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Presenting the (economic) value of patents nominated for the European Inventor Award 2012

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1. The invention

1.1 Historic account

The invention in this nomination is the NEREDA process for treating and purifying wastewater. The process uses aerobic bacteria which clump together in wastewater as granules and remove pollutants. The technology has considerable advantages over other wastewater treatment options and is already in commercial application.

The first viable roots of the invention can be traced back to the late 1960s. At that time, Prof. Lettinga from Wageninigen University (NL) observed bacterial sludge granules in anaerobic (without oxygen) water purification at an industrial wastewater facility. Because such granular sludge sinks more rapidly, the idea was borne that it might be possible to speed up water purification. The ensuing technology based on anaerobic sludge was successfully commercialised in the 1980s und 1990s. It removed organic pollution from wastewater and created biogas as by-product. However, nitrogen compounds and phosphates were left behind, the treated effluent quality did not meet the modern European discharge limits and the process was not very effective at low temperatures. Hence, for extensive treatment of municipal and industrial wastewater, another technology was envisaged in which bacteria under aerobic conditions (with oxygen) purifies the wastewater. This aerobic treatment is based on flocculent growth and having it also based on granular sludge would bring great advantages. Hence, the search was on for finding the conditions leading to granular sludge formation in the presence of oxygen.[1]

In 1988, Mark van Loosdrecht became associate professor at Delft University of Technology. Prof. van Loosdrecht obtained his MSc three years earlier and his PhD in 1988 at Wageningen University on 'Microbial Adhesion'. In Delft he worked initially on a compact wastewater reactor called 'CIRCOX airlift reactor', a reactor type developed primarily by a colleague in Delft, Prof. Heijnen. The reactor already used small particles and aerobic bacteria. It showed already many of the advantages of the later-to-come NEREDA technology, such as the possibility to integrate an efficient reactor on a site where space is limited. Prof. van Loodrecht recounts:

> *"The CIRCOX technology works well for industrial waste water but not for municipal wastewater. Municipal wastewater is particularly challenging, because the flow rates can differ to a large extent – for example between day and night, depending on the time people tend to use the sewage systems -, and also for other reasons.[2] The question was: How could we implement and/or adapt a process such as CIRCOX for municipal wastewater?"*

The problem was posed at a time when researchers, independent of the discussion on wastewater treatment, discussed the phenomenon and the conditions under which bacteria start to form clumps in water. Some scientists believed that this is due to some voluntary self-organisation process. Prof. van Loosdrecht, by contrast, thought that the bacteria clump together because certain conditions leave them no other

[1] http://home.tudelft.nl/en/current/university-magazines/delft-outlook/former-editions/2011/2011-3/achtergrond/purely-based-on-character/

[2] For example, municipal wastewater contains a broader spectrum of contaminants because wastewater from different sources is mixed. Moreover municipal treatment plants have to treat all the rainwater flushing pollution from e.g. the streets in cities. Municipal wastewater is also more diluted which is in particular a challenge for traditional biological wastewater treatment options because of the lower availability of biomass for a given volume of wastewater. This means, for example, that such wastewater plants need larger areas/footprints for operation (see Iaconi et al. (2007): Aerobic Granular Sludge Systems: The New Generation of Wastewater, in: Ind. Eng. Chem. Res. 2007, 46, 6661-6665).

choice. Eventually, through investigating the morphology why bacteria grow and adopt a crystallisation-like process, Prof. van Loosdrecht was able to predict when bacteria start to grow in clumps and form granules. This process proved Prof. van Loosdrecht´s hypothesis and became the basis of the NEREDA technology.

However, there were still many obstacles to overcome: The firm with which the university collaborated on the CIRCOX reactor was only mildly interested, as they had already a proven technology at hand and were not looking for a possibly competing solution. Other firms approached did not believe that Prof. van Loosdrecht´s idea would be doable on a commercial scale. The general belief was that the whole thing was little more than just an idea. Overcoming these hurdles proved to be a tedious process.

A project funded by a research grant by the science foundation NWO was necessary to demonstrate in a more thorough manner that such a plant could be built in principle. However, initial calculations showed that a plant operating on the new process would hardly be cost effective. Rescue came in the form of a French firm, which showed great interest in the new technology. A first pilot plant was built in Paris and used to tweak the technology - and, eventually, to show that granules could be formed in real municipal wastewater. Eventually, the economic operating figures improved. The plant proved that aerobic sludge granules could be used with less than the initially anticipated costs for wastewater treatment. The drawback came when internal management decisions at the French firm resulted in a strategic re-orientation, which left no space for the wastewater treatment technology. The French firm stopped the project.

By that time the technology was nonetheless so advanced, that in 1999 the Dutch waterboards through STOWA (the research foundation from the Dutch waterboards) and consultancy firm DHV became interested. Prof. van Loosdrecht convinced STOWA to finance DHV to make a technological and economic evaluation study as well as to support the research at TU Delft. This study showed that the costs for setting up and running a NEREDA-based plant could be further reduced. The decision was taken to build a new pilot plant in Ede (not Epe!) in the Netherlands. The Ede plant went operational in 2003.

Supported by grants from the Dutch STW technology foundation (a funding agency for applied research) and funds from STOWA, a number of issues were tackled in the transition from laboratory to a real-life environment.[3] Under real life conditions, for example, pump capacity is limited and oxygen levels can never be as high as in a laboratory setting. For quite some time, it was not possible to demonstrate growth of granules. Once growth was finally observed, the whole project was put on the line when, concurrently, a computer for monitoring data was stolen and a technical glitch had the already grown granules washed away. Merle de Kreuk was tasked in her PhD thesis to improve the process to also remove nitrogen and phosphate compounds. For her achievements and for her role in pushing the development of NEREDA as a linchpin between the university and DHV, she obtained the Simon Stevin Fellow (for the best Dutch engineering PhD thesis in NI) in 2007.

At the end of the running time of the Ede pilot plant in 2005, there was enough technical know-how to further scale up the plants to a commercial level, and DHV constructed a first smaller plant for a cheese specialities industry in the Netherlands and in 2006 another for a convenient food producer. DHV wanted to brand the new process, and with NEREDA – the name of a Greek water nymph – a respective trademark was created. For the purpose of further scaling-up for municipal applications, DHV, Delft University of Technology, STOWA and six Dutch waterboards signed a collaboration agreement called ‘National NEREDA Research

[3] http://home.tudelft.nl/en/current/university-magazines/delft-outlook/former-editions/2011/2011-3/achtergrond/purely-based-on-character/

Program' (NNOP in the Dutch abbreviation). Amongst others, this agreement defined in detail the roles of each partner: the university, which was to tackle basic/applied research topics; DHV, which was tasked with the technical implementation; and the waterboards, which acted as 'intelligent pilot customers'. The NNOP, supported by various national innovation funds of the Ministry of Economic Affairs, Agriculture and Innovation, runs until the end of 2012 and involves the construction of a number of full scale purification plants.

Again, a new demonstration plant had to be built, now at municipal level to verify the developed scale-up. In the Netherlands, this proved difficult at that time, but through DHV's global network, links were established to the South African branch of DHV, and, eventually, the full-scale demonstration plant was set up in South Africa. Aided also by the successful operation of a total of three smaller-scale plants for industrial wastewater treatment based on the NEREDA process, the NEREDA technology eventually evolved into larger municipal applications. The first true full-scale plant for municipal wastewater treatment became fully operational in the municipality of Epe in January 2012 in the Netherlands, followed shortly by other projects (see also section 2.2).

1.2 Technological features[4]

Treating wastewater with the NEREDA process is done in several steps. At first the reactor needs to be readied for operation. For this purpose, sludge flocs are added to a quantity of wastewater in a single reactor tank. The sludge flocs feed on the wastewater and form granules. Only granules that clump together to form compact, heavy granules are allowed to remain. Depending on wastewater characteristics this transformation process takes typically two to four months. In future new plants this process is much faster (time needed: a few weeks) by inoculation with granular sludge from an existing nearby Nereda plant.

In actual operation, and as in other traditional wastewater facilities, incoming wastewater needs to undergo some pre-treatment first. A screening filter with holes of around 2-3 mm removes any non-dissolved substances, such as plastic and wood. The water is then also cleared of sand and, if necessary, also from grease and fat.

After pre-treatment, the wastewater enters the actual NEREDA process:

- *Step 1:* The NEREDA reactor is filled with wastewater from below. The granules remain at the bottom while rising wastewater propels the clean water out of the reactor. The key is adding the dirty wastewater in equal amounts without creating turbulence, as this would cause the dirty water to mix with the clear water. The purified water flows away through a network of drainage gutters at the top of the reactor. In each purification cycle, 25% to 50% of the contents of the reactor are exchanged. This cycle lasts typically thirty minutes to one hour.
- *Step 2*: Aeration plates at the bottom of the tanks are used to add oxygen to the water. The sludge granules mix throughout the whole reactor tank. The bacteria in the granules break down the pollution in the water. There are compressors used for adding the air, which account for most of the energy consumption in the purification plant. This step takes about 110 minutes.
- *Step 3*: Aeration is stopped and the relatively heavy granules sink rapidly to the bottom. This step lasts around 10 minutes. The process is repeated from step 1.

[4] This section is based in large parts on the description in a university newspaper articles oft he Delft University of Technology entitled ‚Purely based on character' (http://home.tudelft.nl/en/current/university-magazines/delft-outlook/former-editions/2011/2011-3/achtergrond/purely-based-on-character/). This text includes also a coloured three-dimensional schematic of the EPE power plant useful for illustrative purposes, which has not been pasted into this text.

Several cleaning cycles can be foreseen. Eventually, after leaving the NEREDA process, the water may undergo a final treatment step called sand filtration if outstanding water quality criteria have to be met. This step removes, amongst others, remaining dust and residual phosphate and nitrogen.

The NEREDA technology offers a number of advantages over competing technologies:

- 75% reduction in surface area: The sludge granules are superior to the previously used flocculent sludge, as they sink far more rapidly (50 meters per hour) than sludge flocs (one meter per hour). This enables the separation of the granular sludge and the purified wastewater to occur in the reactor tank itself. There is no need for large sedimentation tanks. Furthermore, the concentration of bacteria in granules is higher than in flocs, which means that pollution is removed more effectively. Together, these advantages translate into the need for only a single and rather small reactor tank, which in turn means that there is much less space needed for a NEREDA plant at a certain capacity than for a plant with a competing technology. The amount of space saved is 75% compared to traditional designs and, under real operational conditions, in the order of several ha of land.
- *Significant reduction in energy consumption*: The use of a single reactor tank translates also into a less mechanically complicated design of the tank because less water needs to be pumped and mixed. Not using mixers and various internal circulation flow saves at least 20% of energy.
- *Higher performance and purer water*: The NEREDA process allows for a better quality of the purified water compared to conventional technologies. Batchwise operation yields already low nitrogen (5 mgN/l compared to 10 mgN/l conventionally) and phosphate levels (0.2 mgP/L compared to 1 mgP/l conventionally) in the treated water. Further optimisation will decrease these numbers further. This makes the system fit for the strict new effluent criteria set in the EU water framework Directive.
- *Significant reduction in construction and operation costs*: The simpler mechanical single reactor design and much smaller reactor volumes translates also into significantly lower cost for setting up a NEREDA plant. Furthermore, there is the possibility to convert/retrofit the plant to work also with traditional technologies, which means that there is also a buffer to reduce risk for the implementing the first plants to the waterboard and construction firms. Along the same line, existing treatment facilities can be retrofitted into NEREDA systems leading to reduced costs or higher treatment capacities if wastewater flows are increasing over time or environmental regulations become stricter.

2. The market

2.1 Overall market prospects

There are a number of market research reports dealing with market developments in wastewater treatment. Despite methodological differences and different projected figures (and the fact that many figures and parts of the analyses are not in the public domain), a picture emerges which shows that municipal wastewater treatment is a large and growing market. Two important growth factors are tightening government regulations and the need to replace old facilities (according to Prof. van Loosdrecht, a wastewater treatment plants needs to be renewed about every 20 years):

- A recent report by Lux Research[5] asserts that the global market for advanced municipal wastewater treatment is US$ 27.5 billion in 2012, US$ 22.3 billion of which is in the developed world and US$ 5.2 billion in developing countries. 94% of the purification plants are old facilities that need replacement, which highlights an important growth factor for the wastewater industry: *"Urban replacement represents more than 55% of the potential market, and more than half of that is in accessible markets in the developing world. Overall, replacement projects constitute more than 85% of all projects, with only 15% going toward building of new capacities."* In terms of geographical spread, the report asserts that the top national markets divide equally between the developed and developing world — the U.S. and China are the largest, followed by Japan, Brazil, Germany, and India. The available information hints at a large variety of technologies employed for different requirements in the field. There are a number of firms active, from small-specialised players in niche markets to large players such as Veolia, GE and Siemens.
- According to a 2006 Frost & Sullivan report *"...the total European municipal water and wastewater treatment market is very promising with a compound annual growth rate of 4.1 % per year to reach an estimated $ 3.09 billion in 2010. Europe represents around one-third of the world's environmental market and is driven by the European Union (EU) environmental regulations that are among the toughest in the world. The demand for wastewater treatment plants to comply with the Urban Waste Water Treatment Directive has been the prime driver behind revenue growth and is expected to be so for several years to come. The EU is offering $4.2 billion every year in cohesion funds to new members to help them achieve EU environmental standards. The most significant sector in terms of revenues is biological treatment equipment, comprising all the various equipment types for both aerobic and anaerobic treatment systems. The market is at the exploitation stage of its lifecycle, with good growth anticipated in the future years."*[6]

The typical customers for wastewater plants are public water boards, which, according to interviewed experts, are very conservative customers (i.e., looking for proven solutions). Against this backdrop, the rapid adaptation of new NEREDA plants can be considered a particular success and proof of performance.

2.2 The business behind NEREDA

The patented and trademarked technology has been in commercialisation since around 2006. For industrial wastewater, there have been, as indicated, a number of installations since 2006. For municipal wastewater, pilot and demonstration plants have been set up in particular in Portugal and South Africa under public-private partnership agreements. The first full-scale commercial municipal wastewater treatment plant is the aforementioned Epe plant that came online late in 2011 and was fully operational in January, 2012. It is set up in collaboration with the Veluwe Water Board and serves a population of around 60,000. The plant has a project volume of around € 15 million[7] and replaces the old Epe wastewater treatment facility. To follow are wastewater treatment facilities at Dinxperlo (project volume: € 8 million)[8] and

[5] http://www.businesswire.com/news/home/20120209005072/en/Advanced-Municipal-Wastewater-Treatment-Market-Offers-27.8, corrected figure of US$ 27.5 billion after enquiry with Lux Research

[6] Frost & Sullivan (2006): Biological Wastewater Treatment: Still Playing the Key Role in the European Pollution Fight, http://www.frost.com/prod/servlet/market-insight-top.pag?docid=73345430

[7] http://www.waterworld.com/index/display/article-display/4677242136/articles/waterworld/world-regions/europe/2010/06/Sustainable-wastewater-treatment-plant-planned-in-Netherlands.html

[8] http://www.dutchwatersector.com/news/news/2011/12/wwtp-dinxperlo-turned-into-public-water-garden-with-latest-nereda-water-treatment-technology/

Vroomshop (also around € 8 million)[9] in the Netherlands. A further plant is now being built in South Africa at Stellenbosch. The total current pipeline of DHV projects is 20 projects for both municipal and industrial wastewater treatment facilities around the world. And some of them are much bigger than the Epe plant.

The full-scale commercial application of the NEREDA process is a service of the Dutch engineering services firm DHV. DHV currently has around 4,500 employees worldwide and is active in a variety of domains.[10] The water technology market is a traditional stronghold of DHV. Against this backdrop, and according to Andreas Giesen from DHV, *"…NEREDA fits naturally in our line-up of technologies as a new step stone"*. The key strategy of the firm is to be a well-recognised technology leader for sustainable solutions, and to be able to offer the whole of the technology out of one hand. DHV can offer NEREDA plants in a variety of contract set-ups and modes. Such set-ups comprise total solutions, design-built solutions as well as solutions where the firm may out-license (part of) the technology and/or operates under specific conditions also the plant. The decision which contract model is to be used depends on several factors, including the presence of DHV in certain countries, the quality of the network of contacts to the waterboards and construction firms as well as the quality of IPR protection in a country. A list of priority countries is maintained. DHV expects that within five years (by 2017), NEREDA will have created revenues in the range of € 100 million for the firm and its project partners. *"Furthermore, by implementing this more sustainable and cost-effective technology societies in Europe will save easily around one billion euro on treatment plant construction and operation"*, says Andreas Giesen.

3. The role of the patent(s) and Intellectual Property Rights (IPR)

3.1 Motives for and benefits of patenting and employed IPR strategy

For analysing the role of patents and Intellectual Property Rights (IPR) for this invention, it is important to look at both the perspectives of the Delft University of Technology and DHV as the main developing actors.

3.1.1 The university strategy

Prof. van Loosdrecht explains that for the university a patent is important because it triggers interest from industry:

> *"It proves substance and ownership. Without a patent, no private firm would seriously start to (co-)develop. At the same time, ownership of the patent guarantees also a certain degree of freedom to operate for the university, e.g. with respect to publication activity. If the collaborating firm were to hold the initial patents, they would most likely want to have a stronger say in publication strategies. But if we own the patents, we can decide to a much larger degree ourselves what we do….patenting never affected our research. Patents are a side product, which may at most have delayed some publications a little."*

However, Prof. van Loosdrecht also points out that the university at some point has to leave the scene:

> *"Universities can be entrepreneurial to some extent, but they will never be actual entrepreneurs. First, there is no true 'risk' because if the commercialisation fails, the salaries are still paid. Secondly, researchers*

[9] http://www.sewagenetwork.nl/nieuws/rwzi--vroomshoop-krijgt-hybride-nereda-installatie

[10] As of July 1, 2012 DHV will undergo a merger and be renamed Royal Hasking DHV. The new company will have around 8,000 employees.

> *will inevitably be interested in research questions. A PhD student will, for example, be interested in answering research questions which lead to his/her PhD. Practical considerations of how to build a plant in the real world, outside the R&D world, are hardly in the focus. This is why a pilot plant should be operated by an experienced private firm, and not a PhD student."*

Prof. van Loosdrecht also asserts that the particular technology field may be to a large degree not suitable for other university commercialisation strategies such as the creation of start-ups and spin-off firms. The main reason is that only larger firms may be in a position to design and build larger plants costing many millions of euros. In some of the newer projects, nonetheless, Prof. van Loosdrecht and the Delft University of Technology have started exploring commercialisation through setting up spin-offs; e.g. the BiAqua company (http://www.biaqua.nl/) commercialising a specific phosphate removal tecchnology. And in any case the university staff should have a good understanding of potential needs and issues of the private sector commercialisation process in order to adequately organise work division and collaboration with the firm.

Against this backdrop, Prof. van Loosdrechts strategy is to patent every research result that is technically patentable in the Netherlands first. The international patenting process provides a window of 18 months, where potential interest in the technology can be sought. If such interest exists in the private sector, the patent application is extended to international markets. By contrast, if such interest does not become apparent, the application is withdrawn. Once the technology reaches a certain level of maturity, the patents are sold to the collaborating firm. This is what happened also in the NEREDA case when DHV acquired the patents in 2006. The deal between Delft University of Technology and DHV involved an up-front payment, and some part of DHV´s revenues stemming from NEREDA will return to the university in the form of licensing fees.

When NEREDA was commercialised in the way described, the process was entirely led by Prof. van Loosdrecht. In the meantime, and in line with developments at other universities worldwide, a technology transfer office has been established which is called 'valorisation office'. Its aim is to support, professionalise and centralise such technology transfer activities. The valorisation office employs some four to five staff on IP and contractual issues (which is commonplace for technology transfer offices) in a patent department, but – and this is a speciality – also uses outside business developers. Such business developers are alumni who run their own businesses. They can provide, according to Paul Althuis from the valorisation office at Delft University of Technology, very practical advice/support on the commercialisation potential for an invention.

The way in which a university invention is commercialised at Delft University of Technology is determined on a case-by-case level. As a rule, no a priori preference is placed on the creation of licensing revenue from patents. In fact, the strategy employed is led by the thinking that the university should be perceived *"…as a good business partner who understands IP in the same way as the firm partners do…which may be different in each technology sector"* (interview Paul Althuis). Against this backdrop, the IP strategy employed allows also for patents with little to no licensing income. Such a situation is, for example, preferred when the university benefits of a commercial market success – such as higher reputation for the university, follow-up projects etc. – outweigh the efforts and costs for out-licensing.[11]

[11] In fact, study evidence shows that when selected top inventions from very few Ivy League universities in a few ICT- and biotech related technologies are left aside, income from university patenting falls way behind expectations.

3.1.2 The firm strategy

According to Andreas Giesen from DHV, patents are especially important in the initial phases of the introduction of a new technology:

> *"Patents provide a head start in a developing market. In the absence of true references in the form of established and operating plants as references, patents can provide for a certain time a trustworthy evidence of solid technology leadership. It is, however, important to build fast on this momentum and develop a branding strategy with a protected trademark. After all, copycats usually come up quite soon, and it is often easy to invent around. As many of the patents protect processes in plants, it is also hard to prove that a patent was infringed (although we do obtain knowledge of potentially patent-infringing activities quite easily from our extensive network). You would need to break into the plant to collect evidence. But if the momentum gained by the patents is used successfully, the value of the brand/trademark and the trust built with a larger number of reference plants can be significant. In the later run, the brand and the reputation replace the patent as value-creating tools to a large extent."*

Another benefit is seen in the fact that it turns out to be easier to out-license the technology if a patent is underlying the licensing agreement. This factor becomes especially important in countries where DHV does not have a subsidiary and applies a 'license-out' sales model.

In countries with weak IP protection, DHV also tries to be involved in the operation of the plant to exert a higher level of control. The additional benefit of this approach is that it also allows the collection of data from normal operation of the plants, which could feed into improvements and follow-up innovations. Eventually, a certain level of protection is also provided by the fact that not all information may be disclosed in the patent. Critical know-how for the operation of the plant, for example on calibration, may be kept confidential in the form of trade secrets.

There is hence the need for DHV to cleverly combine an innovation leadership strategy, selected patenting activity (also due to the cost of patenting), trade secrets and trademarks/marketing strategies. The strategy has to be seen also in the light of the delicate situation for enforcing IP rights. The situation is delicate not least as potential patent infringers may be also potential customers and because the cost of litigation might quickly outrun possible monetary benefits (on the other hand, it may also be embarrassing for a waterboard to learn that one of its projects will infringe patent rights).

3.2 Patent statistics and patenting trends

The technology field is well defined in the international patent/technology field classification scheme IPC (International Patent Classification or IPC). A total of 7,888 patents have been filed in the respective IPC class C02F 3/12 (biological treatment of water, waste water, or sewage) since 1995. Since 1997, more than 400 patent applications have been applied for in this field in Europe each year, with European applicants accounting for around 100 of those each year. Patenting activity has globally increased further for the last three years, however not with European applicants.

The most active applicants are Japanese (Hitachi, Kurita Water Industries, Ebara) and Chinese firms. Germany is placed third, in large parts due to the patenting activities of Siemens. Among European applicants, Siemens (GER), Degremont (FR) and ENVICON KLAERTECHNIK (GER) stand out. DHV has applied for a total of 25 patents, seven of which in IPC class C02F 3/12. Other DHV patents concern filtration technologies. The present data is consistent with a picture where a larger variety of technologies developed by several actors are developed for the wastewater treatment market.

The two nominated patents were applied for in 2002 and 1997, and granted in 2008 and 2002 (respectively) in Europe. Patent protection has been extended to a larger number of up to 17 European and non-European countries. A large number of countries covered by a patent – in particular if it covers the U.S., Europe and Japan - is usually an indicator for a valuable patent.

Other patent applicants have cited the two patents each nine times. Citing patentees are Japanese (Dainippon Sumimoto), U.S. (Zenon Technology Partnership) and Canadian (University of Western Ontario). The number of citations of a patent is also usually associated with the value of a patent, but the absolute number of citations has to be seen in the light of the citation culture in the respective technology field. We believe the number of patent citations for the two patents to be respectable, given the diversity of the technologies available for wastewater treatment.

The significance of the topic in research is also reflected by the publication activity. Prof. van Loosdrecht has published more than 456 double refereed articles, which have been cited in more than 16,500 articles.

4. Overall assessment of the patent value and achievements

The overall conclusion from the available evidence suggests a high technological and monetary value of the patents at the beginning of the lifetime of the NEREDA technology. The fact that the technology is now delivering on its promises, a large geographical coverage of the patents and foreseeable income in the magnitude of € 100 million and an estimated added value for the society of in the magnitude of € 1 billion are indicative evidence to that end. The patents have been mostly used to provide NEREDA a head start, their role in the commercialisation process will diminish with a growing number of installations which increase reputation.

There are a number of factors, which have contributed to the success of the invention:

- On the research side, one factor noted by Prof. van Loosdrecht was a very thorough approach to the technology, where several projects touched in detail on a range of specific problems: *"You have to be versatile and not too narrowly focussed as a researcher. By applying a broad view, you can see outside of the box. While I work very applied, each of my PhD students tackles a fundamental question. Answering these fundamental questions altogether provides the basis for out-of-the box thinking."*
- Another success factor is clearly the envisaged work division between the involved actors, with clearly defined roles. Of particular importance in this context is that the university does not try to commercialise the technology all by itself, but at certain maturity level leaves implementation specifically to a specialised engineering firm. The role of the waterboards as intelligent customers, willing to take the risk to be the first to apply the technology, is also essential. This approach is in line with newer innovation policy approaches, where the value of 'intelligent public procurement' of innovative solutions or sector-oriented approaches[12] for the success of an innovation is underlined. Against this background, it is also important to note the significant government support in the form of grants, awareness raising measures among key stakeholders (for example, that support of innovative solutions through waterboards is important) and other support activities.

[12] Sector-oriented approaches denote policies, where all stakeholders in a particular technology sector work together to bring an innovation to fruition. Respective coordinated measures include research and R&D support, the involvement of sectoral bodies (in this case the waterboards) as intelligent users in the development process, adaptation of government regulations, standardisation schemes etc. By contrast, a non sector-oriented policy would expect, for example, that R&D alone on a particular would lead to the solution of a real-life problem and success of innovations.

- Another key success factor is the competence and personality of the involved researchers. Competence not only covers the technical and research expertise, but also the ability to think about potential applicability and problems that might arise there (i.e., thinking about issues which arise outside of the lab). Critical is also a network of contacts to industry. In the case of NEREDA, working relations – in particular driven by Prof. van Loosdrecht, mutual respect and trust existed already prior to the development process. This situation helped to plan the development of a number of details well in advance, involving all the relevant actors form the beginning.

Andreas Giesen from DHV, when asked about the personality of Prof. van Loosdrecht, answered:

> *"I particularly value his tremendous know-how in the fundamentals, but also his eye on the practical application and the promotion of the technology he develops. He can be very stubborn and this helps push the development further. There are not many people in his field who brought so much revolution in such a short time. He is certainly one of the few 'Ivy league' guys in the field."*

The success of the NEREDA process and also other technologies Prof. van Loosdrecht has been developing is evidenced also in the range of prizes he or his team have obtained. The treatment has won several top awards including the 2007 Dow Energy Award and it was the 2010 national winner of the Energy Globe award. For his new process ANAMMOX, Prof. van Loosdrecht recently received the prestigious 2012 Lee Kuan Yew Water Prize, the award ceremony for which will be in July, 2012 in Singapore. Prof. van Loosdrecht is member of the Dutch Academy of Sciences AND the Dutch Academy of Engineering. In the Netherlands, he received the knighthood in the Dutch Lion.

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