for a manufacturer who wants to know how his device will perform in practice as part of a complete system.

Ecobuild, completed in 2005, was a multi-annual project that looked at energy-neutral homes. The concepts developed during the first phase were targeted in the second phase at three markets: existing homes and new build with an average and high level of comfort. Measurements in the dwellings provided information on the performance (individual and combined) of the system components and the various functions. Although the goal of 'energy-neutrality' was not attained, valuable knowledge was gained on how it could be attained, and this will be applied by industrial partners.

The 'IIGO' project, aimed at utility buildings, was also completed in 2005. This involved a trial of intelligent Internet-mediated control of the installation of a utility building, the innovative aspects being: on-line raising of comfort using individual indoor comfort settings and up-to-date monitoring and weather data; automatic optimization of local use or storage of renewable energy; optimum utilization of variable energy prices for demand-side management, using intelligent software agents and real-time Internet communication. Another aim of the project was to demonstrate that energy savings of 10 to 20% and cost savings of 15 to 20% are feasible. From the technical point of view it was a successful project, but it showed that intelligent control of a building installation needs to be incorporated in the design process at an earlier stage than was the case in the project. Communication between the building management system software and the user was also problematic: this will be addressed as part of the follow-up work.

With TNO work continued in 2005 on Building Future, in which a shared vision on the built environment of the future was developed and a research programme set up.

The 'IDEAAL' cluster (on the integration of distributed and supply-led energy supply) studied the integration of electrical power from wind, fuel cells, micro-CHP and solar energy in 2005, with the aim of increasing the potential proportion of power obtained from these sources. In this context the unit is taking part in CRISP, a major international EU project concerned with getting scattered sources to work together intelligently. A real-time virtual

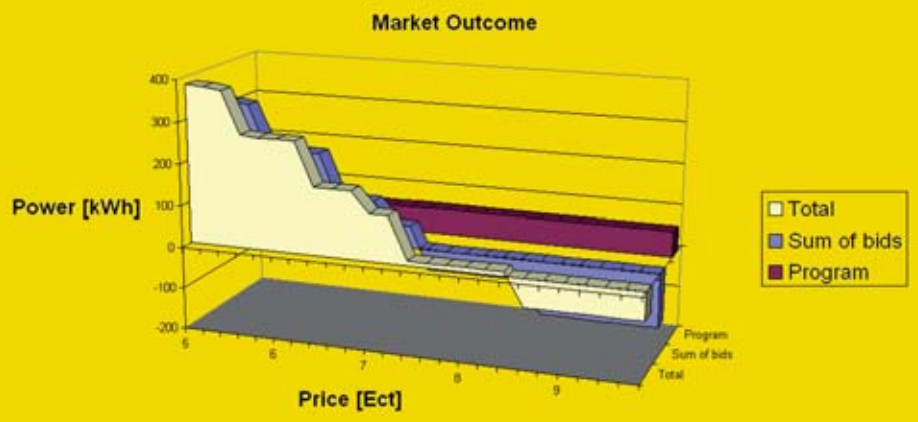
power plant was created in a field test in collaboration with ENECO. This used the PowerMatcher, a smart software concept developed for this and other projects to control supply and demand over power generating units, consumption units and storage units. The CRISP field test applied the concept to reduce imbalance caused by a wind farm and demonstrated that this can be overcome to a large extent by using the flexibility on the supply side. This demonstrates that PowerMatcher works. Work has started for Gasunie on linking up installed micro-CHP units using PowerMatcher so as to minimize the load on the local grid.

A number of studies are gaining knowledge of network stability. As part of the Local Power Quality Management project, with the aim of developing simulation models, software packages for parts of the grid such as the low-voltage network in a residential area have been studied. The Long-Term Energy Research Strategy project on Flexibel Grids (AIMEO) is the interaction between inverters for distributed energy production units and the grid.

An important topic in the future will be electricity storage. The question is, how can this technology be used with an increasing proportion of locally generated power in the grid? The computations on this, which for the time being are based on available technology, show the standards systems need to meet in terms of capacity, efficiency of charging and discharging cycles, service life in unused condition etc. So far no batteries have actually been tested, merely suitable candidates have been selected. For the applications envisaged in the grid in the built environment, cycle

PowerMatcher

Using the PowerMatcher model developed by ECN to match electricity supply and demand we examined how imbalances in the grid can be overcome. The principle is based on the supply- and demand curves of energy suppliers and energy using installations by the principles of the micro economic theory. If there is a balance between supply and demand the price will follow and there will be an allocation for every installation.
The figure below shows the sum of biddings of a commercial portfolio. At a price of 7 ct/kWk equilibrium is reached. If we look at the equilibrium price development as a function of time, the supply above the equilibrium will result in a lower equilibrium price, which will be compensated by more demand and vica versa. This shows that the PowerMatcher principle works in practice.
We have also started work for Gasunie on linking up fifteen installed micro-CHP units using PowerMatcher, the aim being to minimize the loads on the grid by means of the coordinated use of local generation.

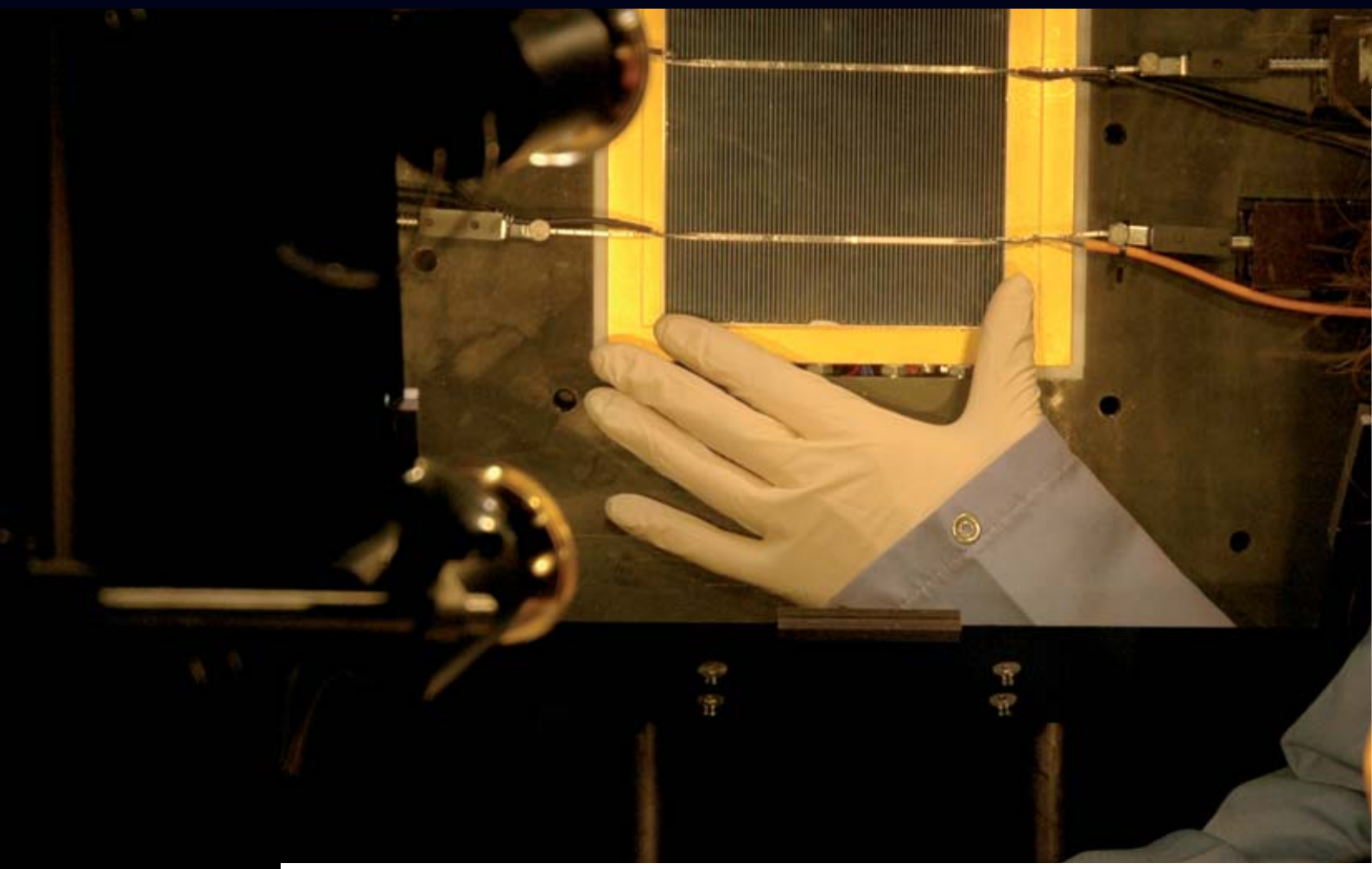


The effect of PowerMatcher on imbalance

efficiency, service life and of course cost per kWh of storage capacity are particularly important.

Lafleur: “Our priority areas for further development are building energetics, thermal systems including heat storage, power storage, control systems for such things as intelligent supply and demand control, grid connections and grid quality, and the development of next generations micro-CHP. An example is heat storage in the built environment. To meet the demand for heat sustainably we need compact high-temperature storage over long periods, but this still requires considerable technological advances.”

Marije Lafleur



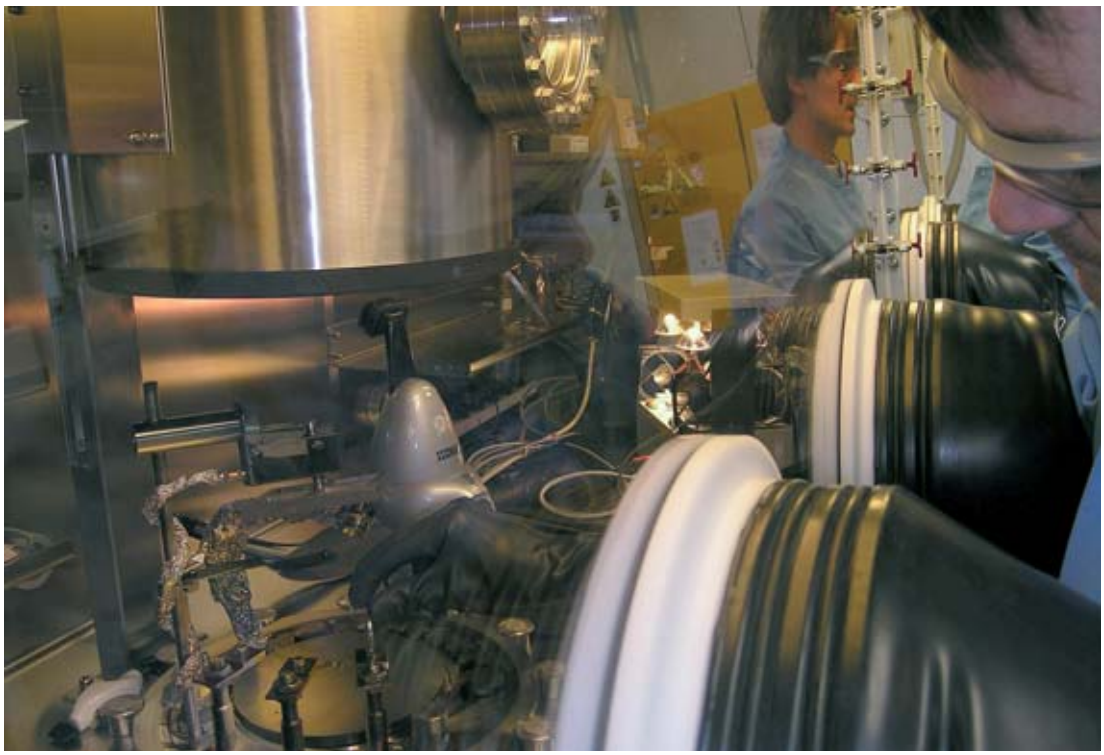
Research into photovoltaic solar energy (PV) covers a broad area. In the case of silicon PV technology alone six disciplines need to come together to achieve systems that work. First, silicon has to be produced in a sufficiently pure form. Wafers—thin layers that meet precise specifications—have to be poured from molten silicon or sawn from a block of crystallized silicon. These are made into solar cells that produce electricity when exposed to light. The cells are connected in series and packed into modules, which then have to be incorporated constructionally in building structures and electrically in a power grid.

The unit Solar Energy has a command of all these disciplines and occupies a high-level position in a few of them. A highlight of 2005 was an increase in cell efficiency of one percentage point with wafers produced using RGS wafer technology developed at ECN. RGS (Ribbon Growth on Substrates) enables silicon wafers to be poured in a thin layer rather than sawn, which makes for substantial savings in material, cost and time. This creates the possibility of producing wafers on an industrial scale at a cost at least twice as low as current wafers on the market.

Paul Wyers, unit manager Solar Energy at ECN: "RGS enables wafer production to be scaled up substantially. Using this technology one machine can produce 50 MWp a year, as against 2 MWp at the moment using the current crystallization furnaces. We are still refining the technology. At the moment the challenge is twofold, to build a machine that can produce RGS wafers at a rate of 1 per second, and to achieve greater solar cell efficiency from this kind of wafers. Last year we achieved a maximum efficiency of 12.8% with RGS material, yet another percentage point added. Efficiency is a major factor in the price per unit of power of the system as a whole. The wafer represents half the price of a module, so every percentage point counts."

To make the fragile solar cells as easy as possible to use, ECN has devised a type of cell that has both electrical contacts at the back (a 'PUM cell'). This makes connecting them in series a simple matter, while minimizing the mechanical stress on the fragile cells. Wyers: "Manufacturing of our PUM cells will start during the coming year at the Solland plant on the Avantis German/Dutch industrial area near Heerlen. The opening of this plant does not mean that the product has completed its development cycle; there is still plenty of potential for further cost saving."

Thin-film PV technology is still at a relatively early stage in its development, so there is only a limited overlap with the other programmes. Wyers: "Nevertheless there is quite some cross-



Dye-sensitized solar cell

A dye-sensitized organic solar cell usually comprises a porous network of nanoparticles of titanium dioxide to which an organic dye (the sensitizer) has been applied. With a solid organic hole conductor this relatively simple and cheap concept yielded 3.5% efficiency. Also positive were the results of a stability experiment on a dye-sensitized cell with a liquid electrolyte (instead of the solid hole conductor). After 1,000 hours at 80°C in the dark and recovery under the influence of light, 97% of the initial efficiency was measured. Outdoor measurements show that this liquid version can remain stable for at least two months. The outdoor monitoring is to continue. The liquid version of the dye-sensitized solar cell has an even higher efficiency than the solid versions: ECN found 5 to 8% for laboratory cells with an active surface area of 1-5 sq. cm.

Day of Open House

ECN technology– the basis for a new solar cell plant

On Thursday 3 November Solland Solar Energy Holding opened one of the most up-to-date plants in Europe for the production of silicon solar cells, on the border between the Netherlands and Germany. It will have an initial production capacity of 20 megawatts per year, corresponding to an output of 5 million solar cells, which would cover an area of 20 hectares. These could supply some 4,000 households a year with electricity. ECN's knowledge should enable Solland Solar to produce high-efficiency solar cells. This year ECN achieved an unofficial world record with 17% efficiency produced with an industry-compatible process, and this process is now being implemented at Solland Solar. The plant will also be making solar cells with all electrical contacts on the back, a type developed by ECN which makes for easy panel mounting and higher efficiency.

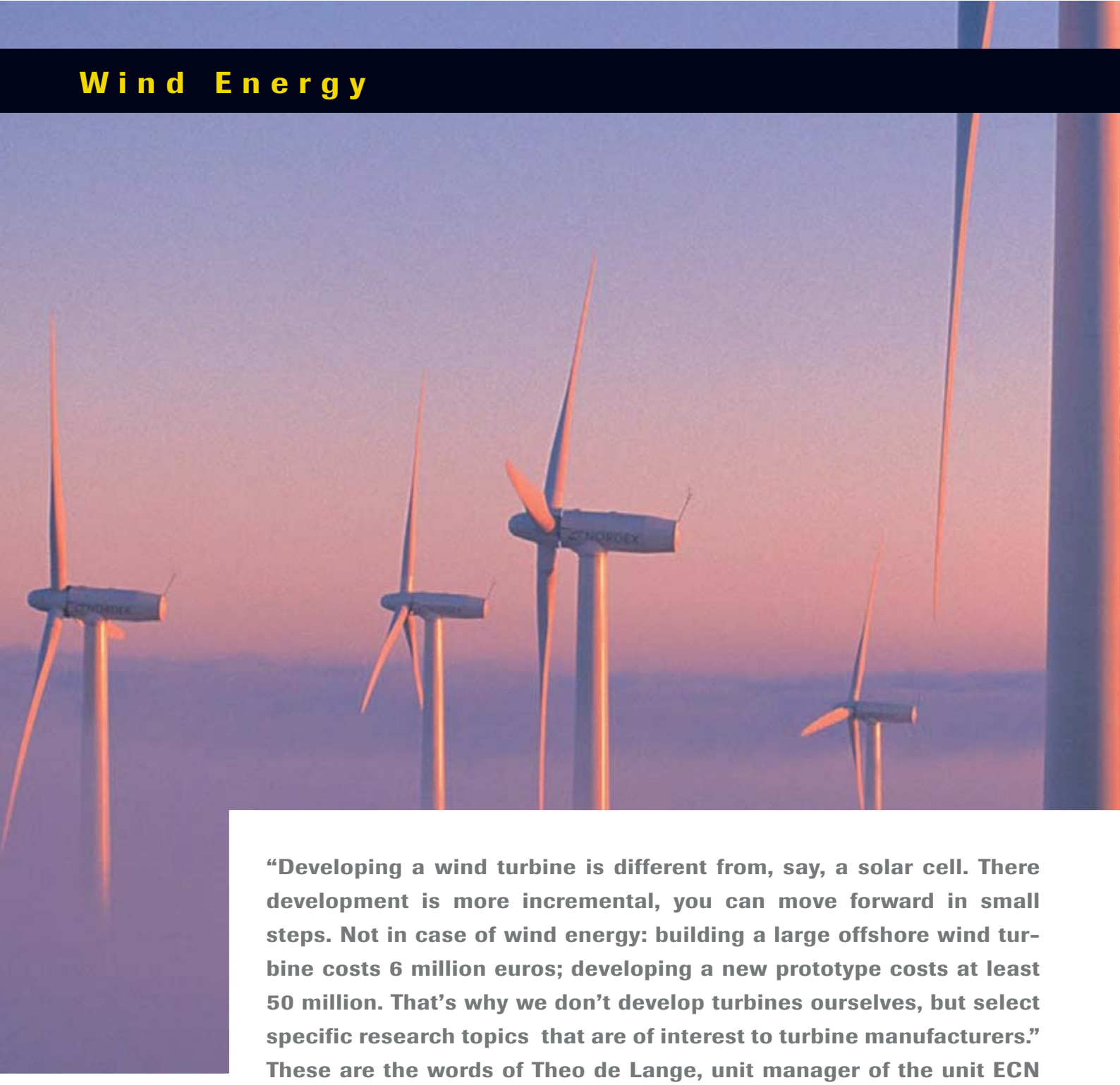
fertilization. One example is the technology used to deposit the anti-reflection coating on crystalline silicon solar cells: this is the same technology we use to deposit thin silicon films on an alien substrate. The characterization and the module technology are also related.

"We are working on two thin-film technologies, thin-film silicon and organic solar cells. The latter are at an even earlier stage of development. We are also doing basic research into methods of increasing the output from solar cells substantially. Wyers: "As the sensitivity of solar cells does not correspond closely to the spectrum of light (there is a spectral mismatch) you lose 55% of the energy from sunlight straight away. Each cell is only sensitive to a part of the spectrum, so if you want to use the entire spectrum you either have to have a stack of cells with different absorption properties (tandem cells) or convert the spectrum—get a blue photon to change into two red ones or vice versa. The maximum theoretical single-cell efficiency of 28% could be exceeded substantially using this approach." But getting this technology to work in practice is still a long way off.

Thus the portfolio of the Solar Energy unit contains short-term, medium-term and long-term research. In the short term we are placing our hopes in a few strong positions that have already produced significant results.

The new Solland Solar plant has a splendid setting on the Avantis industrial area, a cross-border initiative of the Dutch municipality of Heerlen and the German municipality of Aachen.

Paul Wyers



"Developing a wind turbine is different from, say, a solar cell. There development is more incremental, you can move forward in small steps. Not in case of wind energy: building a large offshore wind turbine costs 6 million euros; developing a new prototype costs at least 50 million. That's why we don't develop turbines ourselves, but select specific research topics that are of interest to turbine manufacturers." These are the words of Theo de Lange, unit manager of the unit ECN Wind energy.

The fact that only a limited national wind turbine industry exists has led ECN to reflect on the focus of its research. An extensive round of discussions with the international industry and an elaborate internal evaluation and discussions has led to a new programme of which the results have a good chance of actually being commercially applied in industry.

De Lange: "We developed a lot of models in the past that are being used by the industry to a limited extend only. We want to change this: our

aspiration is to step up our partnership with industry substantially. We do relatively little technology development, instead we develop the knowledge and tools needed to make the technology competitive and bring down the price."

As a result of the reorientation, aerodynamic and aero elastic models for a new generation of turbines are now major elements in the research. The existing design tools and models have only limited usefulness when it comes to designing large turbines; the physics used needs to be more precise. The aim of the new models is to achieve this precision while maintaining suitable computing times so that industrial design departments can use them in practice.

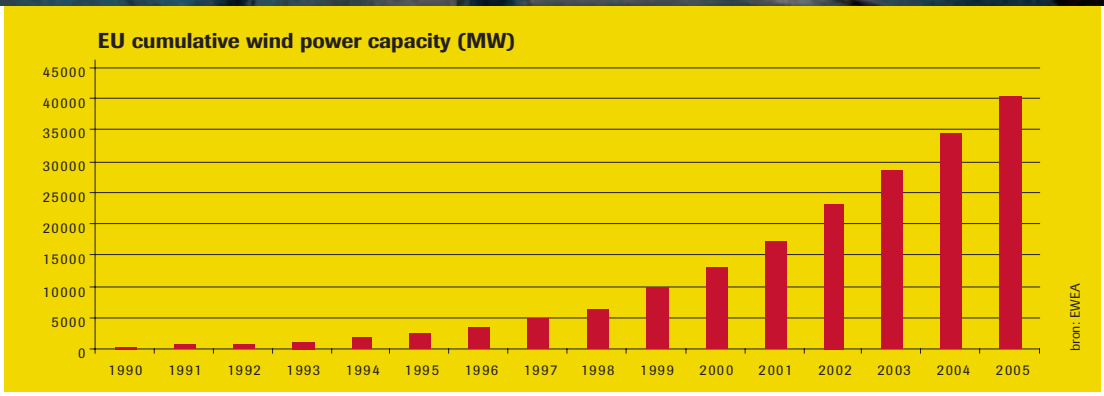
The second focus is wind farm aerodynamics, i.e. the influence turbines have on one another, especially in the large offshore farms projected for the future. Even whole farms can influence one another. Calculating these effects is extremely difficult, but it is essential. The unit has patents on farm control strategies, but these still need to be validated and tested.

Wind tunnel measurements are only to a limited extend suitable for this, as they are difficult to scale up. Validation in a full-scale commercial wind farm is also difficult. The risks associated with changing the control of wind turbine are difficult to deal with in practice. The owner of a wind farm is not willing to bear any risks while changing the control is affecting the validity of the type certificate and the guarantee. The unit therefore intends to build a scale wind farm with turbines equipped with various options to do all kind of experiments. Like the large offshore turbines, these scale turbines will have variable speeds and adjustable blade pitch angles. An elaborate measurement set-up is defined including a high number of meteo masts.

The research on this farm will look e.g. at reducing the power of the turbines at the front row of a farm, facing the undisturbed wind flow. Computations show that the wake effect reduces more rapidly than the output. The lower output is compensated for by the higher energy yield of the next row of turbines, so a greater overall farm efficiency can be achieved. Measurements will be used to validate this in experimental way.

The turbines on this farm can be turned at an offset angle from the wind direction so as to influence the wake. This too may improve the efficiency of the farm, for one thing by guiding the wake from turbines around the turbines in the next rows.

The third focus of research is designing new turbine control systems. Given the increasing size of large offshore wind turbines it is more and more important to gain knowledge of their structural dynamic behaviour. The aim is for manufacturers to be able to develop turbine control systems based on this knowledge that minimize loads and improve the performance, thus leading to lower costs and higher energy yield. A major project got under way in 2005 in which new design tools and control systems are being developed in collaboration with a number of wind turbine manufacturers. An important concept in this line of research is the option to

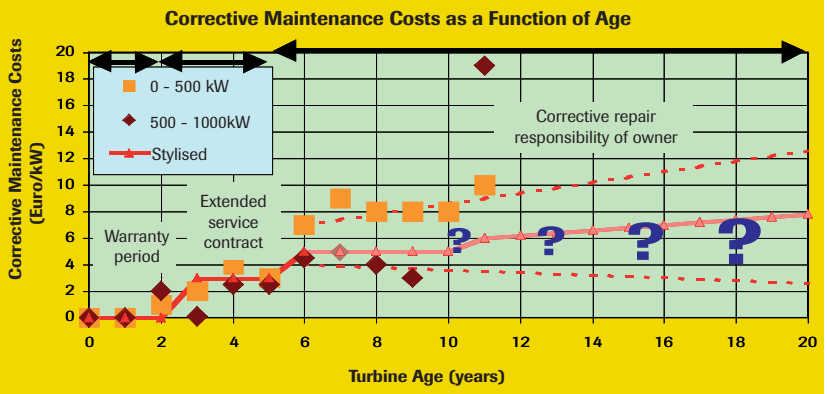


adjust the rotor blades independently and to do this several times during each rotation (multi cycle individual pitch).

The fourth line of research is condition monitoring systems for wind turbines and new measuring systems. A lot of the research is being done on ECN's EWTW test farm in the Wieringermeer, where ECN has five Nordex 2.5 MW turbines at its disposal. The aim is to predict the remaining lifetime of components so that they can be replaced in time, thus saving costs. This line of research includes the WT Bird system, which can detect and record bird collisions. A new system is also being developed to monitor loads on rotor blades using optical fibres in the blades. An area that has recently attracted a lot of attention internationally is nacelle anemometry, a method that is developed to predict reliable output verifications from individual turbines on wind farms from only a small number of wind measurements. Many of the measurements use the ECN-developed Dante data acquisition system, which will also play an important role in the coming years in the monitoring and evaluation programmes of

Maintenance and operation model

The O&M Cost Estimator project got under way at the start of the year, the aim being to be able to quantify the cost of maintenance and operation in the longer term. As an operator might put it, 'How much money do I need to set aside over the next few years to replace gearboxes and blades?'. The problem is illustrated in the figure. This project attempts to predict the cost of maintenance in the years ahead more accurately, based on fault data, operating experience and monitoring data.



Cost of corrective maintenance as a function of service life. This is difficult to quantify at the end of the warranty period.

the Offshore Wind Farm Egmond aan Zee (OWEZ) and an offshore farm being built off the coast of Scotland in 40m deep water.

The fifth focus is developing models to optimize the maintenance and operation of large offshore wind farms. At the planning stage it is important for investors to be able to estimate the cost of maintenance accurately. For day-to-day operation, operators need tools to help them organize large quantities of information on the basis of which to make decisions on maintenance and operation. In the long term it is also important for them to have a good idea of the repair and maintenance work that lies ahead of them. Models are being developed for both day-to-day operation and the longer term. ECN's EWTW test farm is also being used in this line of research to test these decision support models.

A lot of the research is being done in collaboration with the WMC Knowledge Centre on wind turbine blades and materials and Delft University of Technology. ECN is also working together closely on an international basis with Risø, CRES and other research organizations. ECN has a strong position in these partnerships when it comes to research, thanks to the testing facilities at its EWTW test farm. The industry is also closely involved in a number of the research projects.

Last year it was touch and go regarding the future of wind energy in the Netherlands. There was a danger of funding being cut off as a result of the offshore wind incentive scheme being oversubscribed. Finally a positive decision was made to develop North Sea wind energy gradually. A target of 700 MW was set for 2010, a definite and achievable goal that will provide direction for future R&D.

Not officially part of the unit, but associated with it, is the We@sea programme, a short-term and medium-term research programme involving twenty partners, which links up well with ECN's long-term research.

Theo de Lange: "We shall continue to adjust and shift our focus in the coming years so as to meet the R&D requirements of the wind industry and the government. We shall be exporting services and targeting the European market. In this way we hope to strengthen our contacts with international manufacturers. In terms of research we are perhaps number three in the world: this is an essential position that we aim to maintain by developing our international profile."


Theo de Lange

"Biomass technology is like coal technology, except it's more difficult and therefore more challenging. In the earth's crust old biomass was converted into coal over a period of 75 million years, radically changing its composition and thus making for fewer conversion problems. In the case of biomass we have to overcome this by using technology." These are the words of Hubert Veringa, head of ECN's Biomass unit in 2005.

Coal research at ECN dates back to the 1980s. When biomass came on the scene as an important energy source, the coal research that was in progress could be redirected fairly easily. The first step as regards biomass is using it as a supplementary fuel in existing coal-fired power stations. The aim is to achieve a biomass co-firing percentage of 15 to 20%. This entails risks, however, in particular the deposition

problem of heat exchanger pipes in the boiler and changes in the composition of the ash. In order to monitor how bad this problem is and what sorts of biomass cause it, ECN has developed detectors, which have helped to overcome the problems.

Biomass always has to be pre-processed, and this process costs a lot of energy. To overcome these problems ECN has developed a torrefaction process, which involves temporarily heating the biomass to 250-300°C. This makes it easy to grind. The technology developed at ECN has great market potential, and a pilot is being developed in collaboration with PTE Industrial and others, which is attracting a good deal of attention from companies such as electricity producers.

As part of its work on burning biomass as a supplementary fuel the unit is developing an EARS system to detect and control agglomeration in BFB reactors. Ash formation with different types of biomass and coal is also being studied.

Another method of using biomass is gasification (burning in the presence of a low level of oxygen). The product consists of not only methane, hydrogen and carbon monoxide but also carbon dioxide, water, nitrogen (if air is used), dust, ash, sand that has been brought in with the biomass, and tars.

The ECN concept of biomass gasification (BIVKIN), used for many years to classify biomass, is being commercialized for energy production. The first plant has been built in Romania, and the second one is to follow in 2006 in Tzum in Friesland. A feasibility study of the use of BIVKIN in horticulture has produced positive results. The technology is to be scaled up still further by Holec, Stork and HoSt.

The next step is MILENA, an indirect gasifier. Veringa: “The aim of MILENA is to produce a gas with as little nitrogen as possible. This involves separating the process in two steps: gasification and production to supply the heat to the gasification process. The resulting producer gas, in terms of calorific value, consists of about 50% methane and can be upgraded, using a catalytic converter, into a gas that could replace Groningen natural gas. It contains carbon monoxide and hydrogen that is still a problemfor the acceptance in the gas network . This producer gas could if so desired be a good starting point for making SNG (Substitute Natural Gas), though.”

Biosyngas could if necessary be converted into biodiesel in a subsequent step. Together with Shell, ECN has been looking into the possibility of making diesel from imported biomass. Yet another line of research is looking into producing hydrogen directly from biomass.

A major part of the unit’s research is devoted to tars. These are extremely inconvenient by-products of many biomass treatment processes. ECN is working on (a) measuring and

BIVKIN

The first commercial gasifier based on the BIVKIN technology developed by ECN has been taken into commission by HoSt in Romania and handed over to the client. A second one is under construction in Tzum in Friesland and is to start operating in the first quarter of 2006. The first stage of the feasibility study into the use of BIVKIN technology combined with existing CHP in the Bergerden horticultural area has been completed in collaboration with COGEN. Wood chips have been selected as the fuel, the capacity has been set at 6 MWe, and specifications for the fuel gas for existing gas engines have been drawn up in consultation with the engine manufacturer, Jenbacher.

TORTECH

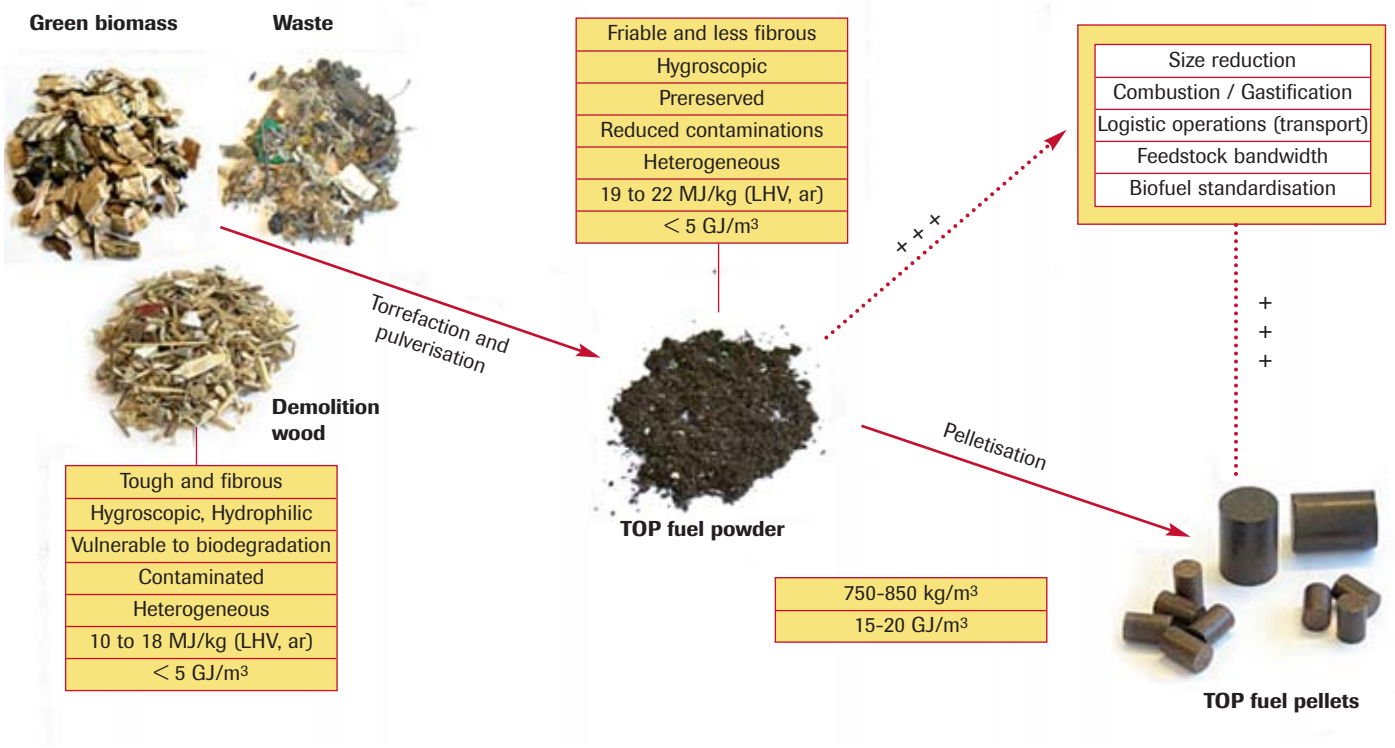
The carbonization process that biomass undergoes over millions of years in the earth does not only change the chemical composition of the material but also its mechanical properties. In a modern coal-fired power station the coal is ground into a very fine powder, with particle sizes of tenths of a millimetre, before being injected into the furnace. The small size of the coal particles makes for fast and complete combustion and enables other side effects of the combustion process to be kept under control. Because of the mechanical properties of the coal, grinding it costs at most one percent of the total power output of the station itself.

This is not the case with biomass, which has a highly fibrous structure. As a result, does grinding it cost a lot of energy, existing grinding technologies are difficult to use and there is a major risk of grinders jamming. Selecting the right kind of biomass that does not have this fibrous structure is a common solution, but more can be achieved with the right pre-treatment. One pre-treatment technology is torrefaction, heat treatment at a temperature of 250-300°C for a few minutes. This reduces the energy needed to grind the biomass by a factor of about 10 and eliminates the risk of the grinder jamming. It also turns out that the chemical properties of the biomass are changed in such a way that it becomes hydrophobic, so it does not rot, or rots less, when stored in a damp place, and the weight is also reduced while the energy content remains almost the same. In effect this treatment enables a wide variety of biomass to be given more constant combustion properties. A follow-up development is combining torrefaction and pelletisation, which produces an ideal, highly marketable fuel that can be used in advanced gasification and combustion processes.

classifying tars and (b) removing them. For the latter it has developed OLGA, a process in which the gas mixture is washed with oil, which is atomized in one of the cleaning stages. The washed product can be reused as fuel and fed back into the gasifier. A pilot system has been built for OLGA, and this shows that the tar problem is difficult but controllable. Attempts are being made to overcome the current problems by using a new washing fluid and incorporating an electrostatic filter unit.

TREC is another method of cleaning tars. It is based on the fact that gasification produces not only tar but also soot (carbon particles), which has been found to work as a catalyst for cracking tar. TREC is designed for smaller-scale systems and could be used e.g. for residual products of BFB gasification. TREC still has some technical problems for which solutions are being sought in 2006.

Veringa: “Even more challenging than incineration or gasification is extracting the chemically reactive components from biomass and converting them into valuable compounds, which we refer to as ‘biorefining’. In the process large quantities of aromatic compounds are released, also alcohols, acetates and furans. These substances can often be used as raw materials for non-energy applications, to replace substances currently produced from fossil fuels. Products made from biomass are CO2-neutral, and their commercial value is higher than the price of ordinary fuel. This principle also sheds fresh light on wastes from the food industry: there too we could look at obtaining valuable products.”



Schematic overview of torrefaction as a technology for fuel production

In practice, however, the problems are often intractable, but the unit has selected a few promising lines of research. In this area it has entered into a strategic partnership with the Agro technology & Food Services Group of Wageningen University.

Veringa: "Developments in biomass are going slowly and I would welcome more interest on the part of industry. We have scored some clear successes in a few areas: the commercialization of our BFB technology, improvements in the burning of biomass in power stations, and the development of OLGA. If agricultural waste were to be used on a local scale to produce energy using our technology, that would also be a success for us."

Hubert Veringa

Fuel Cell Technology

The Fuel Cell Technology unit (merged with part of the Clean Fossil Fuels unit to form the Hydrogen & Clean Fossil Fuels unit on 1 January 2006) is working in friendly competition with industries and research institutes throughout the world. The fuel cell and associated hydrogen technology are the focus of interest worldwide. The standards are high, and so is the potential reward if we succeed.

Manager of the unit Frank de Bruijn, on the field in which he operates: "Industry worldwide is doing a lot of development on the use of fuel cells in CHP systems and cars, for instance. We are linking up with it by focusing our research on the medium-term options.

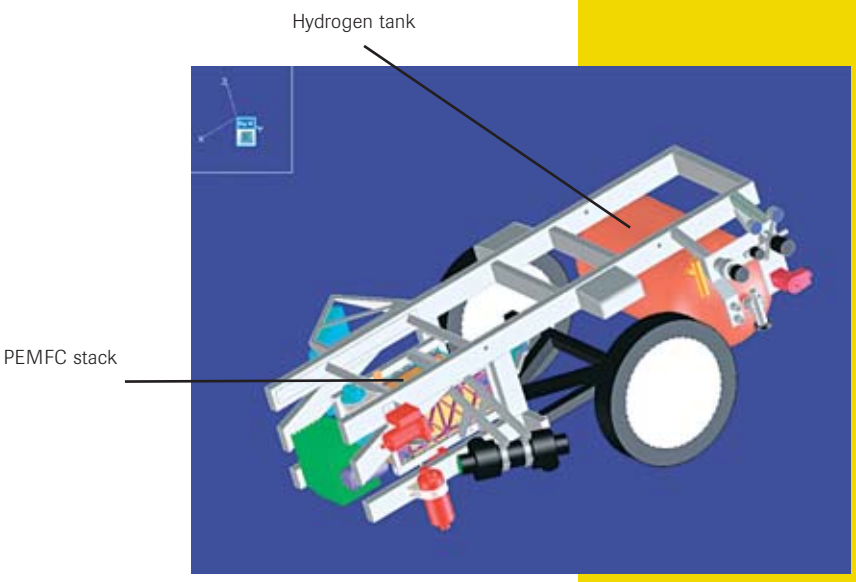
"It is important for us as a research organization to continue to set ourselves apart, even when more and more organizations, both in industry and research, are developing hydrogen and fuel cell technology. In the field of the PEMFC, for instance, we have shifted our attention in recent years from low-temperature PEMFC stack development to high-temperature PEMFC technology (120°C and higher, as against 70-80°C at present). This is a challenge, which may or may not prove successful. A lot of research is being done all over the world into new polymers, and we are already looking at the stack and system level. Other important aspects are less use of precious metals, service life and reliability. What limits useful life in practice? What happens in the event of malfunctions, for example if the coolant leaks or the supply of hydrogen ceases? The answers to these questions are very important to the future of the PEM fuel cell."

The PEM fuel cell (PEMFC) is attracting a lot of attention worldwide, as it is the main candidate for use in the transport sector, where there is a particularly strong drive to find successors to the present generation of engines, combined with the use of hydrogen instead of petrol and diesel. A number of types of fuel cell are under development for use in the stationary sector (industry, homes, buildings), and ECN is developing both SOFC and PEMFC technology for this. Despite the fact that stationary applications receive less attention in the press and popular literature, the technology may be introduced here first. De Bruijn: "The scope for investment in stationary applications is relatively high, in some cases as much as €1,000 per kW. On the other hand, in the case of higher-powered units in particular, there are other technologies that are suitable for CHP, such as gas engines and turbines, and it is not clear at the outset that fuel cells will be superior in all respects. Also, the introduction of micro-CHP, for instance, is hampered by the current setup of the electricity market for consumers. And the advantages of micro-CHP lie more at a higher level, the level of society, than presenting major benefits to individual consumers. The mobile market has the most drivers, politically and socially, such as improving local air quality, reducing our dependence on oil, and reducing carbon dioxide emissions. A market breakthrough, however, can only be expected at a price lower than €100 per kW."

A number of Dutch consortia with industrial partners, Nedstack, Hygear and Exendis, are doing research into stationary PEMFC systems. The HOTPEMS project is looking at a micro-CHP system based on high-temperature PEMFC. Most of the components for the test system that is to be built (membrane, coolant, seals, separator plates) were selected in 2005, but no definitive decisions have been made on reforming the natural gas supply.

Hydrogen-powered utility vehicle

For the HydroGEM project ECN is developing and building a small utility vehicle powered by hydrogen. A working fuel cell system producing 4.3 kWe was achieved at the end of 2005. It will be built into the vehicle and tested at ECN in the first quarter of 2006. Air Products will install a hydrogen filling station at ECN for this purpose. The next stage will involve building a number of vehicles, in collaboration with the private sector, which can be used in hydrogen testing areas.



3D design of H2 PEMFC system for the HydroGEM project

FRESCO scooter ready for its first test drive

The DuoGEN project is looking at a hydrogen generator for a hydrogen filling station. The system also includes a fuel cell system so that the owner can generate electricity if the demand for hydrogen does not come up to expectations. In addition to the partners already mentioned, Ballast Nedam is a member of the consortium, which is the market leader in the construction of petrol filling stations.

At least as important in the ECN programme is the development of the Solid Oxide Fuel Cell (SOFC). Work is being carried out for HCStarck on improving three different types of cell with a view to possible mass production. The development work at ECN for this project contributes directly to improving the industrial client's products. In addition to this industrial research ECN is working on a number of SOFC projects to reduce the operating temperature, to 600°C if possible, which would make it easier to select cheap stack materials. This involves e.g. finding a solution to the lower conductivity of the electrolyte currently being used at this temperature and the activity of the oxygen-reducing cathode.

Fuel cell scooter

A fuel cell scooter has been built as part of the EU FRESCO project in collaboration with Piaggio, CEA and Selin.

The first demonstration in the world of a fuel-cell drive scooter was given on 29 July on an Italian test track.

Another important SOFC topic is linking SOFC to biogasifiers. The SOFC's tolerance of many components makes it ideally suited to this. A number of EU projects are looking into this tolerance to contaminants.

In addition to research and development at material and component level the unit is working on the development of complete systems. A scooter with a direct fuel cell drive powered by hydrogen—the first of its kind—was demonstrated on the Piaggio test track in Italy in July 2005, thus successful completing the EU FRESCO project, which ECN coordinated and on which it worked together with Piaggio, Selin, the University of Pisa in Italy and CEA in France. A small hydrogen-powered fuel cell utility vehicle using hydrogen is to be tested at ECN in 2006, the system having been completed at the end of 2005.

The unit is also active in reforming technology, which aims to produce hydrogen from fossil fuels such as natural gas, diesel/biodiesel, kerosene and propane. An important goal is still to achieve hydrogen of sufficient purity so that the fuel cell (PEMFC or SOFC) can operate properly. This is particularly difficult in the case of diesel reforming. A number of projects this year demonstrated that hydrogen suitable for a PEMFC can be obtained from clean diesel, which is increasingly coming onto the market in the EU and the USA. Once less clean diesel is used it is very difficult to develop a stable reformer than can generate this pure hydrogen. This will be an important topic in the years to come, as many 'early' applications prefer to use available fossil sources.

The work in the field of hydrogen and fuel cell technology aims to minimize energy consumption throughout the supply chain. Frank de Bruijn: "We keep an eye on the energy efficiency of the whole supply chain in all our research on hydrogen systems. We need to make allowance for the fact that in thirty or forty years' time we shall not be able to take the supply of energy for granted as much as we do now, and energy efficiency will be crucial in that case."

Frank de Bruijn

"We have a healthy mix of basic and applied research. We are on track", says Jan Willem Erisman, head of the unit Clean Fossil Fuels in 2005 and currently responsible for the unit Biomass, Coal and Environmental research. This is illustrated by the Climate-Neutral Energy Carriers research programme, a large and healthy programme with broad-based funding and involving a large number of organizations, from universities to energy companies.

This programme is carrying out system studies of zero-emission power plants, power stations that produce no CO2 emissions focussing on the following questions: How 'zero' are these plants, and what combination of fuel and technology provides the biggest CO2 capture at the lowest cost? The studies show that burning powdered coal in the presence of oxygen gives the best results as regards CO2 capture: this

'oxy-fuel' approach commonly produces capture rates of 95-100%, whereas other combinations only surpass 85-90% at higher cost. It also turns out, however, that pre-combustion capture of CO2 is more efficient than post-combustion capture.

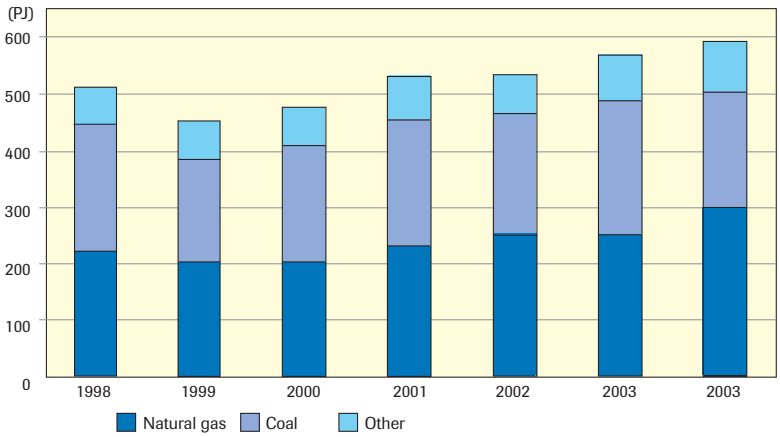
Potentially winning technologies are being developed for both approaches (pre-combustion and oxy-fuel). On the pre-combustion side ECN is working on SERP (Sorption Enhanced Reaction Process), developing adsorbents for CO2. The material that gives the highest yields as regards CO2 adsorption is hydrotalcite (HTC). Erisman: "The problem is that good adsorbents do not readily release the CO2 they have captured. The release is done using steam, thus regenerating the adsorbent and releasing CO2 for further treatment. We combine SERP with a water-gas shift reaction after an autothermal reformer, so there is steam present in the system. The challenge now is to find an adsorbent that can be regenerated effectively with this quantity of steam. If you have to make steam separately, the efficiency goes down drastically."

The Climate-Neutral Energy Carriers programme is also working on another priority pre-combustion technology, the membrane reformer: this is a reformer where hydrogen and CO2 are formed from natural gas and water and the hydrogen produced is constantly diffused through a membrane, thus pulling the reaction 'off balance'. This will enable the reform process to be carried out at lower temperatures, in other words using less energy. Another not insignificant advantage of the membrane reformer is that a separate CO2 separation stage is not needed.

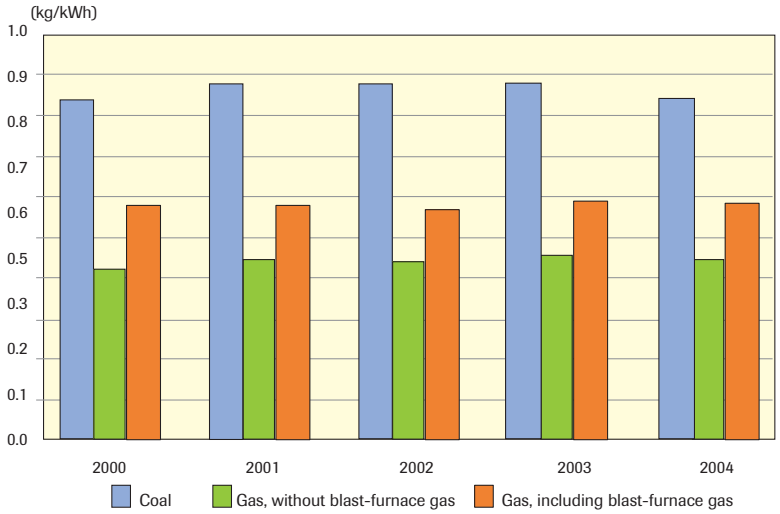
Erisman: "We have already produced a Proof of Concept for the membrane reformer experimentally. A trial ran successfully for a hundred hours. But it's difficult to scale up the membrane: you come up against problems of mechanical strength and stability. At the moment the flux is still too low, we need to get it higher." These, then, are goals for the next stage of development.

This cluster is also doing research into capturing the CO2 in steel slag. Not only would this prevent the emission of CO2 into the atmosphere, the slag also leaches much less pollutants such as heavy metals when re-used, and this is the most important effect. The process is very slow, however, and work is going on to speed it up.

Fuel feedstock power plants, 1998-2004



Average CO2-emissionfactor, coal en gas power



A highly successful development in the Reducing Emissions cluster is N2O removal. Erisman: "We are working on commercializing the technology we have developed. Above all we are working on capturing N2O in nitric acid plants, which are easy to deal with. This is why we are in partnership with a large constructor of nitric acid plants. The feasibility of our technology has been demonstrated; the next step is a durability test at laboratory scale. We shall be setting up a pilot with DSM in 2006."

"N2O is a greenhouse gas that is 310 times stronger than CO2, and under the CO2 credits system of the Kyoto Protocol (the Clean Development Mechanism) credits can also be given for N2O removal. Among 'brokers' there is great demand for the implementation of technologies with which they can rake in CO2 credits and we are constantly being approached by them. So we are on the crest of the development wave."

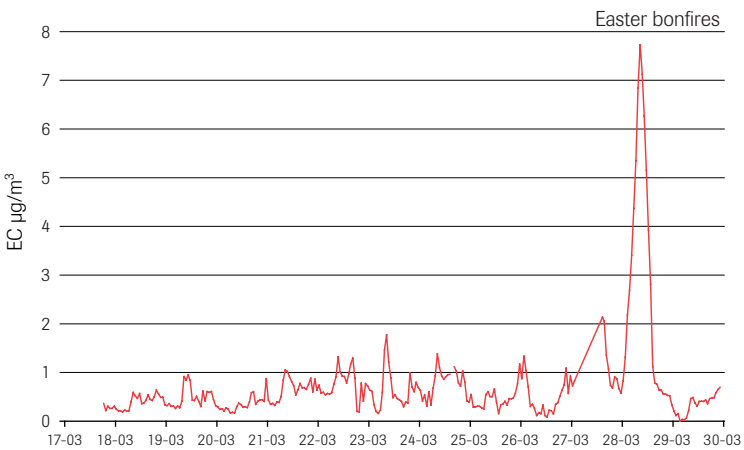
Development of the Stirling engine, in 2005 in the Clean Fossil Fuels unit, now moved to the Energy in the Built Environment and Networks unit, is being continued with the Japanese firm of Rinnai, following lengthy negotiations. Erisman: "We looked for a Dutch partner but were unable to find one. Physically the development of the technology will continue in collaboration with Japan for the next two years, though we stipulated in the licence agreement that the device is to be developed for the European market as well. Working together is not so easy, because of differences in language and culture, but the people at Rinnai are highly motivated, they are keen to improve micro-CHP based on the Stirling engine and have their own ideas on the subject. Every month some of our people spend a week in Japan."

ECN has succeeded in working with Dutch industry on MARGA (the ambient aerosol and gas monitor). The firm of Applikon markets this

Easter bonfires cause sharp increase in open air soot levels

At the Overtoom monitoring point in Amsterdam, where the newly developed C monitor is currently being tested, a C concentration about 15 times higher than normal was measured during the Easter weekend. The C monitor has been running for weeks without any significant problems and has produced a lot of useful data.

Amsterdam Overtoom EC-concentration (µg/m³) in March 2005



ECN LeachXS expert system disseminated internationally

The LeachXS expert system, developed by ECN, has been presented internationally. The system comprises an extensive database of leaching data on a wide range of contaminated materials, combined with basic models for predicting emissions from both granular and monolithic materials. It is possible, for instance, not only to compare up-to-date measurements from column and diffusion tests but also to compute the speciation of substances in a column/product using ORCHESTRA and display it as a video. The template devised for this purpose forms the basis for a large number of environmental scenarios to be developed during the coming year. Users from a few international institutions were trained in its use at a workshop in September and given trial licences to enable them to test the system. A demo version of the program has been sent out to some fifty selected potential users. Ten users have now applied for full licences, and the number is expected to go up rapidly in the near future, thanks to the collaboration with our partners, DHI in Denmark and Vanderbilt University in the US: among other things, a large number of interested parties from the US EPA, DOE, EPRI, universities and industry have enrolled for a workshop to be held in the US.

instrument for measuring the chemical composition of fine particles and acidic gases in the atmosphere. MARGA was nominated by the Netherlands for the European Environmental Press (EEP) Award for innovations in the field of environmental technology. Unfortunately it just missed winning a prize on 30 November 2005. The American Environmental Protection Authority (EPA), however, is showing great interest in MARGA and is testing three prototypes. The systems have been installed in collaboration with Applikon. Erisman: “If it is approved the American market will be open to us.”

The problem of fine particulate matter is commanding a great deal of attention, and the unit is involved in measuring and computing programmes that have direct relevance to government policy, not only nationally but also e.g. in North Brabant. Erisman: “The origin of 50% of fine particulate matter is still unexplained, if you compare the measurements with calculations of emissions based on known sources. Other potential sources are sea salt, soil material blown into the air, agriculture, and secondary fine particles (created in the atmosphere as a result of reactions involving gases such as NH3, NO2, SO2 etc.). We are trying to gain an understanding of this through research so that reduction policy can be more successful.”


Jan Willem Erisman

Meanwhile the unit is also working on the problem of the future: nitrogen streams in relation to the greenhouse effect. The EU approved a major research project, with substantial ECN participation, in 2005.

“The challenge in our unit lies in combining every stage, from laboratory to implementation”, says Erisman. “There is a demand for the products, we are strong technologically, now we have to come up with the goods.”

Technological Services & Consultancy

The Technological Services & Consultancy unit (TS&C) not only provides support to ECN's research units with the design and construction of testing and pilot systems, software development and material classification and consultancy, but also carries out technical maintenance work at ECN. Although set up as a pure service unit, it supplies technical services to other firms and of course ECN's subsidiary company, NRG.

Over the years TS&C has built up broad technical know-how, making it an important link in the chain when it comes to developing hardware. R&D in the programme units has often used TS&C know-how. Nevertheless the idea remained that the collaboration could be improved.

On 1 January 2006 the unit was upgraded to a department that is able to provide support for research from the conceptual stage. Process technology has been added, and all the technical and analytical support groups have been amalgamated in the unit, which has been renamed Engineering & Services. It is now called upon to co-develop technology and software.

Looking back on the process, Jaco Saurwalt, head of the unit, says: "Because of our task we are deeply involved in a lot of different ECN projects. Our combination of knowledge and skills enable us to play a unique role, also externally. We are involved in the development

of a silicon casting machine. When checking the design we came to the conclusion that the device was not going to work. One problem was that it could not provide the required temperature precision of a few degrees at temperatures over 1200°C. The required heating and cooling rates were also not feasible. We put forward a new concept that does permit these. We are able to handle jobs of this kind because our unit combines knowledge of process technology design, simulation and practical construction."

ECN has opted to keep this knowledge in house and not to hive it off. The unit's focus is on work for ECN research programme. Saurwalt: "We want to do at least 10% of our work externally. This brings benefits to ECN in that we know how the world works, we are competitive and customer-centred. But the proportion of external work must not go above 50%, as we are there primarily for ECN."

What does Saurwalt think about the fact that his trade, manufacturing technology, is gradually disappearing from the Netherlands? "Manufacturing technology must on no account be forgotten. Even if you want to operate at system level you need to be able to build things. The fact that equipment manufacturing and production technology and development are disappearing from the Netherlands is cause for concern. Being able to make equipment and products cleverly is essential to innovation."

Innovation often results from interaction on the interface between different disciplines, people talking to one another. If you lose the 'putting into practice' part of the process, you lose more than most companies now realize.

A lot of energy research is about special materials. Not only do you need to be able to create a product from them efficiently, you also need to be aware what you are doing with the material, what properties you are changing by the way you treat it. This is one of the reasons why we are going to do more production technology work. But we shall continue to develop in areas such as materials research and design techniques.

In order to support R&D at ECN efficiently you need to speak one another's language and understand one another. To strengthen this interaction a reciprocal secondment system has been set up among the units. This has produced substantial improvements and speed gains, especially when it comes to modelling and software programs.

Saurwalt: "Fortunately our raison d'être is no longer in question, we are an asset to ECN. We ensure that researchers don't have to worry about practicalities. We are certificated in a large number of areas so we can work reliably and safely. Our aim is to be a good service organization: we provide a good service and are not a cost item for the business. These two conditions have been met."

This is not to say that we do not have to keep a close watch on cost control. We are no exception when it comes to understaffed or unmanned analysis and production, and we are working hard to improve in these areas. Automatic workpiece exchange on the grinders will become operational at the beginning of next year. Even in an R&D support environment you need to be able to produce efficiently.

"Our role is going in the right direction. We need good financial results, but the important thing is the quality and substance of the service we provide. We now think it's time to invest more money in knowledge development."


Jaco Saurwalt

A start was made in 2005 on transferring competence for issuing environmental permits from the Municipality of Zijpe to the Province of North Holland; this was agreed in proper consultation between the three parties, as the Province is better equipped to handle the complex issues raised by an R&D organization. Jos Schrover, head of the QSE department: "The licence in force is a framework licence, issued in 2001. It lays down that for any new activity we have to send a risk survey to the Competent Authority. In other words, we have to assess the risks ourselves in the first instance. This also applies to our relationship with the Labour Inspectorate. For this work we have a QSE department with a staff of five. Apart from complying with the law, we ourselves set high standards of safety and environmental protection."

ECN also falls under the Major-Accident Hazards Decree (the 'Seveso Directive'), because it works with carcinogenic substances (e.g. nickel) and toxic gases such as those used in the manufacture of solar cells. The Decree sets high standards for operation, as regards installations, competences and organization. There was an important inspection on 3 and 4 November by the Competent Authority under the Environmental Management Act, the Labour Inspectorate and the Regional Fire Service. The resulting recommendations are binding, and include tighter control of the change process; discussions are still in progress with the Labour Inspectorate on how this relates to research flexibility, but a solution seems to have been found.

Health & Safety risk surveys take place constantly, for instance into physical stress, work equipment and noise levels in 2005. In the field of 'contractors' the level of education has to go up, both among our own people and the contractors themselves. This entails, among other things, improving dealing with employees, improving supervision, and ultimately a better style of management resulting in safer working. ECN has fairly strict rules on RSI: employees have to take compulsory instruction, workstations are visited, advice is given and, if necessary, action is taken. Policy on smoking is being revised: after outdoor smoking areas had been set up the Inspectorate commented that many of them were on routes used by people walking from one place to another. New smoking areas will therefore be created away from these routes.

The whole infrastructure for storing dangerous substances was also taken in hand in 2005. The facilities have been brought into line with the latest requirements and QSE has laid down additional guidelines in consultation with the Competent Authority. This project was completed on schedule on 1 August 2005.

The court case against ECN resulting from a business-wide environmental inspection in 2003 entered into a new phase in 2005. The court sentenced all three of the organizations prosecuted (ECN, NRG and Tyco) in March 2005 for contravening the regulations. The fines imposed, however, were much lower than those demanded by the public prosecutor: ECN was fined € 25,000, for instance, whereas the prosecutor had demanded € 1,000,000. The court ruled that there had not been any damage to the environment and the public prosecutor had not proved a number of allegations (including one of 'East European conditions'). The appeal is to be heard in 2006.

Jos Schrover: "We have used this lawsuit constructively to tighten up our environmental and safety awareness. Our target for the storage of dangerous substances is a maximum of 0.05 deviation from the regulations per person per inspection. There was only one unit still above this target in the fourth quarter of 2005; seven of the nine units had zero deviations. We have drawn up a five-year plan under which we are aiming at the level of safety in the process industry, but it is not clear on every point how this can be achieved in an R&D organization."

The Esdoorn Project

The Esdoorn Project was delivered on 1 August 2005. This involved complying with the latest requirements and replacing part of the storage facilities for solid and liquid chemicals and gases. The photograph shows an example of a new gas cylinder store, for a welding trolley holding acetylene/oxygen cylinders. The rod on the roof is the lightning conductor; the yellow line shows the area designated as susceptible to explosion. Cost of the project: about € 900,000 euros.

Working on roofs

A risk survey of the danger of falling when working on roofs was carried out in 2004. All roofs were fitted with fall protection in 2005 (fencing and/or a cable system). The cable system is used as follows: the person concerned wears a safety harness with a safety line and a fall-breaker, which is hooked onto the cable. In addition to these facilities, all users are taught how to use these facilities and reminded that they have to have a special work permit before stepping onto a roof.

Jos Schrover

Accident and near misses-accident reports

Year	Number of reports	Health and Safety near misses	Health and Safety accidents	Environmental near misses	Environmental accident
2001	38	31	5	7	0
2002	45	40	5	11	0
2003	35	32	3	2	1
2004	61	53	7	16	1
2005	63	55	7	21	1

The same incident may relate to both health & safety and the environment.

Health and Safety accidents

Year	FTE + trainees, 31/12	Accidents	Accidents involving absenteeism	IF index
2001	668,3	5	2	1,87
2002	625,0	5	2	2,00
2003	619,1	3	2	2,02
2004	611,2	7	3	2,93
2005	612,1	7	1	1,02

IF = accidents involving absenteeism x 1,000,000 / hours worked (= FTE x 1600)

Average IF 2001-05 = 1.97

Personnel Department

"People in our organization are generally highly motivated. They feel committed to the research they do and the people they work with. This intrinsic motivation of our staff is a great benefit, providing a breeding ground for outstanding achievements and a pleasant working atmosphere", says Jack Simons, head of the Personnel Department.

An important point was reached in 2005, when the organization was streamlined and brought in line with the Energy Research Strategy themes. A conspicuous change was the addition of process technology to the central Engineering Department, thus creating the Engineering & Services unit (E&S). This unit will be able to make a more substantial contribution to processes and technologies in the research

programmes. For a number of staff the streamlining entailed a change of post or location, forcing them to leave their familiar setting and work colleagues. Despite the fact that some saw this as a threat, everyone worked hard to make the changes a success.

The services of the Publication Services Department were contracted out to Nashuatec in 2005, resulting in a dramatic period for all concerned. This was the final step in an extensive process to examine ECN and NRG's future needs with regard to publication services, which eventually showed that outsourcing was the best solution. For the staff we either secured suitable new jobs at Nashuatec or made other appropriate arrangements. Jack Simons: "Ultimately we can look back at a successful process."

There were major changes in the national insurance legislation in 2005, weren't there? Simons: "We can say with some pride that we handled the consequences for our staff well, so there was no insecurity or anxiety among them. They expected us to handle matters carefully and scrupulously, and we succeeded in doing so."

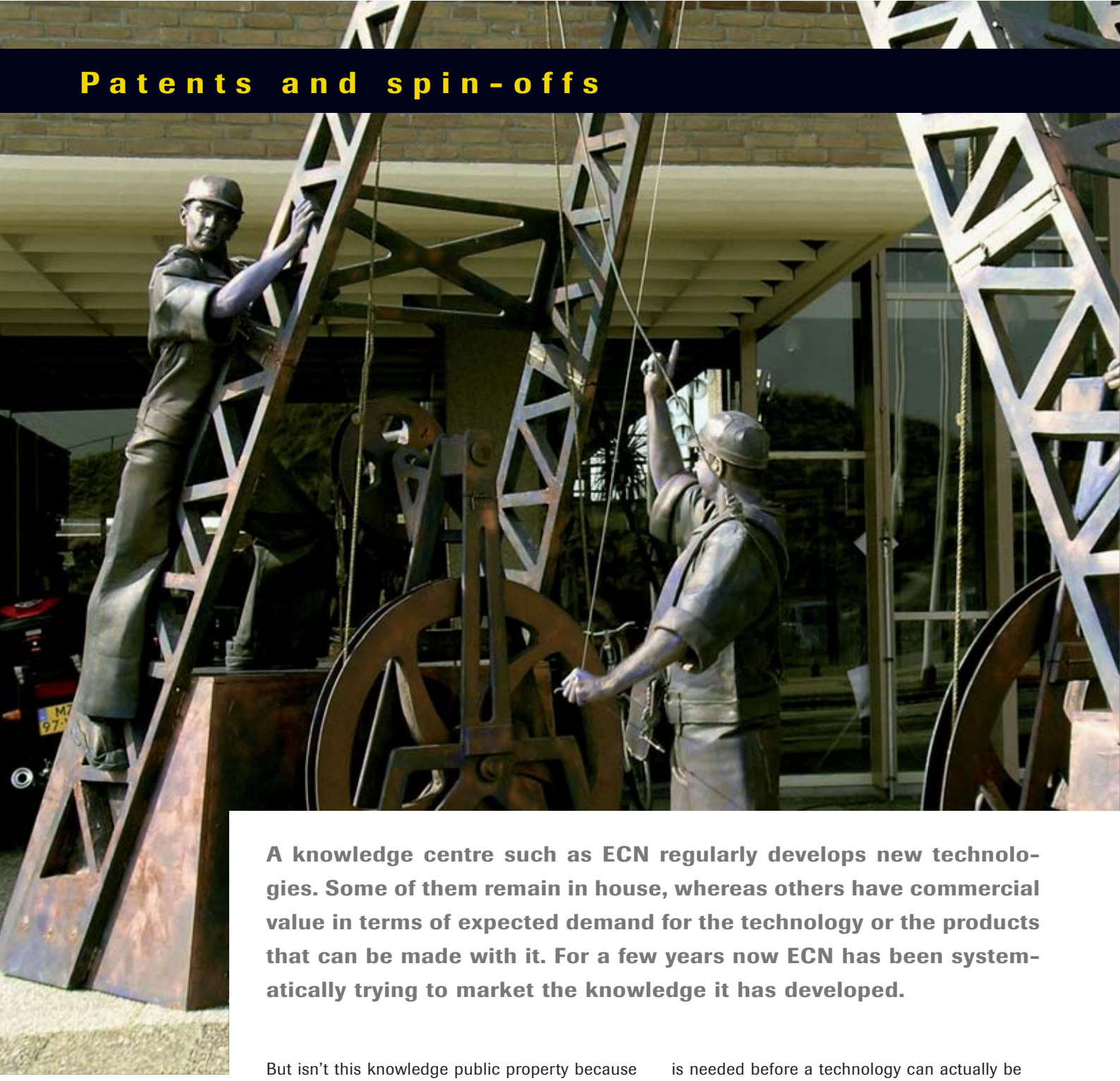
Simons: "We seem to be over the worst of the financial problems of the past years, and that too is thanks to the people in the organization, who have been willing to make an extra effort for their research. This attitude and commitment have got us on top of things again."

Something that is still exercising many minds is undoubtedly the solution to the pension problem. Everyone now realizes that this is a highly complex problem, and finding a solution to it will be no easy matter. In 2005 we thought we had found the solution in setting up a pension fund of our own, but even this option was abandoned at the end of the year. Attention is now focused on an insured pension contract with Centraal Beheer Achmea.

"In 2006 our attention cannot be confined to solving the pension problem; issues such as the assessment and performance cycle, remuneration policy and competency management need to be looked at if we are to compete as an organization in the future", says Simons.


Jack Simons

Patents and spin-offs



Festivities at the opening of "Technostart"

A knowledge centre such as ECN regularly develops new technologies. Some of them remain in house, whereas others have commercial value in terms of expected demand for the technology or the products that can be made with it. For a few years now ECN has been systematically trying to market the knowledge it has developed.

But isn't this knowledge public property because of the public funding? Shouldn't it be public? Gerard Peppink, ECN staff member responsible for patents, responds: "No, on the contrary, we protect our knowledge as much as possible, with a view to our mission. The aim of R&D is to find applications in the market. To apply a technology in the market a company needs a competitive edge. ECN has to give the company that wants to apply the knowledge developed here a head start."

Patents are granted for a maximum of twenty years, and sometimes that period is really too short, given all the additional research that is needed before a technology can actually be applied and profits made on it. Support for patent applications is provided centrally, with the aim of keeping the threshold for units as low as possible. The patent procedure is centrally funded, for instance.

Applying for a patent involves a number of steps: filing the application in the Netherlands, a year later filing an international application under the Patent Cooperation Treaty, then another eighteen months later deciding in which in countries covered by the Treaty to apply for protection. Technical scrutiny does not take place until the application is filed internationally (step 2). This is

followed by the commercial evaluation. The unit manager, researcher and senior staff get round the table and estimate the value of the patent. The assessment is more rigorous at each step in the procedure, with the result that weak candidates are dropped, ultimately leaving only a few strong patents (see Table).

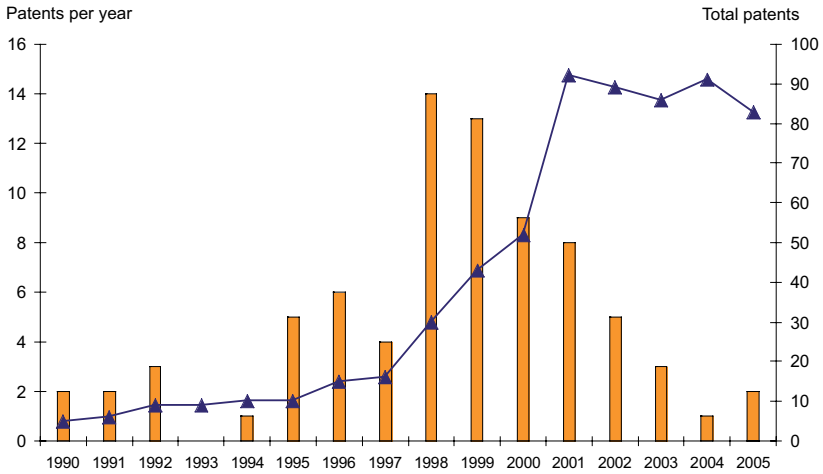
Sometimes a technology is in danger of being dropped because of lack of funds, and it may be worthwhile to get companies involved. In many cases developing a technology to the point where it can actually be applied takes a lot of money. One example is the organic solar cell: this could be used in objects such as noise screens, so powerful companies such as road builders might well want to be involved in developing the technology.

ECN can involve an outside company in development by jointly setting up a subsidiary, which can try to obtain money from the market. Or it can take the form of a spin-off company, more or less ready to put the technology into production. Alternatively, licences can be issued on which royalties are paid.

Indec is a perfect example of a successful commercialization. This company produces ceramic plates for SOFC fuel cells. Set up as an ECN subsidiary, it has largely been sold off to a German company. The technology was the right product at the right time. Its success has been very valuable to ECN, leading us to look more systematically at marketing our inventions.

Another example is the catalytic converter we developed for reducing laughing gas (N2O). N2O is one of the strongest greenhouse gases, and N2O reduction can be traded for CO2 reduction under the emissions trading system. The converter thus has substantial commercial value. Part of the technology has been sold to a German company, and no decision has yet been taken on another part.

Overview of ECN patents



Other successful technologies we have developed are MARGA and torrefaction, which are discussed in the sections on Clean Fossil Fuels and Biomass.

As a result of knowledge development, parts of ECN can also be hived off, thus creating spin-offs: Indec, for example. Hans Bais, central organization staff member responsible for spin-offs: “A recent example is the Solland plant on the Avantis industrial estate near Heerlen producing the highly successful PUM solar cell with technology developed at ECN. PUM technology enjoys some patent protection, but the success of our collaboration with industry lies far more in the skills associated with the core technology which are of interest to Solland.”

Not long ago we also embarked upon hiving off RGS wafer technology, a method of making silicon wafers not by sawing ingots but by casting them in thin layers. We entered into a contract with commercial partners at the end of 2005. We are now planning the construction of a pilot plant in the province of Noord-Holland, the final stage in developing the technology.

Peppink: “In the long run we expect a potential 1 to 2 million euros in additional annual revenue from marketing our technology, provided it is well managed—equal to the net income from all our other activities. A not insignificant sum when it comes to ECN’s financial position.”


Gerard Peppink


Hans Bais

The year 2005 was marked by ECN's fiftieth anniversary. The highlight was the big jubilee celebration on 19 May at the Kurhaus in Scheveningen, entitled '100 Years of Energy in One Afternoon'. Names from academia were seen there, as well as familiar faces from government and industry. Altogether about 300 people attended. The celebration, specially organized, planned and designed for ECN associates from special-interest groups, government and industry, consisted of three parts: lessons from the past, current energy policy and future energy supplies. Two books were published simultaneously to mark the event, *Op weg naar de markt; de geschiedenis van ECN 1976–2001* by Geert Verbong et al. and *The next 50 Years: Four European Energy Futures* by Jos Bruggink.

Hein Willems, head of the Knowledge Agency: "Our aim with the jubilee book was to present a book that would be accessible to everyone on the history of the RCN/ECN over the 1976-2001 period. Following the two previous volumes, written by Professor Goedkoop and Professor Andriesse, we asked the Foundation for the History of Technology and the Eindhoven University of Technology to write the new book, with Dr G.P.J. Verbong as the principal author. It describes the developments at ECN and elsewhere under the influence of social and political movements. An ECN working group supervised the writing of the book, which was designed and printed by Maris Media."

The report "The next 50 Years: Four European Energy Futures" by Jos Bruggink was presented at the same time. Here the author sets out the future of European energy supplies based on four contrasting scenarios. With this report ECN aims to contribute to the debate on what direction European energy transitions should take.

There were large numbers of contacts with the media throughout the year. ECN jubilee gained the attention of Radio Noord-Holland, with a series of five interviews broadcast at prime time. The Noord-Hollands Dagblad, Financieel Dagblad and Technisch Weekblad, along with many other media, also devoted a lot of space to the ECN jubilee.

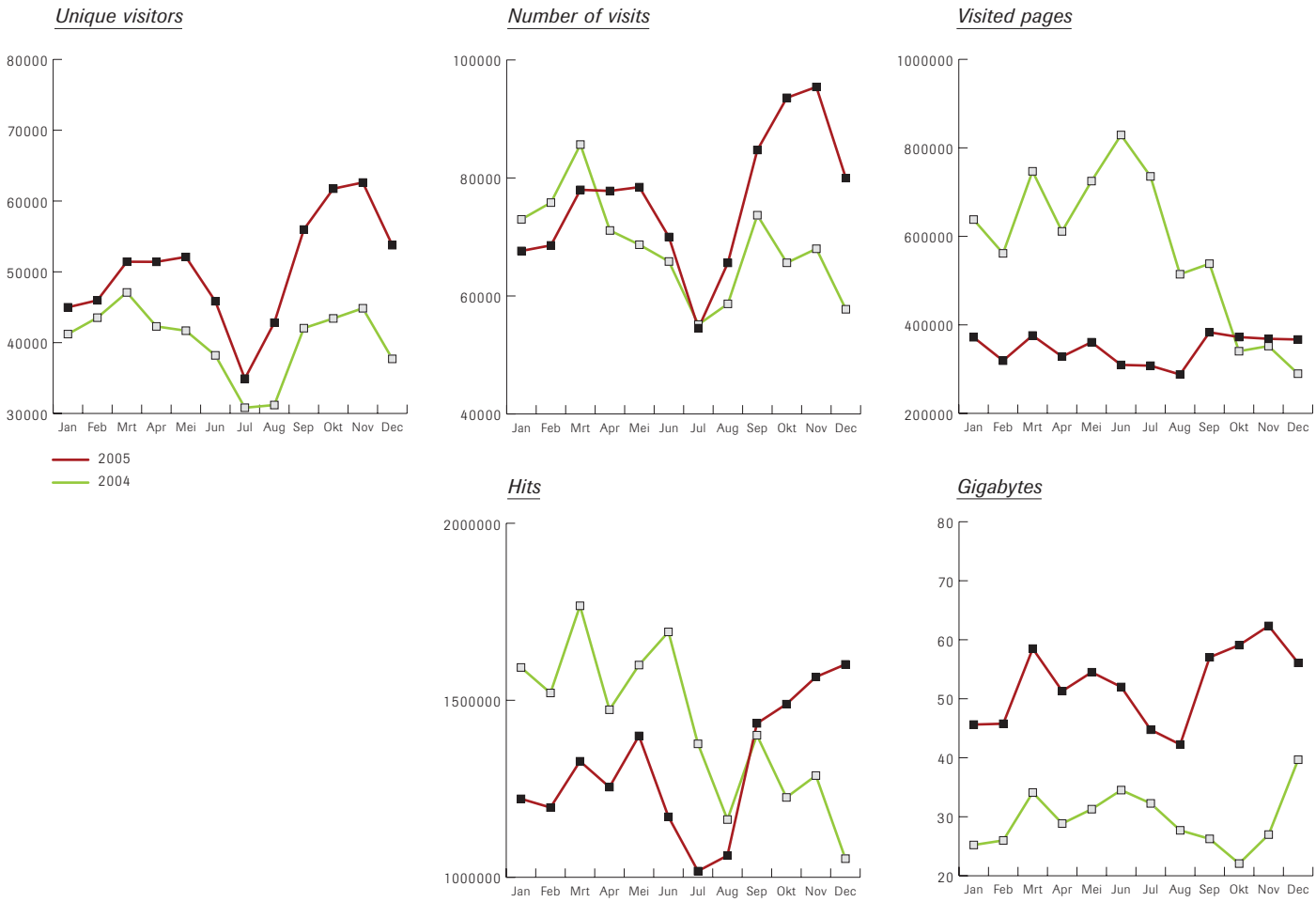
Ruud Lubbers succeeded Jan Terlouw as Chairman of the ECN Supervisory Board on 1 June, and this too received ample attention in the media.

Soon after the jubilee celebration ECN and NRG organized two Days of Open House, the first on 27 May for government and industry, and the second on 28 May for the general public.
On 27 May the knowledge and energy technologies developed at ECN were presented to 350 representatives of government and industry, with dozens of showpieces of energy saving, renewable energy and clean fossil fuels on show. On 28 May ECN welcomed over 2,500 visitors. Not only ECN but also the Nuclear Research and consultancy Group (NRG), the European Institute for Energy (IE) of the Joint Research Centre (GCO) and Tyco Healthcare opened their doors to the public. Special attractions were provided for the many children who came, who were able to make their own hair gel, a device to talk to trees and plants or an electronic dice in the 'Fun Lab'.

In connection with the jubilee a photographic exhibition was organized, which was opened by the mayor of Zijpe, Mrs A.M. van Apeldoorn-Pruijt. Following the success of the exhibition Aris Homan compiled a book of ECN archive photos designed by Ars Longa.

As is the case every year, ECN welcomed many groups of visitors and told them about energy and the research going on at ECN. Among those groups in 2005 were the entire governing board of the Ministry of Economic Affairs and an international delegation from the JOVD. Hein Willems: "This clearly shows that the energy problem is attracting more and more interest. One of the nicest things in the jubilee year for me was the school visits: at the end of 2004 we

Visits www.ecn.nl



invited 150 primary schools in the region to send their years 7 and 8 to visit us, and the invitation did not fall on deaf ears. Just under a hundred schools visited ECN and almost all of them followed up the visit by teaching their pupils about energy and energy research. They sent us all sorts of things, from essays to scale models! In view of the success of this scheme we shall be continuing it in 2006."

Apart from the jubilee book some other special publications were produced in 2005: a special jubilee newsletter was created in association with Ten Kroode & Van Zee, and a special web site giving a historical overview of RCN and ECN was launched. ECN Informatief, ECN's staff magazine was given a new format from the start of 2005, heralding the new corporate style that was introduced throughout the organization at the time of the jubilee celebration.

A great success was the second edition of the book "Alles in de wind", which was written by Jos Beurskens of ECN Wind Energy and Professor Gijs van Kuik of Delft University and edited by Diederik van der Hoeven. This book

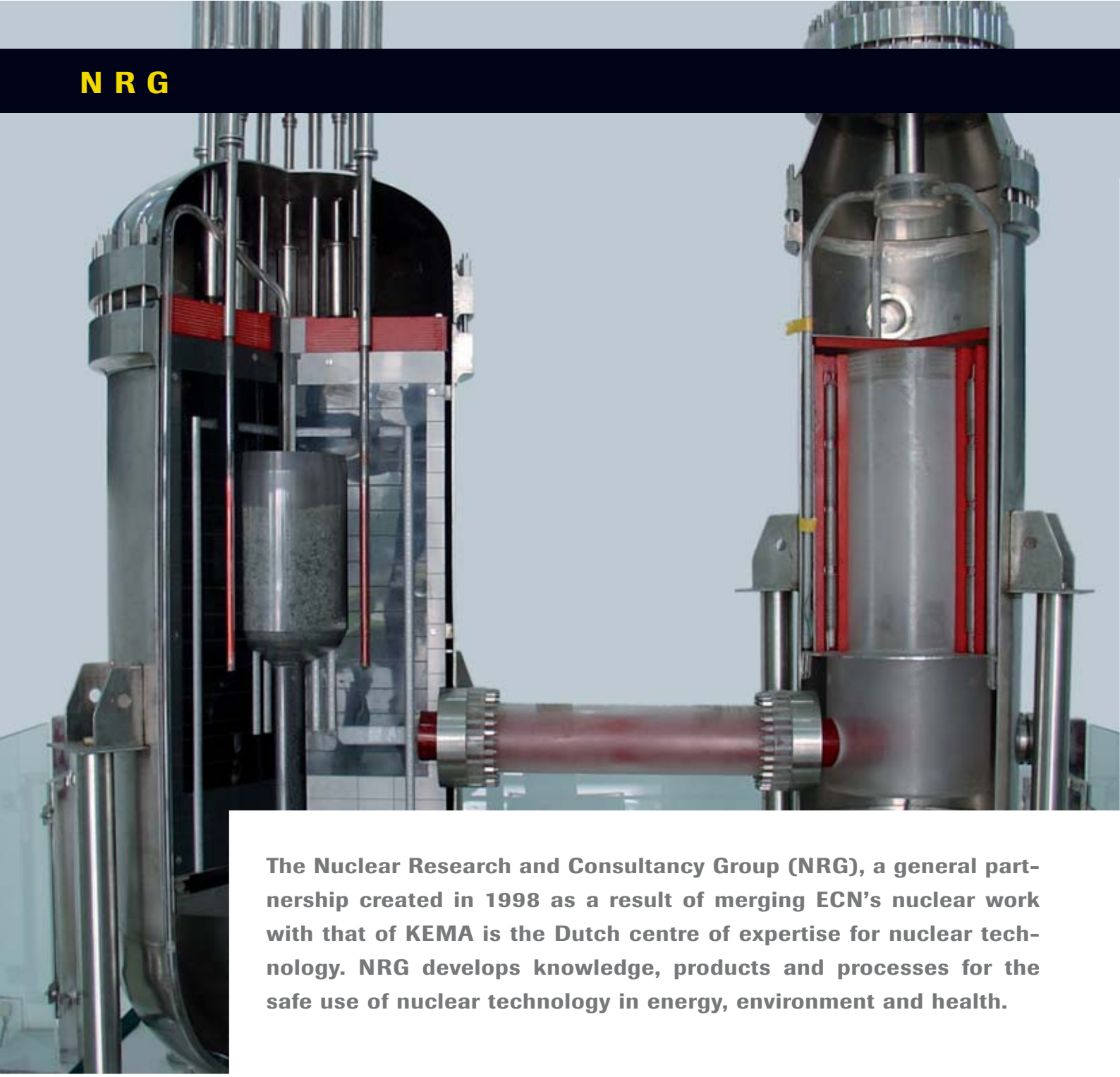
ECN's Day of Open House

Publications	PS	Wind	FCT	EEI	DEGO	TS&C	CFF	BIO	Solar	ECN total	ECN 2004
ECN reports	47	34	23	36	12	7	23	22	8	212	272
magazines	8	3	5	6	3	0	29	5	40	99	90
specialist journals	6	0	0	1	14	2	0	2	0	25	n.a.
Conference papers	51	2	21	11	30	5	78	27	50	275	165
Other publications	14	1	0	1	1	0	0	6	0	23	90
Total	126	40	49	55	60	14	130	62	98	634	617

Hein Willems

sold over 4,000 copies. The interest in it shows that wind energy is now a social issue which many people, including municipal authorities and wind cooperatives, are keen to find out about.

Hein Willems: "The aim of the jubilee year was to draw attention to ECN. In support of this we also changed ECN's image: the HorvathSchenk design agency in Amsterdam brought our corporate style up to date. I think we received a good deal of attention in 2005, not only as a result of our jubilee activities but above all thanks to the results of our research, as can be seen from the various articles in the media and the number of downloads from our web site. The trick now is to keep that attention in the years to come."



The Nuclear Research and Consultancy Group (NRG), a general partnership created in 1998 as a result of merging ECN's nuclear work with that of KEMA is the Dutch centre of expertise for nuclear technology. NRG develops knowledge, products and processes for the safe use of nuclear technology in energy, environment and health.

Model of the High Temperature Reactor (HTR) 4th Generation Power system

After a period of relative 'radio silence' initiated mainly by the Chernobyl disaster, interest in energy in general is on the rise, and nuclear power is even experiencing a renaissance. A new energy law in the United States, statements by Tony Blair on the importance of nuclear energy and the construction of a large new reactor in Finland show that this is a worldwide trend. The friendlier climate for nuclear power is due to the rising prices of fossil fuels, concerns about the dependence on energy supplies from unstable countries, and doubts about the feasibility of the Kyoto targets. Using nuclear energy could help to overcome these concerns:

CO2 emissions are minimal, compared with those from gas-fired power stations and especially coal-fired plants; uranium is mined in stable countries such as Canada and Australia, thus guaranteeing security of supply, and the price is only a fraction of the kWh price.

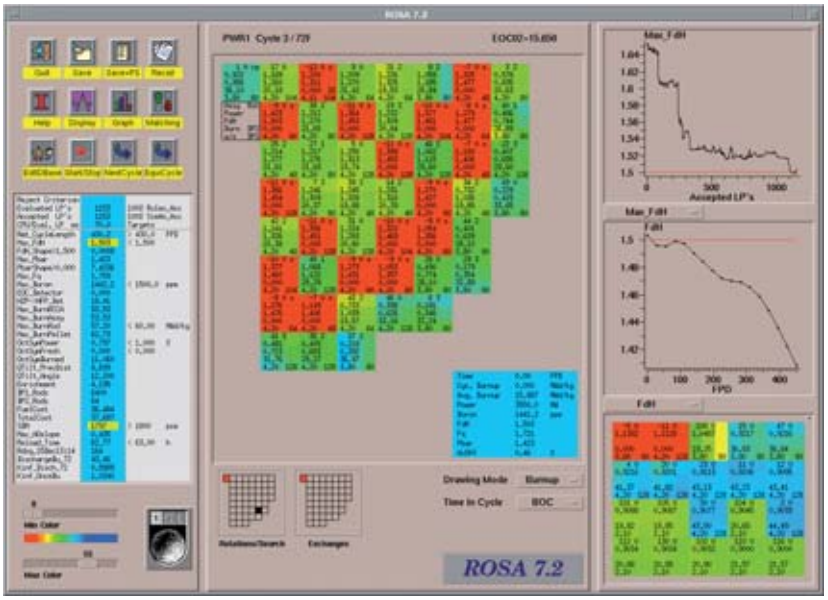
During the past year NRG has set up an information system for the dismantling of a Danish nuclear reactor that enables all the waste components to be traced. This remarkable project resulted in a kind of 'accounting system' that shows at any time which components are where, in which part of the plant or location. This is particularly important to minimize the radiation exposure for those involved.

Another NRG product that has proved to be successful are the ROSA and SOSA computer programs. Whereas the ROSA software package enables fuel saving for a nuclear power plant by means of an ingenious system for placing the fuel rods, SOSA adds the finishing touch by reducing the time needed to perform the actions to reload the reactor core during a change of the nuclear fuel. With the implementation of this software, NRG is taking the side of the operators. The programs are also in use at a large number of American plants. Two new versions of ROSA enabled modification of Combustion Engineering power plants with displaced boundary elements. A successful example of a SOSA application is the Southern Nuclear's Hatch 1 boiling water reactor, where a reduction of about ten hours in the nuclear fuel change process turned out to be feasible.

Research is an other NRG focus. There are two major subjects, high-temperature reactors (HTRs), and recycling nuclear fuel and reducing the half-life of residual radioactive waste. An HTR uses fuel efficiently in an innovative manner. The plant does not use uranium in fuel rods but in pebbles of carbon containing uranium particles. NRG is testing these pebbles as part of the Raphael European research programme. Two PhD students at NRG are doing research into the production of hydrogen with an HTR. The first commercial prototype HTR is expected to come on stream in South Africa in five years' time.

Research into recycling serves two purposes, reducing the half-life of residual waste and reusing nuclear fuel. With this in mind NRG has set up the RAS programme (Recycling of Actinides and fission products), among other things. In an international context NRG is carrying out experiments in the High Flux Reactor (HFR), in particular to develop the material in which to package the actinides in a matrix. This material needs to meet high standards. It must be inert and non activating, have a good heat conductivity and resistant to neutron irradiation. NRG is subjects these matrices to tests at wich the prevention of swelling by helium production is at the centre. These matrices can also be used to burn plutonium without creating new plutonium. The plutonium is also converted into fission products that have a substantially shorter half-life. Research is also taking place in collaboration with Russian nuclear physicists on

Computerscreen of software ROSA



the recycling of weapons grade plutonium, the surplus plutonium that was created when some of the Russian nuclear weapons arsenal was dismantled.

Alongside the aspiration to contribute to making nuclear technology more sustainable and the production of radionuclides for medical, industrial and scientific applications, consultancy accounts for a substantial part of NRG's work. In 2005, for instance, it carried out a study, in collaboration with ECN, for the Ministry of Housing, Spatial Planning and the Environment into the effects of closing down or continuing to run the only Dutch nuclear plant in Borssele after 2013. Partly on the basis of this report, State Secretary Pieter van Geel proposed to the House of Representatives that the plant be kept into operation until 2033.

The preparatory work on Pallas, the successor to the HFR, which will replace the current reactor after 2015, was continued in 2005. There is broad consensus on the need to build Pallas. The shut down of some research reactors abroad and other reactors reaching their technical lifetime, has incresed the need for Pallas as a nuclear research reactor and a reactor for the production of nuclear medicines both nationally and internationally. A lot of

Artist impression Pallas
Successor of the HFR

progress was also made in the HFR during the past year in the field of health in helping to meet the increasing demand for molybdenum for diagnostic purposes. NRG has introduced a new in-core irradiation facility and is supplying the isotope lutetium for the treatment of endocrine tumours in clinical trials. It is currently working on having the production process approved under Good Manufacturing Practice. This is necessary for supplying lutetium to the United States. NRG also advises hospitals on how to efficiently equip rooms where radiation is used, and is doing research in collaboration with universities into the effects of low doses of radiation on tissue.

NRG has further strengthened its role as the Dutch centre of nuclear expertise. Large numbers of clients, politicians, journalists and members of the public have turned to NRG for reliable and independent information on nuclear technology and its applications. This is a field that can only increase in importance with the renaissance of nuclear power.

NRG
AN ECN KEMA COMPANY

Corporate governance

The Board of Directors and the Supervisory Board endorse the general principles and starting points of the Dutch Corporate Governance Code (Code Tabaksblat), namely integrity and transparency of actions, proper supervision of these actions and accountability for these actions. Although this Code focuses on Dutch companies quoted on the stock exchange, the Board of Directors and the Supervisory Board decided in 2004 to implement the elements from the Dutch Corporate Governance Code that are also relevant to ECN. To this end regulations were drawn up in 2005 that incorporate the elements taken from the Dutch Corporate Governance Code that are relevant to ECN.

The **Board of Directors** of ECN consists of one statutory director and one assistant director. The statutory director is the chairman of the Board of Directors. He bears final responsibility for the company as a whole and is accountable to the Supervisory Board. The statutory director is appointed, suspended and dismissed by the Supervisory Board. The current statutory director was appointed for an indefinite period. The Supervisory Board decides on the statutory director's remuneration.

The **Supervisory Board** consists of six members. The task of the Supervisory Board is to supervise the management of the foundation by the Board of Directors and the general performance of the foundation and the companies associated with it. The Supervisory Board advises the Board of Directors. The members of the Supervisory Board are appointed, on the recommendation of the Supervisory Board, by the Minister of Economic Affairs. The Supervisory Board consults the Board of Directors and the Works Council when drawing up its recommendations. Applicants have to fit the desired profile of the Supervisory Board. When drawing up this profile, the Supervisory Board takes into account the nature of ECN, its activities and the desired expertise, experience and independence of its members. The Supervisory Board evaluates the profile every year. A member of the Supervisory Board is appointed for a period of four years and can be reappointed a maximum of twice.

The Board of Directors and the Supervisory Board are responsible for the corporate governance structure of ECN and are accountable on this point to the **Minister of Economic Affairs**. The Supervisory Board provides the Minister of Economic Affairs with all the requested information.

Activities in 2005

The Supervisory Board met four times this year. The Board of Directors was present at each meeting. A different member was absent from a meeting three times in total. The following topics, among others, were covered in the meetings:

- Financial matters, including the annual report and accounts, the periodic financial reports, the investment plan, the operational plan and participations. The annual report and accounts were dealt with in the absence of the external auditor.
- Pension issues. In every meeting the progress made regarding the pension issues was discussed with the Board of Directors.
- Corporate Governance. In 2005 the Supervisory Board drew up regulations which incorporated the elements of the Dutch Corporate Governance Code that were relevant to ECN.
- Other topics. The R&D plan, the implementation of the recommendations of the Wijffels committee, the setting-up of an ECN (internal) scientific recommendations board and a transition think tank.

A member of the Supervisory Board was present at two consultation meetings of the Works Council with the director.

The Supervisory Board has two committees, the Audit Committee and the Remuneration and Appointments Committee, both of which prepare special topics for the Supervisory Board. As part of the Corporate Governance, regulations were drawn up in 2005 for both committees and these were approved by the Supervisory Board.

Audit Committee
This committee, consisting of Mr H.A.D. van den Boogaard (chairman), Prof W.C. Turkenburg and Mr G.H. Verberg, met three times in 2005.
The following topics were covered in these meetings, among other things: the regulations for the audit committee, the annual accounts and the management letter, the auditor's report, the new fraud guidelines, and the structure and functioning of the internal risk-management system.

Remuneration and Appointments Committee
This committee consists of Mr A. van der Velden (chairman), Mr R.F.M. Lubbers and Mr L.M.J. van Halderen. The committee met twice in 2005. Topics covered in these meetings included: the regulations of the committee, the management regulations, the profile of the Supervisory Board, the remuneration and the objectives of the statutory director. Recommendations by the external agency Hay were used to decide on the remuneration.

Conflicting interests
On the basis of the regulations any conflicting interest of a member of the Supervisory Board, the Board of Directors and the external auditor that is of material significance for ECN or for the person concerned should be reported immediately to the chairman of the Supervisory Board. No report of this kind was received in 2005. The stipulations set out in the regulations that relate to this were complied with.

Independence
The Supervisory Board believes that the requirement that each of its members, with the exception of one person at most, be independent was complied with. The Supervisory Board considers all the members to be independent.

Changes to the Supervisory Board
The vacancies that arose in June 2005 as a result of the departure of Mr Terlouw and Mr Scholten were filled by the appointment of Mr Lubbers and Mr Verberg. The Supervisory Board thanks Mr Terlouw and Mr Scholten for their years of dedication to ECN. The Supervisory Board thanks the Board of Directors and the employees for their efforts and for the results achieved in 2005, which made the last year a successful one for ECN.

Rotterdam, 21 March 2006,
The Supervisory Board

Members of the Supervisory Board and their positions

Prof. Dr. J. Terlouw

(74, male, Dutch, chairman until June 2005)

- Chairman of Syntens, MKB innovation network
- Chairman of Koninklijke Schuttevaer, association of inland shipping companies
- Chairman of SVN (Promotion Fund for Public Housing for Dutch municipalities)
- Chairman of Aedes, code committee
- Chairman of the Board of Supervisory Directors of Aquanet, Nieuwegein
- Member of the Board of Supervisory Directors of Nedcon, Doetichem
- Chairman of Leprastichting
- Member of Provisorium Parc Spelderholt
- Ambassador for the 'Varkens in Nood' foundation
- Chairman of Zalmplatform
- Member and trustee of Achmea Hypotheekbank
- Chairman of the 'Organ Donation' coordination group
- Chairman of the Achterhoek Architecture Award
- Chairman of the Woutertje Pieterse Award

Appointment date

First appointment in December 1995.
Mr Terlouw stepped down in June 2005.

Dr. R.F.M. Lubbers

(66, male, Dutch, chairman from June 2005)

- Former High Commissioner for Refugees
- Former prime minister
- Member of the Earth Charter Council
- Member/manager of the management company Breesaap B.V.
- Chairman of the U.A.F. management board
- Ambassador for the Derde Kamer (NCDO)

Appointment date

First appointment in June 2005.
The current appointment runs until June 2009.

H.A.D. van den Boogaard

(66, male, Dutch)

- Chairman of the Board of Supervisory Directors of Grimaflor B.V.
- Member of the Board of Supervisory Directors of ICT Automatisering
- Member of the Board of Supervisory Directors of Mourik Holding
- Member of the Board of Supervisory Directors of Bloksma B.V.
- Member of the management board of the Achmea association
- Member of the investment advisory committee of Interpolis
- Chairman of the Barneveld rental housing organisation

Appointment date

First appointment in May 1996.
The current appointment runs until June 2009.

Ir. L.M.J. van Halderen

(59, male, Dutch)

- Chairman of the Managing Board of NUON
- Member of the Board of Supervisory Directors of Pacques B.V.
- Chairman of the Supervisory Board of Isola-klinieken (Zwolle hospitals)
- Member of the management board of the Introdans foundation

Appointment date

First appointment in April 1996.
The current appointment runs until June 2008

Drs. P.A. Scholten

(60, male, Dutch)

- Government Relations N.V. Nederlandse Gasunie
- Contact group Institute Clingendael
- Foundation WEC
- Member committee on Energy, VNO-NCW

Appointment date

First appointment in April 1996.
Mr Scholten stepped down in June 2005.

Prof. Dr. W.C. Turkenburg

(59, male, Dutch)

- Professor of the Department of Science Technology and Society, Faculty of Science, Utrecht University
- Head of the Departmant of Science Technology and Society, Faculty of Science, Utrecht University
- Scientific Director of the Copernicus Institute for Sustainable Development and Innovation, Utrecht University
- Member of the Board of the International Institute for Industrial Environmental Economics (IIIEE), Lund University, Sweden
- Member of the Board of Directors of the International Energy Initiative (IEI), with regional offices in Bangalore (India) and Sao Paulo (Brazil)
- Member of the Board of the SENSE Research School, Vrije Universiteit Amsterdam
- Chairman of the steering group of the BSIK research programme CATO (CO2 capture, transport and storage), Utrecht Centre for Energy research
- Member of the Programme Committee for Energy Reseach at Universities, NWO and SenterNovem
- Member of the Advisory Committee for the scientific journal 'Energy for Sustainable Development', IEI, Bangalore, India
- Member of the Review Committee for the International Conference on Greenhouse Gas
- Control Technologies (GHGT), IEA Greenhouse Gas Programme, Cheltenham, UK
- Member of the Science and Technology Committee for the EU programme CASTOR (Capture And Storage of CO2)
- Member of the Platform Communication on Climate Change (PCCC), KNMI and MNP, Bilthoven
- Member of the organisational committee for Global Energy Assessment (GEA), IIASA, Laxenburg, Austria

Appointment date

First appointment in September 2001.
The current appointment runs until September 2009.

Ir. A. van der Velden

(65, male, Dutch)

- Chairman of the Board of Supervisory Directors of Vitens N.V.
- Chairman of the Board of Supervisory Directors of Nedcap N.V.
- Vice-chairman of the Board of Supervisory Directors of Stork N.V.
- Member of the Board of Supervisory Directors of TKH Group N.V.
- Deputy-chairman of the Netherlands Commission for EIA
- Member of the Committee on Development Cooperation for the Advisory Board on International Affairs
- Member of the Energy Transition Task Force

Appointment date

First appointment in February 1996.
The current appointment runs until June 2007.

Drs. G.H. Verberg

(63, male, Dutch)

- President of the International Gas Union
- Chairman of the Board of Supervisory Directors of Berenschot Holding
- Chairman of the Supervisory Board of the University of Groningen
- Chairman of the Board of Supervisory Directors of UCN N.V.
- Vice-chairman of the Board of URENCO Ltd.
- Member of the Board of Supervisory Directors of Essent N.V.
- Member of the General Energy Council
- Member of the Advisory Board for E.ON Ruhrgas AG
- Member of the General Board of the Prins Bernhard Cultural Fund
- Member of the Supervisory Board of the International Institute for Social Studies (The Hague)

Appointment date

First appointment in June 2005.
The current appointment runs until June 2009.

Programme Advisory Council

- Drs. R.W. Boerée, SenterNovem
- Ir. J.W.M. Bongers, EPZ nv
- Drs. B.J.M. Hanssen, Energy Council
- Dr.ir. G.E.H. Joosten
- Ir. G.R. Küpers *(chairman)*, SDE/ Kandt Management BV
- Mr.drs. P.W. Kwant, PXT, Shell International bv, Corporate Centre
- W.J. Lenstra, Ministery VROM
- Dr.ir. B. Metz, RIVM
- Drs. A.A. Stroop, Ministry of Economic Affairs
- Prof.dr.ir. W.P.M. van Swaaij, Twente University
- Mr.drs. A.A.H. Teunissen, Ministery of Economic Affairs
- Prof.dr. H. Verbruggen, Vrije Universiteit
- Dr. G.J. Zijlstra, Zijlstra Management & Advies

Policy Studies

- Drs. H.E. Brouwer *(chairman)* Ministry of Economic Affairs
- Ing. F.J. de Groot, VNO-NCW
- Drs. B.J.M. Hanssen, Energy Council
- Dr. J.T.N. Kimman, SenterNovem
- Drs. J.A. Oude Lohuis, RIVM
- Ir. E.J. Postmus, Nederlandse Gasunie
- Drs. F. Vlieg, Ministry VROM

Energy Efficiency in Industry

- Dr.ir. W.J.W. Bakker, Akzo Nobel Chemicals bv
- Ir. J.S. Feenstra, Akzo Nobel Energy bv
- Ir. H. Keuken, PDC bv
- Ir. B.Ph. ter Meulen, MolaTech BV
- Ir. J.W. Nijdam, SenterNovem
- Dr. ir. Nijmeijer, Shell Global Solutions International
- Ir. A.M.G. Pennartz, KWA Bedrijfsadviseurs
- Ir. E.J. Postmus, Gasunie Trading & Supply bv
- Mw.ir. T. de Vries Ministry of Economic Affairs

Renewable Energy in the Built Environment

- Ir. W.C.T. Berns, SenterNovem
- T. Bokhoven, Solair Systems bv
- Ir. H.J.M. van Hout, Association of Energy Consultants
- T. Reijenga, Bear architecten
- E.J. Wissema, Ministry of Economic Affairs
- J.J. Overdiep, Gasunie
- J. Verlinden, Ministry VROM
- P. Hameetman, BAM Vastgoed
- Prof.dr.ir. R.J.C. van Zolingen, Shell Solar Energy
- C. Zijdeveld *(chairman)*

Solar Energy

- Dr. G.J. Jongerden, Akzo Nobel Chemicals
- Ing. W. van der Heul, Ministry of Economic Affairs
- Prof.dr. P.W.M. Blom, University of Groningen
- Ir. J.J. Swens, SenterNovem
- Prof.dr.ir. R.J.C. van Zolingen, Shell Solar B.V.
- B. Wiersma, Sunergy
- Dr. A. Goossens, TU Delft
- Ir. E.H. Lysen, UCE

Wind Energy

- Ir. G.F. Bakema, Essent
- H.W. Boomsma, Ministry of Economic Affairs
- Ir. W. Kuik, Stentec bv
- Prof.dr.ir. G.A.M. van Kuik, TU Delft
- Ing. H. Lagerweij, EWT
- E. Luken, SenterNovem
- Ir. J. Olthof, NUON nv
- Ir. R. Roelofs, NGUP
- Ir. H. den Rooijen, Shell
- Ir. F. Verheij, KEMA
- Ing. C. J. A. Versteegh, Garrad Hassan & Partners
- Ir. A. Winnemuller, Vestas-Nederland Windtechnologie B.V.

Biomass

- Ir. M. van Berlo, Afval Energie Bedrijf
- Ing. J.A. Bouman, NV Afvalzorg Holding
- Prof.ir. J.P. van Buijtenen
- Mw.drs. L. van Egmond, NV Huisvuilcentrale N-H
- Ir. E.J. van Heugten, Haskoning Nederland BV
- E. de Jong, Agrotechnology & Food Innovations
- Dr.ir. F.P.J.M. Kerkhof, Jacobs Engineering Nederland BV
- Dr.ing. J. Klimstra, Wärtsilä NSD Nederland B.V.
- L.M. Kroon, Essent Energie Productie
- Ir. K.W. Kwant, SenterNovem *(chairman)*
- Dr.ir. L. Petrus, Shell Global Solutions International B.V.
- Ir. E.J. Postmus, Gasunie Trade & Supply
- Ing. J.W.L. Spiegeler, Ministry VROM
- Ir. A.J.M. van Tienen, NUON
- Drs. E.W.J. Wissema, Ministry of Economic Affairs
- Prof.dr.ir. M. Wolters, Gastec NV
- Dr. W.T.M. Wolters, Electrabel Nederland NV

Clean Fossil Fuels and Fuel Cell Technology

- Prof.dr. K. Blok, ECOFYS
- Dr.ir. L.J.M.J. Blomen, Blomenco bv. *(chairman)*
- Ir. A. Brouwer, SenterNovem
- Dr. H. Cahen, Ministry of Economic Affairs
- Dr. G.H.M. Calis, DSM
- Drs. S. Faber, Ministry of Transport
- W.J.T. van Gemert, Gasunie
- Dr.ir. M.J. Groeneveld, Shell International Exploration and Production
- Ir. U.Ph. Lely, ESSENT Netwerk Noord
- Drs. M.W.M van der Linden, ENECO Energy
- E. Middelman, Ned Stack
- Ir. E.A.M. de Nie
- H. Spiegeler, Ministry VROM
- B. Stuy, SenterNovem
- Dr. H. van Wechem, Shell Global Solutions

Nuclear Research

- Ir. M. van der Borst, EPZ
- Dr. H.D.K. Codée, COVRA
- Prof. dr. ir. T.H.J.J. van der Hagen, IRI, TU Delft
- Dr. P.J.W.M. Müskens, Ministry VROM
- Ir. G.R. Küpers, Kandt Management
- Mw. mr. A. van Limborgh, Ministry VROM
- Ir. P.H.M. te Riele, Urenco (chairman)
- Ir. G.C. van Uitert, Ministry of Economic Affairs
- Prof. dr. ir. A.H.N. Verkooijen, IRI, TU Delft

Board of Directors

Dr. Ton Hoff

- Member Committee on Energy, VNO-NCW
- Chairman of the Council on Innovation Knowledge & Innovationcircle (KIK)
- Steering committee "Duurzaamheidskenniscluster Amsterdam-Noord"
- Advisory Council "Syntens", West-Nederland
- Task Force Energy Transition of the Ministry of Economic Affairs
- Board EMVT (ElektroMagnetic High Power Technology)
- Board of the WEC (World Energy Council) The Netherlands
- Board of the foundation "Tecnostart"
- Member of The Netherlands Society of technological Sciences and Engineering (FTW)
- Advisory Board Interpay
- Supervisory Board Energy Valley
- Board of the Association of Technology Transfer (ATO)

Dr. Kees van der Klein

- Supervisory director InDEC B.V. (fuel cell components)
- Supervisory director Enatec B.V. (stirlingmotor)
- Supervisory director RGS B.V. (solarcelcomponents)
- Member Advisory Council EU Technology Platform Hydrogen and Fuel cells
- Member Advisory Council Kompetenz-Netzwerk Fuel cells and Hydrogen, Nord Rheinland-Westfalen
- Member Program Advisory Committe of Forschungs Zentrum Julich
- Chairman Committee on Energytransition of the Scientific office of the CDA
- Member Transition Platform "New Gas"
- Member Advisory Committe on Energyresearch of NWO/SenterNovem
- Member Executive Board ACTC / NWO
- Member Executive Committee on the roadmap Seperation Technology
- Member Steering Committee BSIK program CATO

Managers Programme Units

- Ir. P.T. Alderliesten, Energy Efficiency in Industry
- Ir. T.J. de Lange, Wind Energy
- Ir. J.R. Ybema, Policy Studies
- Dr. F.A. de Bruijn, Fuel Cell Technology
  (from 1-1-2006 Hydrogen & Clean Fossil Fuels)
- Dr.ing. J.W. Erisman, Clean Fossil Fuels
  (from 1-1-2006 Biomass, Coal & Environmental Research)
- Mw. ir. M.C.C. Lafleur, Renewable Energy in the Built Environment
  (from 1-1-2006 Energy in the Built Environment & Intelligent Grids)
- Prof.dr. H.J. Veringa, Biomass (from 1-1-2006 member of the Staff)
- Dr. G.P. Wyers, Solar Energy

Supporting Services

- Mr. G.P.J. den Hartogh MFM, Facility Services
- Ir. J.J. Saurwalt, Technological Services and Consultancy

Staff

- J.M. Bais, Marketing and Innovations (till 1-3-2006)
- Ir. G. Peppink, Programme Secretary
- Dr.ing. J. Prij, Manager General Affairs
- Drs. J.A.G. Stallinga RA, Finances
- Dr. H. Willems, Knowledge Agency
- Ir. J.H.P.C.A. Simons MBA, Personnel & Organisation
- Mr. G. Tunzi, Legal Counsel
- Ing. A.J.M. Schrover, Quality, Safety and Environment

NRG Management

Board of Directors NRG

- Dr. R.J. Stol, General Director
- Ir. A.M. Versteegh, Director

"The Finance Department's job is to ensure that the company can operate without problems and that the research is not affected by financial vicissitudes or overdue maintenance. In general our financial endurance needs to be sufficient to cope with unexpected setbacks. It rose to 10% in 2005, a substantial improvement."

Jan Stallinga, head of the Finance Department in ECN's central organization, is very pleased with ECN's stronger financial position. Part of Stallinga's job is managing the Financial and Administrative Service Centre (F&ASC), which has been operating as a central department of ECN for a few years now. Stallinga: "In my opinion, the Department is working better every year: it is reporting more quickly and more frequently, and the depth is improving from one year to the next. Researchers at ECN often come up against the limits of feasibility in financial terms too. That makes the work exciting, it forces them to consult with one another more than in industry."

ECN has computerized a lot of information flows. Good use is being made of the new SAP system and staff are on the lookout for new developments and ways of improving ease of use. Every two years randomly selected users are interviewed in a quest to find areas for improvement. On top of this it is important for SAP to keeping coming up with new releases so that pampered ECN users feel well served in this area.

In the payroll department 2005 saw some major changes in the rules on tax and employee insurance. Preparations had to begin in 2004 to deal with amended legislation that came into force on 1 January 2006. Stallinga: "I consider myself fortunate that ECN has a good knowledge of this area, enabling it to play a clear-cut role in the national SAP consultations on the Social Insurance (Reduction of Administrative Burden and Simplification) Act (Wet Walvis)."

ECN has also had to (and still has to) cope with the complicated situation regarding terms of employment: do salary rises count when calculating pensions, for instance? This is the result of the consultations with current ECN staff and pensioners that have been going on for some considerable time on whether entitlements should be index-linked.

Stallinga: "Fortunately it now seems that the end of the tunnel is in sight and hopefully there can again be 'normal' payments of salary and 'normal' donations to the pension funds."

And there is another thing Stallinga would like to say about the payroll department: "The department has managed to keep its head above water in 2005, a difficult year, ensuring that some €60 million a year is paid out on time."

"I consider myself fortunate that we have open communication in the Finance Department, so we don't have to push things under the carpet."


Jan Stallinga

MANAGEMENT REPORT

ECN's objective can be summarised concisely in its mission statement: "ECN develops high-quality know-how and technology that are required for the transition to sustainable energy management."

ECN functions as a 'task institute' at the forefront of its specialist field in Europe. ECN's wide-ranging know-how makes it unique in the field of sustainable energy ("balanced programme portfolio").

ECN develops and exploits know-how and innovative technology and has a unique high-quality research infrastructure. In addition to its positioning with regard to the tasks it carries out, ECN also contributes to the exploitation of know-how and new technologies in collaboration with partners from industry.

ECN is a foundation governed by public law. Since 1998 its research activities in the field of nuclear technology have been the responsibility of a general partnership, namely NRG, the Nuclear Research and consultancy Group. The partners in NRG are ECN (70%) and KEMA (30%).

At 31 December 2005 ECN's workforce numbered 808 (FTEs), 280 of whom were employed by NRG.
At the end of 2004 these figures were 823 and 279 respectively.

Several important elements of the policy that was pursued in 2005 are:
- The recommendations of the Wijffels committee were implemented. These concluded, among other things, that ECN is the energy research institute in The Netherlands and should be managed and positioned accordingly. The committee recommended in concrete terms that the research be built up around multi-year demand-led programmes. The implementation was given shape over the last year in close consultation with the Ministry of Economic Affairs and SenterNovem. Starting points for this were:
  - an increase in the intrinsic synergy between the EZS research programme and the EOS tasks (EOS is the government's energy research strategy).
  - granting of subsidies on the basis of multi-year programmes.
  - recognition that ECN holds an exclusive position in the research fields in which it is a leader, possibly in combination with third parties in a consortium.
  - In 2005 multi-year programmes were drawn up and implemented for the eight research areas. Consortiums were set up for nine fields of ECN research.
  - The structure of the ECN organisation was brought into line with the structure of EOS.
  - To find a solution for the pension issues that be fair and balanced regarding the interests of the employees still working and those no longer working and the company itself.

From a financial point of view ECN ended 2005 with a positive result with a profit of € 4.4 million. (2004: € 2.4 million). Shareholder's equity rose, after the addition of this profit, to € 11 million, which slightly improved solvency, which rose to a level of around 8%. Investment totalled almost € 5 million in 2005, an amount similar to that of 2004.

In 2006 turnover is expected to be slightly up on that of 2005 (almost € 107 million).
Investment will rise in 2006. In addition to the usual investment there are plans to build a new radiology laboratory for NRG, worth over € 4 million. This investment will be financed using liquid assets raised externally. ECN's current funding is sufficient for the implementation of the normal operational activities. For the funding of activities linked to radioactive waste the money will be used that was received from the Ministry of Economic Affairs (EZ) especially for this purpose. EZ and ECN will jointly manage the amount, worth over € 14 million.

In addition, a great deal of attention will be devoted in 2006 to improvements to the infrastructure in Petten.

In 2006 the number of employees will be similar to that of 2005. In 2006 discussions with ex-employees and current employees about a new pension scheme will probably be completed. It is important for the development of ECN's result that a solution will be found.

The legal structure that currently exists between ECN and NRG will be re-evaluated in 2006.

Petten, 21 March 2006

Consolidated balance sheet as at 31 December (in € x 1000)

	Assets	2005	2004
	Fixed assets		
1	Intangible fixed assets	11	37
2	Tangible Fixed Assets	25,234	26,689
3	Financial fixed assets		
	· Participations in knowledge-based companies	928	342
	· Other participations	45	226
	· Securities	25,536	26,730
	· Other receivables	7,415	6,823
		33,924	34,121
	Total fixed assets	59,169	60,847
	Current assets		
4	Work in progress	12,236	11,166
5	Receivables and prepaid expenses	16,478	15,596
	Inventory	4,467	225
		33,181	26,987
6	**Cash at bank and in hand**		
	Delta Lloyd Bank NV	7	7
	In hand	3	4
	ING/Postbank	29,100	25,051
	ABN/AMRO	12,650	9,870
		41,760	34,932
	Totaal	134,110	122,766

	Liabilities	2005	2004
7	**Group equity**		
	Equity	9,757	6,252
	Minority interest	1,331	944
		11,088	7,196
	Provisions		
8	Provision for early retirement (FUT)	0	9
9	Provision for redundancy	1,590	2,810
10	Provision for transitional retirement regulation	4,400	4,617
11	Provision for functional redundancy (FLO)	2,317	2,044
12	Provision related to anniversary disbursement	1,014	0
13	Provision for radioactive waste	54,316	52,756
14	Provision for work in progress	3,116	2,617
14	Other provisions	4,409	2,062
		71,162	66,915
15	**Current liabilities**		
	Deferred income third parties	15,281	17,846
	Accounts payable	9,746	7,776
	Taxation	2,071	2,023
	Other social security charges and personnel costs	18,054	15,414
	Other liabilities and accrued expenses	6,708	5,596
		51,860	48,655
	Total	134,110	122,766

Consolidated statement of income (in € x 1000)

		2005	2004
	Operating income		
16	· Basic, ENGINE and Cooperative funding by the State of the Netherlands	36,922	34,303
17	· Third party income		
	· Increase/decrease in work in progress	60,664	63,581
		833	-1,323
		61,497	62,258
18	Capitalized corporate production		
19	Other operating income	2,188	1,938
		6,261	3,773
	Total operating income		
		106,868	102,272
	Operating expenses		
20	Wages and salaries		
	Social security contributions	47,920	46,607
	Pension charges	3,277	3,800
	Depreciation of intangible fixed assets	8,108	13,697
21	Depreciation of tangible fixed assets	7	205
22	Other operating expenses	5,199	5,163
		37,294	30,178
	Total operating expenses		
		101,805	99,650
	Operating income		
		5,063	2,622
23	Financial income and expenses		
		-381	89
	Result on ordinary operations before taxes	4,682	2,711
24	Taxation on result from ordinary operations	-353	-260
	Result on ordinary operations after taxation	4,329	2,451
	Share in the results of participations		
	Minority interest in group result	536	-8
		-446	-25
	Net result		
		4,419	2,418

Consolidated cash flow statement (in € x 1000)

	2005	2004
Cash flow from operating activities		
Operating result	5,063	2,622
Depreciation of tangible fixed assets	5,199	5,163
Depreciation of intangible fixed assets	7	205
Movement provision	4,247	6,359
Movement equity	-973	0
	13,543	14,349
Movement in working capital		
- Work in progress	-1,070	2,020
- Receivable and inventory	-5,124	-2,243
- Accounts payable	1,970	1,404
- Other liabilities	1,235	3,961
	-2,989	5,142
	10,554	19,491
Cash flow from operating activities		
Financial income and expenses	-381	89
Paid income tax related to operations	-353	-260
Result from participations	536	-8
	-198	-179
	10,356	19,312
Cash flow from investment activities		
Movements in financial fixed assets excl. participations	602	7,904
Movements in participations	-405	261
Movements in intangible fixed assets	19	-37
Investment in tangible fixed assets	-4,813	-4,824
Disposals of tangible fixed assets	1,069	79
	-3,528	3,383
Cash flow from financing activities		
Movements in long-term liabilities	0	0
Movements in Cash	6,828	22,695
Balance of cash at January 1	34,932	12,237
Balance of cash at December 31	41,760	34,932
Movement in cash	6,828	22,695

General

Unless indicated otherwise, all amounts stated in the annual report are x EUR 1,000. Stichting Energieonderzoek Centrum Nederland [Energy research Centre of the Netherlands] (ECN) has its registered office in Petten, municipality of Zijpe, the Netherlands.
As to the Stichting's objects, reference is made to Article 3 of the Articles of Association, which reads: 'The object of the Stichting is to gain knowledge and experience in the field of energy and to ensure that it is effectively made instrumental to the public interest and the various sub-interests to be distinguished therein.'

Activities

The activities of Stichting Energieonderzoek Centrum Nederland, with its registered office in Petten, the Netherlands, and its group companies consist primarily of:

a. conducting and commissioning fundamental, strategic and applied research and related studies in fields determined by the Stichting itself, or as instructed by the national government, lower government authorities, companies, including electricity companies, other organizations and individuals.
b. making accessible and transferring the results of research and studies as referred to under a., and supervising and providing support in the application of those results.
c. partnering with companies, included energy companies, and other research institutions in research and studies as referred to under a.
d. contributing to the coordination of research and studies in the Netherlands and to international collaborative efforts in this field.

Group structure

Stichting ECN heads a group of companies. Please see note 3 to the consolidated balance sheet for an overview of the data required on the basis of Book 2, Section 379 and 214 of the Dutch Civil Code.

Principles of consolidation

The consolidated financial statements of Stichting ECN include the financial statements of the group companies and other legal entities in which Stichting ECN has significant influence or which it manages on a unified basis. The consolidated financial statements were drawn up in accordance with the principles for the valuation and determination of result of Stichting ECN.
The financial statements of the group companies and other legal entities and companies included in the consolidation have been included in their entirety in the consolidated financial statements. All intercompany relationships and transactions have been eliminated. Minority interests in Stichting ECN's equity and in the results of group companies are reported separately in the consolidated financial statements.
The results of newly acquired group companies and the other legal entities and companies included in the consolidation are consolidated as from the date of acquisition. On that date, the assets, provisions and liabilities are valued at real values. The paid goodwill is capitalized and depreciated on its useful life. The results of divested participations are included in the consolidation until the date the group affiliation was terminated.
The consolidated financial statements comprise the financial statements of ECN, the group companies NRG vof, NRG Personeel vof, Wind Energy Facilities B.V. (WEF) and Sunlab BV, all having their registered office in Petten, municipality of Zijpe, the Netherlands. All intercompany claims, debts and transactions have been eliminated in the financial statements. ECN holds 100% of the shares in WEF BV and Sunlab BV and holds 70% in both NRG entities. The remaining 30% is held by KEMA.

General principles for the preparation of the consolidated financial statements

The consolidated financial statements were prepared in accordance with the provisions in Title 9, Book 2, of the Dutch Civil Code.
The valuation of assets and liabilities and the determination of the result are based on the historical cost convention. Assets and liabilities are recorded at face value, unless another basis is stated for the specific balance sheet item.
Income and expenditures are recognized in the year to which they relate. Profits are recognized only to the extent they were realized on the balance sheet date. Obligations and possible losses originating before the end of the year under review will be taken into account if they were identified before the financial statements were drawn up.

Financial system changes

ECN and NRG first applied RJ 271 in the 2005 financial statements. With regard to the regular pension plan, this first application did not lead to a movement in the opening equity at 1 January 2005, because on balance, a surplus of EUR 8.7 million was calculated. This surplus is the balance of the cash value of the pension rights and the real value of the fund investments. At the 2005 year-end, there was still a surplus of 1.5 million. The provision related to the functional redundancy plan (FLO) had already been calculated by the actuary, and has led to a charge of EUR 149 in the 2005 results. The provision for the anniversary disbursement was fixed at a deficit of EUR 1 million, as consolidated for ECN/NRG. Of this deficit, two-thirds has been allocated to ECN (single). On balance, EUR 1 million was accounted for in the equity at 1 January 2005. The final balance for the anniversary disbursement was also calculated at EUR 1 million. Accordingly, the effect of RJ 271 on the result for 2005 is nil.

Changes in the presentation

To facilitate comparison, the figures for the 2004 financial year have been modified in order to reconcile them with the presentation used for the 2005 financial year.

Translation of foreign currencies

Receivables, liabilities and obligations in foreign currencies are translated at the exchange rates prevailing at the balance sheet date. Transactions in foreign currencies during the year under review are recognized in the financial statements at the exchange rates prevailing at the transaction date. The exchange differences resulting from the translation as at the balance sheet date are taken to the statement of income, taking into account any hedge transactions.

Valuation principles of assets and liabilities

Intangible fixed assets

Intangible fixed assets are stated at the amount of the cost incurred, less the cumulative depreciations and, if applicable, impairments. The annual depreciations are calculated according to the straight-line method over a period of five years.

Tangible fixed assets

Tangible fixed assets are stated at the acquisition price, less cumulative depreciations and, if applicable, impairments. Depreciations are based on the estimated useful life and are calculated on the basis of a fixed percentage of the acquisition price, taking any residual value into account. Depreciation commences when the asset is first used. Land is not depreciated.

Depreciation is calculated according to the straight-line method, over the following periods:

- Buildings 20 years
- Temporary buildings and land facilities 10 years
- Installations and fixtures l0 years
- Instruments, machinery, etc. 5 years
- Computer equipment and software 3 years

The site was acquired in 1957 through a long-term lease from the Dutch Forestry Commission. In 1996, the term of the lease was extended from 2007 to 2032.

Financial fixed assets

The non-consolidated participations in which significant influence is exercised on the business and financial policies are valued at net asset value, but not lower than nil. The net asset value is calculated on the basis of the valuation principles of Stichting ECN.
Participations with negative net asset value are valued at nil. If the Stichting fully or partly guarantees the debts of the relevant participation, a provision will be created, primarily charged to the receivables against this participation and, for the rest, under the provisions in the amount of the share in the losses incurred by the participation, or for the payments expected from the Stichting for these participations.
Participations in which no significant influence was exercised on the business and financial policies are valued at acquisition price and, if applicable, with a deduction of impairments.
Capital interests of a durable nature, other than participations, are valued at the lower of cost or market value. The receivables from and loans to participations, as well as other receivables are included at face value with deduction of any provisions deemed necessary.

The securities included under the financial fixed assets are valued (per fund) at the lower of cost or market value as at the balance sheet date. The bonds are valued at the lower of cost or market value at the balance sheet date, with any premium or discount at the acquisition of bonds, divided across their terms, are either charged or added to the result.

Inventory and work in progress

Inventory of raw and ancillary materials and trade goods are valued at the average acquisition price, with deduction of provisions deemed necessary due to stock obsolescence.
Work in progress is valued at costs incurred, less the amounts already stated on the balance sheet date and losses already foreseeable on the balance sheet date. The costs incurred include the direct use of materials, the direct wage and machinery costs and other costs that can be attributed directly to the research project. The financing income attributable to the research project is determined on the basis of the costs incurred in connection with the work at the balance sheet date.

Receivables and prepaid expenses

Receivables are included at face value, less provisions deemed necessary in connection with the risk of bad debts. These provisions are determined on the basis of an individual assessment of the receivables.

Provisions

Provisions for pensions and other deferred remuneration: The provision for pensions is accounted for as an obligation pursuant to pension plan commitments. In this respect, pension rights have been granted depending on aspects such as age, years of service and salary. The obligations pursuant to contribution schemes are accounted for on the basis of actuarial calculations. The cash value of pension right commitments is determined according to the actuarial Projected Unit Credit Method.

Actuarial losses are charged and actuarial profits are added to the result if and insofar as the cumulative amount of the actuarial results at the start of the financial year, not yet included in the result, is more than the higher of 10% of the cash value of the rights granted and 10% of the real value of the fund investments.
These results are accounted for in the statement of income according to the straight-line method across the expected remaining years of service of the active participations in the respective plan.

Other deferred remuneration, including the FLO, transitional regulations for retirement and anniversary disbursements, are accounted for in accordance with the provision for pensions, provided that actuarial results are not included in the valuation of the provision for other deferred remuneration, but accounted for directly in the statement of income.

Other provisions:

- Provision for radioactive waste:
  This provision is intended for the costs of future treatment and storage of radioactive waste. This provision is determined at face value, included 5% interest in connection with alignment with future price levels.
- Major maintenance:
  The provision for the equal distribution of charges for major maintenance on buildings is determined on the basis of expected costs over a series of years. The provision is set up according to the straight-line method. The maintenance performed is charged to this provision.

Principles for determination of the result

Operating income

Operating income includes: income from services and products provided in the year under review, less the taxes levied on the turnover. Income from research projects is included in proportion to progress made. Costs incurred in connection with these research projects are allocated to the same period.

Taxes

Corporate income tax is calculated by applying the applicable rate to the result for the financial year, taking into account permanent differences between profit calculations according to the financial statements and those for tax purposes.

Share in the result of non-consolidated companies

The result of participations in which significant influence is exercised on the business and financial policies is stated as the share in the result of these participations to which the Stichting is entitled. This result is determined on the basis of the principles for valuation and determination of the result applicable at Stichting ECN.
In participations in which no significant influence is exercised on the business and financial policies, the dividend is regarded as result. It is included under financial income and expenses.

Principles for the preparation of the consolidated cash flow statement

The cash flow statement is prepared according to the indirect method. The cash in the cash flow statement consists of cash and cash equivalents.

Fixed assets

1 Intangible fixed assets

The acquisition of TNO-CSD by subsidiary NRG involved an agreement for goodwill in the amount of EUR 1,026, At WEF BV, the superficies for the "Transformator station" asset were capitalized.
Based on a tax insurance (transfer tax), the purchase value was adjusted downward in 2005.

Intangible fixed assets are specified as follows:

	Goodwill	Superficies	Total
Purchase price			
At 1 January 2005	1,026	37	1,063
Investments	0	0	0
Disposals	0	-19	-19
At 31 December 2005	1,026	18	1,044
Depreciation			
At 1 January 2003	-1,026	0	-1,026
Depreciation during FY	0	-7	-7
Disposals	0	0	0
At 31 December 2005	-1,026	-7	-1,033
Book value			
At 1 January 2005	0	37	37
Investments	0	0	0
Disposals	0	-19	-19
Depreciation during FY	0	-7	-7
At 31 December 2005	0	11	11

2 Tangible Fixed Assets

Tangible fixed assets are specified as follows:

	Buildings and land	Industrial installations and fixtures	Instruments and machinery	Fixed assets in progress	Total
Purchase value					
At 1 January 2005	41,530	41,948	42,458	991	126,927
Investments	660	459	2,281	1,413	4,813
Disposals	0	-599	-45	-700	-1,344
At 31 December 2005	42,190	41,808	44,694	1,704	130,396
Depreciation					
At 1 January 2005	-26,071	-34,809	-39,358	0	-100,238
Depreciation during FY	-1,630	-1,975	-1,594	0	-5,199
Disposals	28	210	37	0	275
At 31 December 2005	-27,673	-36,574	-40,915	0	-105,162
Book value					
At 1 January 2005	15,459	7,139	3,100	991	26,689
Investments	660	459	2,281	1,413	4,813
Disposals	28	-389	-8	-700	-1,069
Depreciation during FY	-1,630	-1,975	-1,594	0	-5,199
At 31 December 2005	14,517	5,234	3,779	1,704	25,234

3 Financial fixed assets

Participations (knowledge-based and other): total results

	2005	2004
Balance as at 1 January	568	829
· Debit: Sunlab (due to consolidation)	-161	0
· Credit: investments	0	32
· Debit: Disposals	-17	-285
· Credit: Results of participations	583	-8
Balance as at 31 December	973	568

Participations in knowledge-based organizations

	Address	ECN share at year-end	2005	2004
· ENATEC BV	*Zevenaar*	12,8%	0	0
· RGS BV	*Petten*	30,0%	480	10
· SWEAT BV	*Duiven*	33,3%	36	36
· SUNDYE BV	*Petten*	100,0%	16	18
· INDEC BV	*Petten*	36,5%	396	278
· ASTER INTELLECTUAL PROPERTIES BV	*Veessen*	20,0%	0	0
Total as at 31 December			928	342

Other participations

	Address	ECN share at year-end	2005	2004
· DNC Nuclear Technology BV	*Arnhem*	100,0%	18	18
· TIFAN BV	*Groningen*	0,0%	0	9
· ECN-INTERNATIONAL BV	*Petten*	100,0%	16	16
· ENERSEARCH AB	*Malmö*	12,5%	11	11
· SULPHCATCH BV	*Petten*	80,0%	0	11
· SUNLAB BV *	*Petten*	100,0%	0	161
· HYDRORING BV	*Wassenaar*	2,0%	0	0
Total as at 31 December			45	226

** SUNLAB BV was consolidated in 2005*

Securities

The movement of this portfolio is as follows:

	2005		2004	
Balance as at 1 January		26,730		29,259
· Debit: Sales	-7,799		-6,915	
· Credit: Purchases	6,583		4,049	
· Credit: Exchange differences	22		338	
		-1,194		-2,528
Balance as at 31 December		25,536		26,730

Bonds are pledged to the maximum value of the credit facility extended by ING Bank, in the amount of EUR 15,000. The other securities are at the free disposal of ECN.

Movement in securities portfolio according to type:

	Bonds	Shares	Total
Balance as at 1 January	21,907	4,823	26,730
· Debit: Sales	-4,509	-3,290	-7,799
· Credit: Purchases	2,750	3,833	6,583
· Credit: Exchange differences	22	0	22
Balance as at 31 December	20,170	5,366	25,536

Bonds

The face value of the bond portfolio is EUR 22,407 (2004: EUR 25,442). The market value at the 2005 year-end was EUR 21,143 (2004: EUR 23,328).

Shares

The market value of the share portfolio was EUR 6,114 at the 2005 year-end.

Other receivables

In 1992, ECN entered into an agreement with Tyco for the construction and operation of a facility for the production of Molybdenum. ECN built this facility and placed it at the disposal of Tyco for the Mo-project. Tyco uses the permit held by ECN. The total amount invested at the time was NLG 25 million. The term of the agreement is 20 years, commencing in 1996. Tyco pays its installments in the form of a lease.
The remaining outstanding receivable at the end of 2005 is EUR 7,415.

Current assets

4 Work in progress

	2005	2004
Recap:		
Work in progress	12,236	11,166
Provision for work in progress*	-3,116	-2,617
Balance as at 31 December	9,120	8,549

** This provision is included in the balance sheet as credit.*

5 Receivables and prepaid expenses

Receivables and prepaid expenses expire within one year and are specified as follows:

	2005	2004
Summary:		
Trade debtors	11,423	12,982
Receivables from participations	1,256	362
Other receivables	3,799	2,252
Balance as at 31 December	16,478	15,596

6 Cash

Cash is freely disposable, with the exception of the funds in the ING Escrow account (EUR 14,661), the ING 6th framework account (EUR 2,838) and the cash of the WEF (EUR 1,420). The characteristic feature of the Escrow account is that payment orders can only be effected subject to the approval of both parties involved, i.e. the Ministry of Economic Affairs and ECN. (See also: 'Contingent liabilities'). Based on supplementary provisions in the lease, the WEF created reservations by way of security.
The credit facility with ING amounts to EUR 15,000. A credit facility of EUR 4,338 is available at ABN AMRO.

The bonds have been pledged to the maximum value of the credit facility extended by ING Bank, in the amount of EUR 13,000. No security was provided at ABN AMRO.

7 Group equity

Reference is made to the notes on equity in the statutory financial statements.

Provisions

8 Provision for early retirement (FUT)

This provision is related to the introduction of the pre-retirement regulation effective July 1, 1999 and to the abolition of the former early retirement regulation.
As of January 1, 2006, there are no more obligations related to early retirement benefits in payment.

The provision comprises:

		2005		2004
Balance as at 1 January		9		350
· Debit: withdrawal	-9		-358	
· Debit: release	0		0	
· Credit: interest compensation	0		17	
		-9		-341
Balance as at 31 December		0		9

As in previous years, interest compensation was calculated at 5%.

9 Provision for redundancy costs

This provision is intended to cover costs as a result of staff redundancies ensuing from reorganizations. As in previous years, the annual interest compensation was based on 5%.

The movement of this provision is as follows:

		2005		2004
Balance as at 1 January		2,810		5,278
· Debit: withdrawal	-1,242		-2,726	
· Debit: release	-395		0	
· Credit: addition	300		0	
· Credit: interest compensation	117		258	
		-1,220		-2,468
Balance as at 31 December		1,590		2,810

10 Provision for transitional law related to pension regulation

This provision is based on transitional law providing for compensation of differences between the pension regulation dated July 1, 1999 compared to the former pension right. The term of this transitional law extends to 2018. In previous financial years, the costs pursuant to these pension rights were charged directly to operations. At the end of 2005, costs expected through 2018 pursuant to these rights were estimated at EUR 4,400. Within the framework of the transitional law, a provision was created to be used for the fixed payments to be made within the scope of the pension regulation.
The movement of this provision is as follows:

		2005		2004
Balance as at 1 January		4,617		2,936
· Debit: withdrawal	0		0	
· Debit: release	-448		0	
· Credit: addition	0		1,534	
· Credit: interest compensation	231		147	
		-217		1,681
Balance as at 31 December		4,400		4,617

No withdrawals were made from this provision in 2005 or in 2004.

Pension regulations granted

The primary pension regulations at ECN/NRG, the transitional pre-retirement regulation and the regulation for functional redundancy qualify as a granted pension regulations.
The pension regulation is still insured at Centraal Beheer Achmea.
The pension commitments have been fully funded with CBA (according to insurance standards).

Please refer to the table below with regard to the development of the pension provision in 2005:

	01-01-2005	31-12-2005
Fair value	280,000	283,154
Discounted commitments	-271,332	-281,640
Surplus	8,668	1,514

ECN and NRG jointly entered into the agreement with CBA. When the financial statements were being drawn up, there was insufficient insight into and disposal of the data to allow a separate calculation of the pension commitments for each of NRG and ECN. This applies equally to the development of the claims and the fund investments included in the pension RJ 271:321 provision in 2005. On balance, there is a surplus of EUR 8.7 million at the end of 2004, and of EUR 1.5 million at the end of 2003, and accordingly, a breakdown between ECN and NGR is less relevant. Since ECN/NRG do not have discretionary disposal of this potential asset, no receivable was included on the basis of RJ 271:321.

The main premises and assumptions upon which the determination of the claims granted and the investments are based, are:

	2005	2004
Discount rate	4,25%	4,50%
Inflation	2,00%	2,00%
Average increase in the pensionable salary	0,00%	0,00%
Indexation of pensioners and former participants	0,00%	0,00%
Expected yield on fund investments	4,75%	5,00%

The average increase of the pensionable salary has been set at 0%. This is a reflection of the developments in 2003, 2004 and 2005, when the pensionable salary did not increase either. In addition, the indexations of pensioners and former participants was assumed to be 0%, which is in fact what occurred over the past three years.

A pension liability of EUR 8.0 million is included under current liabilities; this was not included in the RJ 271 calculation, as it has been granted to staff.
The Board of Directors drew up a new pension regulation in March 2006. The pension regulation is based on a Defined Contribution regulation.
The Works Council is currently considering this new pension regulations.

11 Provision for functional redundancy (FLO)

Employees working in shifts can use the Functional Age Discharge regulation (FLO) as from the age of 57.5.

The movement of this provision is as follows:

		2005		2004
Balance as at 1 January		2,044		2,007
· Debit: withdrawal	-257	0	-407	0
· Credit: addition	435		340	
· Credit: interest compensation	95		104	
		273		37
Balance as at 31 December		2,317		2,044

12 Provision related to anniversary disbursement

This provision is intended for future anniversary disbursements. The development of the provision for other deferred remuneration in 2005 and 2004 is as follows:

		2005		2004
Balance as at 1 January		0		0
· Debit: withdrawal	0		0	
· Credit: Correction of starting capital (Change of system)	1,014		0	
· Credit: interest compensation	0		0	
		1,014		0
Balance as at 31 December		1,014		0

13 Provision for radioactive waste

This provision is intended for the costs of future treatment and storage of radioactive waste.

The movement of this provision is as follows:

		2005		2004
Balance as at 1 January		52,756		45,182
· Debit: withdrawal	-1,344		-754	
· Credit: addition	260		5,908	
· Credit: interest compensation	2,644		2,420	
		1,560		7,574
Balance as at 31 December		54,316		52,756

14 Provision for Work in Progress and other provisions

The provisions for 'Building Maintenance', Lead Cells' and 'DWT sludge storage' have been included under other provisions. In addition, there is a separate provision to correct work in progress, to cover any risk of a cost overrun in current projects.

	WIP 2005	Mainte-nance buildings	Lead cells	Storage sludge DWT	Total other 2005
Balance as at 1 January	2,617	1,031	545	486	2,062
· Debit: withdrawal	-247	-1,033	0	0	-1,033
· Credit: addition	746	3,373	0	7	3,380
· Credit: interest compensation	0	0	0	0	0
Balance as at 31 December	3,116	3,371	545	493	4,409

Building Maintenance Provision

The "building maintenance" provision serves to equalize the costs of building maintenance works based on an LTO maintenance scheme over the years. In the past few years, a backlog has occurred in this maintenance scheme. An additional contribution was made on the basis of the investigation performed by DHV/TEMID.

15 Current liabilities

Current liabilities are specified as follows:

	2005	2004
1. Deferred income from third parties	15,281	17,846
2. Accounts payable related to deliveries and services from third parties	9,746	7,776
3. Taxation		
- Corporate income tax	353	260
- Turnover tax	264	222
- Wage tax	1,454	1,541
4. Other social security charges and personnel		
- Pension charges	11,390	6,496
- Reservation for holiday allowance and leave balances	5,447	4,847
- Other personnel charges	1,217	4,071
5. Other liabilities and accrued expenses		
- Payable to co-contracting parties in projects	3,092	2,078
- Deferred payments related to the storage of uranium filters	973	1,400
- Other liabilities	2,643	2,118
Balance as at 31 December	51,860	48,655

Current liabilities are deemed to be settled within a single financial year.

Rights and Obligations not apparent from the balance sheet

Rights

InDEC BV

ECN has a put-option on its remaining shares in InDEC BV that is worth approximately EUR 3,500, to be exercised no later than December 31, 2006 through the sale of the shares in question.

Obligations

a) The site was acquired in 1957 through a long-term lease from the Dutch Forestry Commission. b) In 1996, the term of the lease was extended from 2007 to 2032. The annual ground rent was set at EUR 194 in 2003.

b) During the financial year 2003, ECN Windturbine Testpart Wieringermeer CV, wholly-owned by Wind Energy Facilities BV, itself a wholly-owned subsidiary of ECN, entered into a sale and lease-back agreement to finance a wind turbine testing field in which large wind turbines will be tested for offshore locations. The ensuing lease obligation is EUR 1,632 per year, in the period 2004 to 2012.

c) Specification of contractual obligations undertaken:

Description	< 1 year	>1year <5year	> 5 year
Rent for Arnhem M01 and M05	420	0	0
Rent for Arnhem B48	117	468	0
Car leases	131	217	0
NIB lease obligation (WEF BV)	1,632	6,528	6,528
Nashuatec	166	664	83
Asito	393	393	0
Pre Ned Beveiliging	640	0	0
	3,499	8,270	6,611

d) In the financial year 2003, several former ECN employees filed a claim related to the indexation of pensions. This claim was submitted to the Alkmaar District Court. The Board of ECN disputes the validity of the claim and accordingly, did not include a provision. In 2003, the Court dismissed this claim on procedural

grounds.
An interlocutory judgment was rendered in the proceedings instituted by the OMEN ['oude medewerkers van ECN en NRG', or 'former employees of ECN and NRG'] association on 16 February 2006. In that judgment, the Court held that the pension regulation contains an unconditional indexation commitment.
ECN was given an opportunity to explain in more detail why complying with this commitment could lead to continuity problems for ECN. (It is estimated that, in the event this commitment is complied with for the years 2003, 2004 and 2005, approximately EUR 11.4 million will have to be paid).
The Court indicated that it might appoint an expert. As a result, it is unclear when a decision can be expected. If an expert is appointed, the decision will take several months at the least.

e) The Tax Authorities in Alkmaar informed ECN by letter that the allegations will be followed up, and that it wishes to conduct a further investigation of the extent to which ECN satisfies the concept 'entrepreneur' in the sense of the Turnover Tax Act. It has been indicated that as from 2004, ECN itself is responsible for assessing whether activities in the context of the dispute referred to here are covered by the VAT system or not.

Bank guarantees

On the balance sheet date, ECN itself provided bank guarantees for an aggregate amount of EUR 1,106 (EUR 460 ING Bank, EUR 646 ABN).

ING Escrow bank account

Over the course of 2004, ECN received an amount in excess of EUR 14.4 million from the Ministry of Economic Affairs (which had risen to EUR 14.6 million at the end of 2005), intended for the payment for work related to clearing up radioactive waste.
In the event ECN is unable, for any reason whatsoever, to perform that work itself or to have it performed under its supervision, it is obliged to repay the remaining amount to the Ministry of Economic Affairs. Effecting payments to the debit of this earmarked Escrow account is only possible if payment orders have been signed by both parties (Ministry of Economic Affairs and ECN).

Environmental case

On 25 March 2005, the Arnhem District Court ordered ECN and NRG to each pay a penalty of EUR 25,000 due to violation of environmental regulations. Both the Public Prosecutions Department and ECN and NRG lodged an appeal against the judgment of the District Court. When this annual report was published, it was unknown when the appeal will be heard.

Transactions with affiliated parties

During the financial year, transactions were effected between affiliated parties, namely between ECN and NRG, for a total of: ? 9.174
Transactions primarily related to charging-on the joint use of infrastructure (EUR 5,800), services from the TS&C unit pursuant to orders placed directly (EUR 1,100), share in corporate staff services (EUR 1,174), and the share in project provisions (EUR 1,100).

- between ECN and WEF BV and Sunlab BV for a total value of EUR 897. Transactions between ECN and WEF are related primarily to the engagement costs for the management of WEF and ECN.

Transactions between ECN and Sunlab primarily concern the charging-on of costs for the joint used of infrastructure.
Costs are charged on at generally prevailing rates for the internal allocation of costs within ECN.

At the end of the financial year, the following total of mutual receivables and debts remained:
- at total of EUR 6,263 between ECN and NRG. 6.263.
- a total of EUR 1,610 between ECN and WEF BV and Sunlab BV.

Notes to the consolidated statement of income

Operating income

Income

16 Basic, ENGINE and Cooperative funding

	2005	2004
- Basic and ENGINE funding	17,533	16,930
- Cooperative funding	19,389	17,373
Totaal	36,922	34,303

ECN receives an annual subsidy from the Ministry of Economic Affairs for research activities.
As from 2004, the environmental program is no longer funded by the Ministry of Economic Affairs, but by the Ministry of Housing, Spatial Planning and the Environment.
Both subsidies are reported in their entirety as operating income.

17 Third-party Income

		2005		2004
Third-party assignments		57,548		60,964
Increase / decrease in work in progress	833		-1,323	
Provision for WIP	3,116		2,617	
		3,949		1,294
Total		61,497		62,258

Specification of third-party assignments, including increase / decrease of work in progress, by client:

	2005	2004
Domestic trade and industry sector	23,099	23,508
Domestic energy sector	1,981	3,220
European Commission	10,941	11,973
Foreign trade and industry sector	12,858	9,857
Government agencies	2,720	2,821
Technological institutes	1,438	1,546
Senter Novem etc.	8,460	9,333
Total	61,497	62,258

18 Capitalized corporate production

Capitalized corporate production involves operating expenses incurred through work carried out by the company's own staff and with its own assets, which can be allocated to investments or provisions.

	2005	2004
Movable assets	443	416
Immovable assets	473	716
Radioactive waste	962	462
RI&E en BIM	0	1
Major maintenance and other provisions	310	343
	2,188	1,938

19 Other operating income

Reported under 'other operating income' are the proceeds from licenses (EUR 365) and the proceedings from the lease with the Molybdenum facility (EUR 1,524). The latter item progresses parallel with the depreciation on the facility according to ECN's system. The difference between what was charged to Tyco based on an annuities calculation (EUR 1,153) and the depreciation determined according to the straight-line method (EUR 1,036), has been included under financial fixed assets, as are the proceeds from WEF BV (total EUR 4,368), including the proceeds related to the lease of prototypes (EUR 512) and the re-supply of energy to the public grid of Eneco and Enerq (EUR 3,610).
3,610).. And finally, proceeds from the sale of movable property, EUR 5.

Operating expenses

20 Wages and salaries, social security and pension charges

		2005		2004
1. Permanent contract of service	38,676		38,529	
2. Other personnel charges	9,244		8,078	
		47,920		46,607
3. Social security contributions		3,277		3,800
4. Pension charges		8,108		13,697
		59,305		64,104

Employees:

Average number of employees (FTEs):	2005	2004
- Permanent contract of service	756.4	762.1
- Temporary contract of service (including promovendi)	60.8	70.6
Financial year total average	817.2	832.7

Note: The figures reported above do not include employees working through staffing agencies.

21 Depreciation tangible fixed assets

This item is specified as follows:

	2005	2004
- Buildings, installations, fixtures and land facilities	3,605	3,395
- Instruments and other inventory	1,594	1,768
Total	5,199	5,163

22 Other operating expenses

This comprises:

	2005	2004
- Projects	19,580	18,160
- Cost centers	12,336	10,861
- Staffing agency workers and seconded employees	1,933	1,869
- Addition and release provision doubtful debts	-39	306
- Addition provision maintenance of buildings	3,224	1,227
- Addition provision for radioactive waste	260	-2,245
	37,294	30,178

23 Financial income and expenses

	2005	2004
- Interest and similar income	2,823	3,062
- Interest and similar expenses	-3,204	-2,973
	-381	89

Interest income

	2005	2004
Interest compensation bonds	778	1,002
Interest compensation current account/giro	562	430
Result on the sale of bonds	415	353
Other interest income	1,068	1,277
	2,823	3,062

Interest expenses

	2005	2004
Interest compensation current account/giro	0	358
Addition of interest provision for redundancy costs	117	240
Addition of interest provision for radioactive waste	2,644	1,963
Addition of interest provision for early retirement (FUT)	0	13
Addition of interest provision for functional redundancy (FLO)	95	99
Addition transitional retirement regulation	231	147
Other interest expenses	117	153
	3,204	2,973

24 Taxes

The nominal tax rate was 31.5% in 2005 (2004: 34.5%). The effective tax rate is 7.5%. The difference between the nominal and effective tax burden arises because Stichting ECN is exempt from corporate income tax. The tax burden included concerns the activities of ECN Wind Energy Facilities BV and Sunlab BV.

Statutory balance sheet of ECN as at 31 December (in € x 1000)

Assets	2005	2004
Fixed assets		
Tangible fixed assets	22,164	24,590
Financial fixed assets		
25 · Participations in group companies	5,378	3,738
· Other participations	955	550
· Securities	25,536	26,730
· Other receivables	7,415	6,823
	61,448	62,431
Current assets		
Work in progress	8,297	8,452
Receivables from group companies	1,673	1,790
Receivables from other participations	1,256	362
Trade debtors	5,058	5,264
Inventory	232	225
Other receivables	2,747	1,621
	19,263	17,714
Cash at bank and in hand		
Delta Lloyd Bank	7	7
ING/Postbank	34,745	16,506
ABN/AMRO	0	188
	34,752	16,701
Total	115,463	96,846

Liabilities	2005	2004
26 **Equity**		
Foundation capital	45	45
Legal reserves	875	0
Other reserves	4,418	3,789
Result for the year	4,419	2,418
	9,757	6,252
Provisions		
Provision for early retirement (FUT)	0	9
Provision for redundancy	1,590	2,810
Provision for radioactive waste	52,182	50,977
Provision for transitional retirement regulation	4,400	4,617
Provision for FLO	825	766
Provision for anniversary disbursement	681	0
Provision for work in progress	607	854
Other provisions	3,371	1,031
	63,656	61,064
Current liabilities		
Accounts payable	5,676	4,714
Debts to group companies	494	491
Debts to other participations	621	62
Taxation	1,115	889
Deferred income from third parties	9,175	11,352
Pension liabilities	7,661	3,261
Other social security charges and personnel costs	4,740	7,084
Other liabilities and accrued expenses	3,077	1,677
	32,559	29,530
Debts to credit institutions		
ABN/AMRO	9,491	0
Total	115,463	96,846

ECN statutory statement of income

Operating income:	2005	2004
Income		
· Basic, ENGINE and Cooperative funding by the state of the Netherlands	27,978	25,449
· Assignments and other funding	27,297	29,689
· Increase/decrease of work in progress	-155	-1,365
· Income at group companies	8,545	7,991
	35,687	36,315
	63,665	61,764
Capitalized statutory production	1,908	1,844
Other operating income	1,892	1,347
Total operating income	67,465	64,955
Operating expenses:		
Personnel costs: Wages	31,100	30,741
Social security contributions	2,337	2,073
Pension charges	5,381	9,176
Depreciation	4,564	4,645
Other operating expenses	20,812	16,618
Outsourcing to group companies	1,538	702
Total operating expenses	65,732	63,955
Operating income	1,733	1,000
Financial income and expenses	-689	-146
Profit on ordinary operations before taxation	1,044	854
Taxation on result from ordinary operations	0	0
Profit on ordinary operations after taxation	1,044	854
Result from participations	3,375	1,564
Net result	4,419	2,418

Notes to ECN's statutory financial statements:

The statutory financial statements were prepared in accordance with the provisions in Title 9, Book 2, of the Dutch Civil Code.

General principles for the preparation of the financial statements

For the general principles for the preparation of the financial statements, the principles for the valuation of assets and liabilities and determination of the result, as well as for the notes to the specific assets and liabilities the results, reference is made to the notes to the consolidated financial statements, if not stated otherwise hereinafter.

25 Participations in group companies

Changes in participations are as follows:

	2005	2004
Balance as at 1 January	3,738	3,114
· Debit: correction of NRG's equity due to anniversary disbursement	-233	0
· Debit :license fee received	-977	-948
· Credit: NRG participation result	2,047	1,036
· Credit: WEF BV participation result	656	536
· Credit: Sunlab BV (contribution due to consolidation)*	161	0
· Debit :Sunlab dividends received	-50	0
· Credit: Sunlab BV participations result	36	0
Balance as at 31 December	5,378	3,738

**Sunlab BV was not included in the consolidation in 2004*

Minority interest in group result

In accordance with the joint venture agreement with the KEMA, the results of NRG are first reduced by the Danish Fee invoiced and indexed by NRG (on behalf of the ECN) (1996=100) in the amount of EUR 771* (1.03)0=EUR 1,007 (2004: EUR 977). This is followed by the agreed allocation of the remainder on the basis of KEMA 30% and ECN 70%.

Rights and Obligations not apparent from the balance sheet

a) Stichting ECN, as a partner of the general partnership (NRG and WTW), is jointly and severally liable for the debts of this general partnership.

b) ECN and NRG perform work for each other. These transactions have been eliminated in the consolidated statements. It was agreed with NRG that, if necessary to shore up its equity and possibly improve the liquidity, it can call upon the extension of credit that will be provided in the form one or more subordinated loans by the partners for a maximum amount of EUR 2,813.

Other information and signing of the financial statements

Remuneration for (former) directors and Supervisory Board members

In 2005, EUR 319 (2004: ER 311) was debited to the Stichting and its group companies for the remuneration of directors of the Stichting. In 2005, EUR 49 (2004: EUR 48) was debited to the Stichting and its group companies for the remuneration of Supervisory Board members of the legal entity.

26 Equity

	Foundation Capital	Statutory reserve	Other reserves	Profit Realized	Total Equity
Balance as at 1 January 2004	45	0	2,600	1,189	3,834
Allocation of the 2003 result			1,189	-1,189	0
Result after taxation 2004				2,418	2,418
Balance as at 31 December 2004	45	0	3,789	2,418	6,252
Correction of starting capital (anniv. disbursement)			-914		-914
Balance as at 1 January 2005 after correction	45	0	2,875	2,418	5,338
Allocation of the 2004 result			2,418	-2,418	0
Breakdown of statutory reserve participations		875	-875		0
Result after taxation 2003				4,419	4,419
Balance as at 31 December 2005	45	875	4,418	4,419	9,757

The statutory reserve concerns a reserve for 'retained profit participations'

Signing of the financial statements

Petten, the Netherlands, 21 March 2006

Dr. R.F.M. Lubbers
Chairman of the Supervisory Board

Dr. A.B.M. Hoff
Chairman of the Board of Directors of ECN

Other Information

Auditor's Report

In this regard, please see the auditor's report included below.

Provisions in the Articles of Association regarding the appropriation of the result

Article 15 of the Stichting's Articles of Association state as follows regarding the appropriation of the result:
'The Minister of Economic Affairs, also in consultation with the Minister of Education, Culture and Science, will appropriate any positive liquidation balance in accordance with the Stichting's objects as much as possible.

Appropriation of the result for the 2005 financial year

The 2005 financial statements were adopted by the Supervisory Board on 21 March 2006. The Supervisory Board determined the appropriation of the result in accordance with the relevant proposal.

Proposal for the appropriation of the result for the 2005 financial year

The Board of Directors proposes to the Supervisory Board that the result for the financial year in the amount of EUR 4,419 be added in its entirety to the other reserves.
This proposal has not yet been incorporated in the financial statements.

Post balance sheet date events

There have been no exceptional events after the balance sheet date.

Auditor's Report

Introduction

We have audited the financial statements for 2005 of Stichting Energieonderzoek Centrum Nederland, Petten, the Netherlands, included in this report on pages 69 through 80. The financial statements are the responsibility of the foundation's management. Our responsibility is to express an opinion on these financial statements based on our audit.

Scope

We conducted our audit in accordance with auditing standards generally accepted in the Netherlands. Those standards require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by the management of the Foundation, as well as evaluating the overall presentation of the financial statements. We believe that our audit provides a reasonable basis for our opinion.

Opinion

In our opinion, the financial statements give a true and fair view of the financial position of the foundation as at 31 December 2005 and of the result for the year then ended in accordance with accounting principles generally accepted in the Netherlands and comply with the financial reporting requirements included in Part 9 of Book 2 of the Netherlands Civil Code.
Furthermore we have, insofar as we are able to determine, verified that the management report is consistent with the financial statements.

Amsterdam, 21 March 2006

Deloitte Accountants B.V.

P.J. Bommel

Colophon

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