Workshop on Innovation Theory and Innovation Processes
Universität Hamburg Centrum für Globalisierung und Governance, Germany,
28–29 Juni 2006

# Technology Diffusion Patterns in Services for Kyoto Protocol Clean Development Mechanism (CDM) Projects to Abate $N_2O$ Emissions

Thomas Grammig

R&D statistics have been used to identify sectoral patterns of technical change falling into 4 categories, mostly reflecting the number of suppliers against the number of users (Pavitt 1984). This paper will discuss these sectoral patterns and apply the Specialized Supplier parameters to firms active in Clean Development Mechanism (CDM projects under the Kyoto Protocol) development for the abatement of $N_2O$. Large firms with the required R&D capacity are outsourcing CDM development to CDM developers. The resulting competition between independent CDM developers creates blockages because the typical technological trajectories are not available as secrecy, process know-how and lengthy technical lags do not allow to appropriate technology. A failed Public Private Partnership is analysed as an initiative to advice fertilizer companies to overcome these blockages. When the sectoral parameters allow to describe what services these large firms need, predictions for suitable firms for CDM development are possible. Thereby evolutionary economics' can inform the organizational patterns explored in CDM in industry in general. Technical change is an underlying rational for all CDM and when CDM development barriers appear that differentiate between the 4 categories, this rational might be strengthened. Here, only the Specialized Supplier category is discussed and the applicability of the other three is unknown.

Table of Contents

Introduction
Patterns in CDM as these were submitted and approved by the Executive Board 3
$N_2O$ abatement as a specialized supplier trajectory 6
Technological orientation in $N_2O$ abatement 8
Engineering knowledge for CDM in process industry 9
Outsourcing of CDM by specialized suppliers so far 11
Case study on the behaviour of the technology suppliers in a PPP on $N_2O$ CDM 13
CDM development blockages in sector conditions 16
Conclusions 17

## Introduction

Kyoto instruments are a new source of technology to reduce the energy and materials intensity for developing economies. A CDM allows a developed country company to finance an emission reduction in a developing country and account for it towards its own emission obligations. In an emerging market, commercial actors create CDM in the order of abatement costs, first HFC-23, and second $N_2O$ in adipic acid and then in nitric acid plants. $N_2O$ (laughing gas or nitrous oxide) is a greenhouse gas regulated under the Kyoto Protocol with a GWP of 310. It is also a powerful ozone depleting substance responsible for a third of stratospheric ozone destruction.

CDM is also called the "Kyoto Surprise" (Grubb 1999: 226) because it combines *national* emission obligations and *project or plant based* emission reductions. This combination is still a source of ambiguity. CDM regulation is uniform for all countries and economic sectors, framing the efforts of the Northern investor and the benefit the Southern operator can sell. That Northern investor can be planting trees or modify a steel plant, obviously straining the concept and calculation of „Northern efforts" and „Southern benefit". The carbon intensity of industrial production in the South is frequently a larger multiple of that in the North. The scope of CDM is huge, but given the CDM realisation so far, the framing of Northern efforts and Southern benefit is creating heavy biases. Most CDM in Latin America use biogas from pig farms, most CERs come from abating a waste gas (HFC-23) in the production of refrigerant chemicals, the largest number of CDM is methane recovery of landfills. Certainly the first group of 1,000 CDMs which have appeared is quite an eclectic bunch. A sociological account of this eclecticism shows that the institutional factors are strongly path dependent.

A fertilizer plant is typically large because of economies of scale (Tech Factor 1), and highly integrated to save energy costs (Tech Factor 2). A fertilizer plant usually operates almost a whole year without interruption. Adding a $N_2O$ abatement technology is thus only realised when it does not create any risk of production interruptions. One day without production would represent a product loss worth more than the income from selling the emission reduction certificates (CERs) from a whole year.

A typical abatement technology costs 1 - 3 mio. € and allows the company to sell on average 500.000 Certified Emission Reductions (CERs) on the international carbon markets, currently worth around 10 mio. € per year. The first two $N_2O$ CDM to achieve registration (official approval) by the Kyoto Protocol CDM secretariat are Abu Qir Fertilisers (Egypt) and Yeosu (South Korea). The transaction costs are lower than elsewhere because the engineering company who designed the plants Uhde, part of ThyssenKrupp, also supplies the $N_2O$ technology. The plant operator in Abu Qir and Yeosu could trust Uhde to fully master the process engineering and thereby minimise the technological risk.

The diffusion of $N_2O$ abatement technology is shaped by the behaviour of eight technology suppliers and the behaviour of around 700 plant operators worldwide. Exit and entry among the suppliers and operators is rare because it involves large investments. Operators compete only in national markets because fertilizer is too bulky for long distance transport. The technology suppliers act in one global market and they are all based in OECD countries or „Annex I countries" in the Kyoto jargon. That the geopolitical lines in the Kyoto Protocol (Annex I versus non-Annex I) coincide with the geography of technology source is of course one of the basis of the Kyoto Protocol instruments CDM and JI. Technology suppliers are Yara, Mitsubishi, Heraeus, Umicore, Johnson Matthey, Uhde and the BASF. CDM developers companies are Ecosecurities, Carbon Ventures, N.serve, MGM, Carbon Projektentwicklung, Marubeni, Mitsui and Sindicatum.

## Patterns in CDM as these were submitted and approved by the CDM Executive Board

CDM methodologies, the calculation of the emission reductions, are appearing in a bottom-up fashion. Anybody can submit a methodology and the UN-F.C.C.C.'s Methodology Panel assesses it in a public and structured manner. The core of $N_2O$ abatement technology is a catalyst and the technology suppliers produce this as a standard output of their R&D. What is new is that in order to sell it successfully, there must be an approved CDM methodology available that allows to use the catalyst. Establishing a methodology is costly and thus the catalyst supplier must decide whether to undertake that risky venture or wait for others to do so.

In total 12 methodologies have been submitted and three have been approved. The first to be submitted was NM0111, in May 2005, and finally approved as AM0028 in February 2006 (MP19). The second one, NM0117, was finally rejected in April 2006 (MP20), and the third NM0126, was rejected in February 2006. NM0143 and NM0164 were submitted in January 2006 and accepted in June 2006 (EB35). Five methodologies were thus submitted in parallel since NM0164 was submitted one month before the final verdict on NM0111 appeared. Whereas NM0176 was submitted in May 2006, when one was already accepted and two rejected. This NM0176 was approved in May 2007, one year after the second one was approved. Finally NM0284 was submitted in September 2008 and is pending.

Who decided to undertake these risky ventures ? The first one NM0111 was paid by a CDM developer company which in exchange got the exclusive right to use the abatement technology from Uhde. The following two submissions were funded by BASF, a technology provider. These two failed and the following ones were again funded from other CDM developer companies, MGM and N.serve. Possibly these two decided to submitted their own (NM0143 and NM0164) taking advantage of the errors made by BASF in the prior submissions (NM0117 and NM0126). But this is far from certain since the decisions by the Methodology Panel are difficult to foresee, notably because public comments can appear and influence the deliberations. The only technology supplier to undertake his own methodology development and outsource it, BASF, thus failed while three CDM developer companies succeeded. Based on Thomas Grammig's discussions with all of them, the knowledge of the catalyst technology was not the decisive factor, rather prior experience with the UNFCCC's Methodology Panel allowed the three CDM developer companies to achieve where BASF failed.

Only one technological factor should have played a role but did not since the Methodology Panel could not learn about it. Uhde's catalyst is installed in the tail gas stream, called a tertiary system, and the other catalysts, called secondary systems, from Yara, Mitsubishi, Heraeus, Umicore, Johnson Matthey and the BASF one are installed directed behind the platinum gauzes in the main ammonia reactor. Because of the Tech Factor 1 and 2, this difference is important for the plant operator. Uhde's technology is preferable in terms of operating safety because the main ammonia reactor is not modified, but it is more costly and its installation is sometimes not possible because of lack of space in the integrated plant for the Uhde system. All secondary systems can easily be fitted in the ammonia reactor during normal maintenance stops, but whether the main reactor is affected can not be entirely certain and the plant operator is forced to place his trust in the secondary system technology provider who does not have all experience in a particular plant.

Which system is chosen depends on the hand on the operator's concerns and trust in the technology provider and on the other hand in the CDM developer's interest in buying emission reductions (CERs). When a CDM developer offers attractive financial terms and absorbs the risk of the technology installation, a plant operator might be persuaded to follow the developer's choice against his judgement of the technology provider. When a plant operator follows his concern about production reliability, he might insist on a technology and give the CDM developer concessions in the financial terms.

Uhde is the only technology provider to give exclusivity to a CDM developer called Carbon Projektentwicklung GmbH, from Austria, who is not connected to Austrian governmental CDM accumulator, Kommunalkredit. All other technology providers offer their product to all CDM developers. There was intense competition among the CDM developers, some submitting proposals to operators without even informing the technology provider that they were offering their technology. Some technology provider learned that competing CDM developers offered their solutions, but they let the CDM developers fight it out. The end results is from 55 CDM projects, Ecosecurities gained 16 (all in China), Mitsubishi got 14 (in various countries), N.serve has 11 (India, Israel, South Africa, Korea), MGM got 5, Carbon Projektentwicklung 4, Marubeni 3 and finally Sindicatum grabbed 2.

Since unsuitable technology has been put in some plants, it is likely that in most cases the CDM developer got his preferred solution. This is best evident in China, where all 16 Ecosecurities CDM used Yara and Heraeus technologies, whereas the three CDM from Mitsubishi used the Sumikomo technology although the tail gas temperature is far too low and an expensive pre-heating system is necessary. The three Mitsubishi CDM projects in China are more suitable to use the Ecosecurities' solution with Yara and Heraeus. Obviously Mitsubishi insisted on Japan-sourced technology (only one, Shaanxi Xhinghua managed to force Mitsubishi to accept the Heraeus technology). Likewise Mitsubishi forced the plant operators in Thailand and Pakistan to pre-heat the tail gas stream so that the Sumikomo technology works. In other words, Chinese $N_2O$ CDM appeared in two shapes, each one had a CDM developer imposing his technology of choice, all Ecosecurities CDM are secondary catalysts with the methodology AM034 and the Mitsubishi CDM are tertiary systems with AM028.

Only one CDM developer, N.serve, has used the competition between technology suppliers to his advantage. All $N_2O$ CDM in Israel were prepared by N.serve and Johnson Matthey technology was preferred in some cases replacing the competitor

Heraeus. In all $N_2O$ CDM in South Africa, N.serve PDDs show that Heraeus replaced Johnson Matthey catalyst. And finally in the three $N_2O$ CDM projects in India, N.serve documents show that Johnson Matthey technology is used in plants where the Heraeus platinum gauzes remain, so that the competitors have to cooperate to service the plants. Since N.Serve also uses an Umicore technology, it is the only CDM developers to use three different technologies in $N_2O$ CDM. N.serve also developed a CDM in India where Johnson Matthey technology is used in a plant originally built by Uhde although this plant would have been more suitable to use the same Uhde tertiary system as the one in Abu Qir Egypt.

Without much evidence as nobody attended all these negotiations, one can hypothesize that where Ecosecurities and Mitsubishi used their financial potential and skill to bind the plant operators, N.serve managed to use the competition between Johnson Matthey and Heraeus to offer attractive solutions to plant operaters. This is reinforced by the fact that the countries where these CDM developers operated do not overlap, where Ecosecurities and Mitsubishi are active N.serve was not active and vice versa.

The only difference between AM034 and AM051 is in the baseline. In fact, AM051 uses a $N_2O$ Decomposition Factor (NDF) instead of as moving average emissions factor. The NDF had already been suggested in NM0126 and had been rejected then because of the criticism from the developer of AM028, Carbon Projektentwicklung. It is plausible to assume that when AM051 was considered this developer had already completed his offering of the Uhde technology to all operators and it was not necessary for him to repeat his criticism to NM0126 again to prevent the approval of AM051. His criticism of NM0117 and NM0126 had created the delay necessary for him to pursue the commercial negotiations. AM051 was approved in the first months of 2007, when the last Uhde technology CDM (Enaex in Chile) was already submitted and the commenting period had passed. The other factor is certainly that AM051 was submitted for a CDM located in Mexico whose CERs were bought by Sindicatum Carbon Capital of UK. Sindicatum has submitted only one $N_2O$ CDM for validation, for Multi Nitro in Indonesia. Both in Mexico and in Indonesia Sindicatum is the only $N_2O$ CDM developer which underlines the importance of developers capturing a CDM type in a country.

Overall, the attempts by technology suppliers to gain advantage by submitting methodologies have not worked. While Uhde used the availability of AM028 and got all $N_2O$ CDM prior to November 2006, once N.serve and MGM got their AM034, Uhde got no more plants even in the above mentioned plant in India Uhde had built originally. When Uhde learned that Carbon Projektentwicklung did not succeed any more in creating CDM projects, Uhde unilaterally abandoned the exclusivity it had assured to Carbon Projektentwicklung. Likewise BASF's support for methodologies NM0117 and NM0126 failed, but earlier in the process than the Uhde attempt since the one who submitted AM028 argued more skilfully and discredited NM0117 and NM0126. This was possible with the BASF supported ones, but the experienced CDM developers took over the technology providers' influence once the Methodology Panel had established what it saw as the most relevant factors. While personalities in Carbon Projektentwicklung and in N.serve (competition) played a small role, it was prior experience with the regulator's thinking that shaped the outcome.

Both strategies, outsourcing it and giving it away, failed and technological factors could be at work in both. We will return to Uhde and Mitsubishi when we look at the orientation of R&D, page 9. Before this step, a crucial bit of theory is introduced.

## $N_2O$ abatement as a specialized supplier trajectory

The chemical industry is dominated by large companies with more than 10.000 employees less so because of economies of scale than because of economies of scope. Based on continuous-process technology, innovation is largely firm specific and cumulative with distributed tacit knowledge among professionally and functionally specialized groups in the firm. Patent data is therefore a privileged research route to study innovation, picking up trends in innovation success which cannot otherwise be ascertained from observations of organizational behaviour in single firms. The late Keith Pavitt has championed this approach at the Science Policy Research Unit (SPRU) at Sussex University, UK (together with Chris Freeman the force behind these Schumpeterians). He has linked this research to the debates about organizational forms, learning processes and resource allocation in large firms.

If it is correct that large firms are also dominant industrial players in climate change mitigation, Pavitt's results are an obligatory starting point to assess innovation for climate change mitigation. Pavitt (1984 and 1989) derived his sectoral patterns of technical change from data on innovations in Britain from 1945 to 1983. Because of the data on patents and R&D expenditures, his sample contained an over-representation of mechanical engineering, instruments and textiles and an under-representation of chemicals, electronics and aerospace. In total, 2000 innovations are analysed.

> Such a construct allows us to compare sectors in terms of:
> (1) The sectoral *sources* of technology *used* in a sector: in particular, the degree to which it is generated within the sector, or comes from outside through the purchase of production equipment and materials.
> (2) The institutional *sources* and *nature* of the technology *produced* in a sector: in particular, the relative importance of intramural and extramural knowledge sources, and of product and process innovations.
> (3) The *characteristics* of *innovative firms*: in particular, their size and principal activity. (Pavitt, 1984: 346)

Most revealing are the results regarding firm size and technological diversification. Firms in mechanical and instrument engineering and textiles use innovations produced in other sectors but contribute little to innovations in other sectors. In contrast to firms in chemicals, electric and electronic products which tend to be more closed to other sectors. This correlates to firm size, where the latter group shows more innovation coming from larger firms. The gist of this research is that these patterns can be explained by distinguishing whether innovations concern products or processes and whether they come from outside or inside a sector. Pavitt thereby provides a macro foundation for research on technological trajectories.

**Table 1**: Basic technological trajectories in Pavitt (1992: 216)

| Definition | Source of technology | Trajectory | Typical product groups |
|---|---|---|---|
| Science-based | R&D laboratory | synergetic new products | electronics, chemicals |
| Scale-intensive | production engineering and specialized suppliers | efficient and complex production and related products | basic materials, durable consumer goods |
| Information intensive | software / systems dept. and specialized suppliers | efficient (and complex) information processing, and related products | financial services, retailing |
| Specialized suppliers | small-firm design and large-scale users | improved specialized producers, goods | machinery, instruments, speciality chemicals, software |

At first sight, $N_2O$ abatement innovation could be a case of either a science-based, a scale intensive or a specialized supplier trajectory since the fertilizer technology can qualify as basic material, as chemicals or as speciality chemicals sector. For the specialized supplier trajectory,

> "the innovative firms produce a relatively high proportion of their own process technology, but the main focus of their innovative activities is in the production of product innovations for use in other sectors. Innovative firms are relatively small, they diversify technologically relatively little, either vertically or otherwise, and they do not make a relatively big contribution to all the innovations produced in their principal sector of activity, where users and other firms outside the sectors make significant contributions." (Pavitt, 1984: 359)

All of these parameters apply to six out of the total of eight $N_2O$ abatement technology suppliers, they have less than 10,000 employees and they focus on a specific type of clients. Neither the science-based nor the scale intensive trajectories apply because in both the innovative firms tend to be relatively big and in both they make a relatively large contribution to the innovations produced in the sectors. Differences among the technology suppliers reflect the scope of their respective supply offer. The most lucrative part of the technology for fertilizer plants are the platinum gauzes in the nitric acid reactor. Some suppliers concentrate on this part, while others have an all-in-one strategy, offering all parts of the production process. Only one of the eight is a large and diversified corporation which would fit better in the scale intensive trajectory and this particular one is active in $N_2O$ abatement only as a side market from a product it produced elsewhere. So the only exception from the specialist supplier type firm is also the one who pursued the $N_2O$ abatement market with the least innovation effort. All others have invested relatively much higher R&D expenses.

Following Pavitt, specialized suppliers should show specific habits when it comes to the type of knowledge they seek, where they look and how they retain it. For knowledge about future products they look in those markets they specialize on, i.e. they know the customers very well. Then they scan their sector intensely for ideas on innovations which they can not rely to find within. In their innovation efforts they anticipate that there is a limited number of competitors as well as a limited number of possible clients. They know all their competitors and they know that each others' technology suffers from low appropriability because they depend more on their customers for information and skills related to operating performance. For firm-specific learning, Pavitt asserts that for specialized suppliers "learning by using is of greatest importance, the limitations and further potentialities emerge from experience in use" (Pavitt 1992: 220).

What could be the specific factors which shape innovation by specialized suppliers for the Kyoto instrument CDM ?
**They should seek to add new features to their existing technology in order to strengthen their relations to their clients.**
To achieve this, it is necessary to find a modification of their product that enables the client to reduce the carbon intensity. The likely limitation of this innovation would be the professional habits of the specialized suppliers' and the users' experts. Since they tend to be working together over many years, they are likely to share some paradigmatic assumptions about the orientation of their efforts. This limitation would also reduce the effectiveness of searching for such technology in other sectors. Obviously it is impossible to verify this at the current stage of the carbon market, when there are very few carbon intensity reduction seeking innovations to observe. Nonetheless, the innovations pursued by the eight $N_2O$ abatement suppliers can be compared to this theoretical extrapolation from Pavitt's typology. Before doing so, I briefly describe recent related innovations in these firms.

## Technological orientation in $N_2O$ abatement

$N_2O$ has no toxicity and was not considered to be of environmental significance. Its environmental significance increased when it was discovered that $N_2O$ influences the formation of stratospheric ozone. However while it was listed as an ozone depleting substance in the Montreal Protocol, contrary to all other ozone depleting gases, it was not given a ozone depleting multiplier and thus no funds from the Montreal Protocol's Multilateral Fund were available to abate it. In the Kyoto Protocol, $N_2O$ was given a $CO_2$ multiplier (GWP 310) and thus its abatement became a target for technological efforts in industry.

$N_2O$ appears only in two processes in the chemical industry, the production of adipic acid and of nitric acid. The innovations eventually chosen in these two processes are shaped by the technological trajectories. In adipic acid, all firms involved are very large and this production has steep scale economies. Adipic acid is an intermediary product for Nylon, so it has varied uses. Although there are many nylon production sites, there are only twelve plants producing adipic acid worldwide. No smaller unit can compete with these twelve. Similarly, these twelve are distributed across the industrial centres, three in the US, two in Germany, two in China, and one in Brazil, France, UK, Japan and Singapore. Each chemical conglomerate has its own plant and each one developed its own abatement technology. Thus there are six different $N_2O$ abatement technologies in use in adipic acid production, because the twelve plants belong to six conglomerates (Rhodia, Asahi, BASF, Bayer, DuPont and Solutia), each conglomerate pursuing its firm specific elements. The conglomerates with most R&D in catalysis developed catalyst-based technologies, those with a specific set of surrounding plants re-cycled the $N_2O$ and those with neither possibility used a thermal abatement system.

All of this clearly shows that for adipic acid, innovation efforts were shaped by the scale intensiveness of the production system. For nitric acid production, the scale intensiveness is considerable smaller. There are 700 nitric acid producers around the world and the production volumes vary with a factor of 100 between the largest and the smallest units.

Uhde's innovation is motivated by Uhde's strategy to offer the entire plant equipment and with no R&D in catalysts, the firm chose an add-on technology (tertiary abatement). Similarly, Mitsubishi developed an add-on technology. Both established exclusive supply contracts with specialized catalyst producers. BASF, Heraeus and Johnson Matthey chose a technology which builds on their position in the fertilizer technology market, requiring no reactor modification (secondary abatement) only adding something which each plant owner can realise on his own. The other supplier, Norsk Hydro, pursued a technology building only on reactor geometry modifications. The technical route to abatement pursued reflects the marketing situation of each technology supplier. Each one of the eight $N_2O$ abatement technologies uses a different catalyst material.

The difference in $N_2O$ abatement between adipic and nitric acid reflects the trajectory types suggested by Pavitt. The adipic acid $N_2O$ abatement has been exclusively developed in-house in very large firms, the nitric acid $N_2O$ abatement appeared in specialized supplier which do not themselves operate production plants (with one exception). Finally regarding the nitric acid $N_2O$ abatement catalysts chosen, all firms continue to undertake R&D to improve the catalysts' reaction kinetics and there is a general belief among the researchers that no catalyst material will become dominant. I. e. all technology suppliers will manage to maintain a share of the $N_2O$ abatement technology market.

The commercial strategy habits are easy to see, the operational constraints are fare more difficult to detect. The following chapter suggests the cause of this.

## Engineering knowledge for CDM in process industry

The fertilizer production process is highly integrated and to reduce $N_2O$ emissions a small part of the process has to be modified. The process is dependent on local conditions of natural gas supply, cooling water, electricity prices and fertilizer markets. CDM in process industries should always use locally specific engineering skills. Process engineering involves knowledge which remains unarticulated because „the Codebook is Displaced", in the typology proposed by Paul David and Dominique Foray (French equivalents of SPRU), i.e. the knowledge remains tacit because members of the group of specialists refer to it so rarely that the reference is indiscernible to an outside observer (Cowen, David and Foray 2000: 231). $N_2O$ CDM are particularly salient because the Tech Factors 1 and 2 are strong, the engineering is complex and costly. Firms active in fertilizer production technology have commercial incentives to build specialized teams and keep their skills tacit so that these skills cannot be acquired by other firms. The codebook for the engineering knowledge is displaced because of profit motives. Perhaps these motives increase the professional biases of these engineers. Irrespective of the question whether the "Codebook is Displaced" for commercial or for engineers' biases, the creation of CDM is strongly shaped by this type of tacitness of the technological skills required. The abatement of $N_2O$ is in this regard technologically typical for CDM in process industries.

This definition of the tacitness is suitable to describe the relation between technology supplier and plant operator. The engineers in the plant have the opportunity to study the parameters of the plant over years and acquire in-depth understanding of that one plant, whereas the engineers in the technology supplier have the opportunity to study these parameters in many plants. The operator's engineers have far more information about the particular plant but they need the supplier's engineers to make sense of it. For example, a supplier knows what happens elsewhere to a piece of equipment when it operates at 6.5 bar pressure. By contextualising this information in a particular plant, the supplier helps the plant engineer to decide, for example, to change his operation of that equipment from 6.0 to 6.1 bar pressure. Whether an innovation is realised or not depends on the ability to create a contractual relationship between supplier and operator that allows this meeting of minds to occur.

The most important technological determinant is the high integration of the fertilizer production process (Tech Factor 2). This integration reflects the thermodynamic side, comprising natural gas combustion and process gas compressors driven by steam turbines. Because of this integration, the introduction of $N_2O$ catalysts requires close cooperation between plant operator and technology supplier, where both always first sign an exclusivity agreement before exchanging any information. Only then will the operator disclose details on temperature, pressure and gas composition which allows the supplier to design the catalyst application.

The commercial determinant derives from the de- $N_2O$ catalyst especially because it is only weakly patentable. The chemical composition of all available catalysts is not patentable. The only patent possible is on the formulation, the steps of chemical treatment of the catalyst substance during catalyst production. All catalyst producers constantly refine this formulation. It is generally assumed in that sector that no catalyst producer will be able to define a formulation and impose it as a patent (a chemistry nonhuman agent). This has strong repercussions for the relation between technology supplier and plant operator.

The operator must measure process parameters in the plant following the prescription of the catalyst supplier, who then custom designs the catalyst for the particular plant. The operator will then continuously buy more catalyst year after year from the same supplier. The operator can only repeat the whole procedure with a different supplier. The outcome for both depends on the quality of their joint process R&D. Some catalyst suppliers provide catalyst under leasing agreements stipulating that the operator must return the catalyst to the supplier at the end of its usage. That allows the supplier to assure that a competitor supplier doesn't get a catalyst sample for analysis and uses it in his own R&D. By returning the catalyst, the operator also gains insight from the physical and chemical analysis of the used catalyst, allowing him to draw further conclusions about his plant operating conditions.

## Outsourcing of CDM by specialized suppliers so far

All $N_2O$ abatement technology suppliers have not escaped aligning themselves with CDM developers and outsource the CDM creation to them. Most CDM developers are new firms offering a variety of services to the investor or technology supplier on one side and the plant owner or operator on the other side. There is intense competition between the CDM developers especially in the early stages of the carbon market since they can exploit information asymmetries and risks in that market.

The services a CDM developer provides comprise:

- CDM registration documentation (PDDs, methodologies and monitoring plans)
- creating local subsidiaries when necessary that act as project entities
- market emission reductions, so-called CERs
- negotiate a variety of CDM agreements
- relate to CDM Designated National Authorities (DNAs) and Designated Operational Entities (DOEs)
- provide investment capital, risk insurance
- particular engineering services for parts of the CDM

All of these services could also be made available within the technology supplier's organization, however, the emerging carbon market is too unspecific that the suppliers would use their in-house capacity. The technology suppliers' access to venture capital is certainly superior to that of independent CDM developers so this possible reason is not in play. The attraction of the outsourcing possibly lies in the packaging of all these services and leaving it with one entity. The technology supplier does what he knows best, designing catalysts, and leaves everything else to independent CDM developers. This behaviour can be found in many types of CDM, in industry, in mining, in agriculture and in food-processing. In $N_2O$ abatement it is uniformly followed.

The outsourcing separates the R&D skills from the other aspects. The supplier relies on the CDM developer to transmit the technological information between their catalyst designers and the plant operators. This could be the major inherent technological limit for these CDM projects. Suppliers consider whether integrating the CDM development into their organization does enhance their capacity to influence their „carbon exposure". All suppliers are subject to obligatory emissions trading in their home countries. To meet their emission reduction goals and to be able to influence the costs and risks of these goals is important but evidently not important enough so that they use their in-house capacity so far. To express it in other words, their technological competence remains at a certain level of firm strategizing despite the opportunity to add a new and higher level firm policy value to it. This could be interpreted as purely an expression of corporate inertia, a theme remains at a level of corporate hierarchy and is not passed on upward.

The **first hypothesis** is that suppliers change strategy when they realise that outsourcing the creation of CDM does not allow them to demonstrate their technological competence and then define how to acquire the CDM creation competence in-house. Their reflex to seek to align themselves with CDM developers could be influenced by the Specialized Supplier trajectory habits, seeking not to divert from their traditional role in their market. **As Specialized Suppliers they do not wish to grow as a company in scope**, even if the additional activities build quite organically on the core work, or in other words, are close to their accumulated technological competences (maybe a CDM would be a horizontal not a vertical diversification). One reason for the CDM outsourcing thus lies in the organizational management of the firm. The Specialized Supplier trajectory suggests also a second reason, as Specialized Suppliers, firms want to stick to the privileged relation with the users they know. This privileged relation has been the source of commercial inroads because it has allowed to accumulate knowledge from user experience. It would be endangering an important part of their firm strategy if they would bring a different level to this relation, i.e. instead of selling technology against payment, they would enable a user to earn income from selling CERs instead of producing fertilizer. This second reason reflects Specialized Suppliers' customer relations.

The plant operators seem not to influence this choice since all CDMs in preparation are pursued by independent developers, even where the original initiative came from a plant operator. Probably the operators would prefer to deal only with the supplier and the CDM developer is an unwanted intermediary. Perhaps it is an exaggeration, but a CDM developer always remains an alien between technology supplier and plant owner. Both don't want the CDM developer to distract them in their cooperation, but they have to use the CDM developer as they cannot find an alternative between themselves (supplier and owner).

I mentioned above that one of the eight technology suppliers is much larger than the others and it is significant that this one is the first to decide to acquire more CDM competence in-house. Furthermore this corporation does plan this acquisition carefully and anticipates that it will take them a long time to build up this in-house competence. This is quite prudent because as a large innovative firm it should be used to manage different product divisions and synergies between them. This one large technology supplier does not motivate this competence ambition with climate change mitigation objectives but purely with commercial reasoning, by being able to create CDM of their liking they believe that they might gain new product opportunities in the future.

The private sector participants in the PPP case study are bringing their funds and skills to the PPP as a means to assess their future CDM activities. They are dissatisfied with the track record of the CDM developers such as Ecosecurities, Carbon Ventures, N.serve, MGM, and Carbon Projektentwicklung because these have not shown to be able to conduit the technological competence to the plant operators. The choice of the technology suppliers to use CDM developers and the automatic separation between the technological aspects and all other aspects creates problems in CDM creation. What is unclear to the technology supplier is where these problems originate, is it the insufficiency of the Kyoto Protocol administrations such as the CDM Board and the Methodology Panel, or the CDM host country administration, or the CDM developer ?

**The second hypothesis** is that their views on CDM developers are shaped by their experience in relating to other technology companies. The suppliers see CDM creation as similar to other innovation activities. Therefore they approach a CDM developer assuming that their relation is similar to the relation with a partner in a joint R&D project. In the PPP case, the two suppliers use different CDM developers and these developers have a mixed record, some CDM developers realised CDM successfully others failed or were rejected by the Kyoto Protocol Secretariat. Since in the competition between technology supplier speed is a crucial variable, the suppliers hesitate initially in their choice of CDM developer but then "stick it out" assuming that this is always necessary to let the engineers involved see whether they can work with the "Codebook Displaced" and produce results or not. Once failure of a CDM developer is irredeemably clear they change CDM developer.

The first hypothesis concerns the actual CDM partner choices and how these choices are taken. The second one concerns more the interpretation of the events between CDM partners, how the relation between technology provider, CDM developer and plant owner is seen, with what categories and parameters it is recorded and talked about.

## Case study on the behaviour of the technology suppliers in a PPP on $N_2O$ CDM

The generation of CDM projects for $N_2O$ abatement is hampered by technological and carbon market risk barriers. Chinese fertilizer companies have pursued $N_2O$ CDM later than elsewhere because they hesitate to change the complex production process, because they cannot choose between abatement technologies, because they avoid scrutiny by international and national Kyoto Protocol authorities, and because they are not certain about the commercial gains from such a CDM. The latter are substantial.

In China, only the first $N_2O$ CDM to be submitted for approval at the Kyoto CDM Board, as NM0117, was located at Nanjing Chemicals company. This $N_2O$ CDM was rejected on formal grounds, due to somewhat negligent paperwork by the developer. Nanjing Chemicals is also the object of the largest foreign investment in China, where the foreign investor realises $N_2O$ abatement as a matter of corporate environmental management. The cause of this exception is thus not significant for general $N_2O$ CDM blockages.

The case study Public Private Partnership (PPP) was intended to be financed by chemical industry firms, and the PPP budget of a German aid organization. As a governmental agency it had a budget line to undertake joint projects with the private sector (all European companies eligible). The PPP $N_2O$-CDM described here was a prominent example of such PPP because it comprises public and private funds to advice a Chinese counterpart. Elsewhere, PPP are suggested to be to the new Carbon governance paradigm per se, as if environmental stakes of this magnitude can only be addressed by state and private sector (Benecke, Friberg, Lederer, Schröder 2008). As a failed case, this PPP wouldn't support this axiom.

The German aid organization intended to accelerate $N_2O$ CDM generation in China through a Package CDM study as a suitable case of expanding CDM in industrial sectors in general. This aid organization has advised the Chinese counterpart on regulatory and technology matters since 1995. The private sector companies are also foreign investors in China who claim environmental modernization benefits for China on many occasions. These private sector companies are also technology suppliers for $N_2O$ abatement. This PPP $N_2O$-CDM combines the competence of the Chinese counterpart's regulation record and potential abatement technology suppliers' R&D capacity for the generation of CDM.

This PPP serves as a case study to see what specialized suppliers seek to get from an opportunity unlike their normal CDM efforts. The case study adds to the evidence for CDM efforts visible elsewhere as well. This implies that the engagement of the specialized suppliers in the PPP follows from the same strategic intentions pursued elsewhere, only that in the PPP, the specialized suppliers have more freedom to shape their role further than they find in general CDM generation opportunities.

The Specialized Suppliers intended to produce an inventory of all nitric acid production units (the production step where $N_2O$ arises as an unwanted by-product). Following a first data generation phase, the inventory should identify groups of plants where process parameters are sufficiently similar so that the same $N_2O$ abatement technology is the best solution, the condition for so-called Package CDMs. Package CDMs are an intermediary step from single CDM projects to CDM on sectors or policy. CDM components (parts of CDM preparation work) for these packages are then elaborated to enable CDM developers to conclude CDM agreements and respective emission reduction purchase agreements (ERPAs). While this PPP $N_2O$-CDM elaborates CDM components (those parts of CDM preparation work which reoccur in each case), it avoided to appear as a formal CDM participant in official submissions because the plant owners are required to be the CDM developers. Given the size and complexity of fertilizer plants, this is crucial and thus the PPP $N_2O$-CDM can only be a source of advice available to them.

The third stage was to derive CDM guidelines for the fertilizer industry in China, again at the discretion of the Chinese counterpart so that the Chinese counterpart's assistance to the plant owners can be enhanced. Finally, the PPP $N_2O$-CDM should analyse the first three phases in order to identify lessons for CDM reforms at the level of the Kyoto Protocol and its administrative institutions, the CDM Executive Board (in charge of CDM validation and registration) and the Methodology Panel (one of the four working groups under the EB). The lessons concern guidelines reflecting and enhancing technology competition in CDM development, taking into account technology supplier competition and guidelines for dependencies between CDM owners, CDM developers and ERPA partners, all with reference to industrial CDM. The data generation was led by the Chinese counterpart, the Package CDM definition and CDM components phase by the german aid organization and the fourth phase jointly by both. The technology suppliers contribute during the four phases according to their independent judgement. Their incentive to do so rests on their participation in ERPAs (which remain under the discretion of the Chinese fertilizer companies) to acquire Certified Emission Rights (CERs), on their interest to demonstrate their technical know-how and on their interest to assist the Chinese counterpart in modernizing Chinese industry.

The efforts of the suppliers in the PPP $N_2O$-CDM are now selectively described in order to identify how these suppliers find innovation services in their organization or try to define the services they buy. Over the course of the meetings among the PPP participants over the first six months, relations between technology suppliers and

CDM developers were mentioned by all but no supplier ever qualified the relations to the CDM developer other than mentioning them in the simplest terms.

Only once the decision in Specialized Supplier A was taken, the representatives from A briefly and simply stated in the presence of all PPP participants:

Supplier A: our attempt with X is now definitely failed and for us, it is now clear we will not try again with X, that is certain.
Supplier B: ours is Y, they are really doing the CDM, Y is good they tried difficult cases and when they failed they failed honourably, they havn't done bad work
Supplier A: he relied on our partner, it makes no sense to continue, I see you have a partner but you not sure either.
Supplier B: no we are not sure either

Supplier B continues to work with Y although they are not clear about his competence. Both A and B did not attempt to identify why their relationship with the respective CDM developer turns out in a particular case. They assume that they cannot analyse that relationship and they treat the technology supplier – CDM developer relationship as a black box. This is coherent with the second hypothesis, this relationship is seen as similar to that of other joint innovation activities. Furthermore, the suppliers A and B do not seek to learn something from a failure in order to approach a new CDM developer in a different manner. Supplier A's explanation and account of the failure with X consists only of the decision to discontinue the relationship. Over a number of meetings between PPP participants, A only states "we stopped" and nowhere relates future actions back to the experience with CDM developer X.

Nor do supplier A and B exchange any information on their habits of relating to X and Y. When the governmental PPP participants express views on X and Y there is never a reaction from suppliers A and B. They accept any statement on X and on Y without questioning and without stating their own views. Never was there any attempt to open the black box of the technology supplier – CDM developer relationship. When I suggested that two CDM developers might meet in person, the suppliers remarked that they would have to duel since their competition is so aggressive and negative (anything goes). After my suggestion nobody else mentioned these particular CDM developers.

The PPP could have allowed technology suppliers to consider various options to use their $N_2O$ technology competence to create CDM projects. Providing this competence to the German aid organization and the Chinese counterpart would enable them to assess whether they can shape CDM more to their interests, catalyst sales and access to the CERs which result from these CDM. The German aid organization and the Chinese counterpart provide the opportunity to approach Chinese plant operators not with their commercial interest but from the governmental and regulatory side. Neither the governmental side, nor the private sector side expected from the PPP any new form of coordination. They feared that any regulation might restrict their technological opportunities and the readiness to cooperate within the PPP was only motivated by the need of an initial push to overcome CDM development blockages.

The supplier behaviour reflects these firms' habits of appropriating innovation benefits, they first seek patent protection and when they cannot get this, they seek protection in lengthy technical lags to imitation.

These suppliers' anticipation of their relations to plant owners also contained particularities of the Chinese context. Without qualifying this further, we simply list some aspects that where mentioned in the PPP $N_2O$-CDM.

- Chinese owners' mimetism
- Suppliers anticipate that the owners will try to act in isolation while the suppliers seek opportunities to expose their competence to all owners
- Focus on pilots is plausible
- Suppliers often get data which is not plausible.
- In order to work on the sector, all government agencies have to be informed, CDM is governmental and that needs to be respected
- Technologically we know what fits best but the owners have their own Angst parameters

## CDM development blockages in sector conditions

Institutional factors vary among countries because of laws for business management and many other factors for organizational shapes. It is thus uniformly the case that technological factors while applying everywhere alike, appear in national shapes and patterns. A one case description as above cannot separate national from technological factors.

In $N_2O$ technology as a Specialized Supplier type market where the differences in technology are large, the German aid organization and the Chinese counterpart provide coordination services in the form of a sector CDM also because the Specialized Suppliers have common interests in reducing the transaction costs in creating a CDM project. Other technological trajectories in other markets could well lead to different coordination services from governmental actors. Certainly different trajectories require different sector CDM approaches. Finally another reason why it is not clear how to extrapolate from the PPP $N_2O$-CDM case is that the number of technology suppliers in Germany and the number of plants in China both played a role in making this PPP $N_2O$-CDM viable.

These sectoral conditions in a national context affect CDM developers more than technology providers. For example the capital market in Brazil plays a role for a Brazilian CDM developer like Econergy. A firm like Econergy, gaining regional competitive advantage, does not appear in China or in India. In Brazil the possibility to raise venture capital smart enough to reflect the risks of carbon trading leads to CDM developers who accumulate CDM investment capital and provide it on conditions to plant owners on specific conditions. The availability of finance plays a stronger role in Brazil than in China or India because the opportunity does not arise there. In China and India a different institutional factor shapes the same CDMs.

Nonetheless, it is quite straightforward to extrapolate from Pavitt's categories of technical change to those problems in CDM development that are likely to appear. Technical change is influenced by very different actors among the categories. CDM regulations enable some actors, which in line with the technical change type, allow these actors to enhance technical change for CDM and for other actors burden them with unrealistic tasks.

**Table 2**: Climate change mitigation factors for technological trajectories

| Sector-typology | Emitters | Actors | Innovation drivers | CDM barriers |
|---|---|---|---|---|
| Science-based | | | scientists, patents | Additionality |
| Scale-intensive | Aircraft, electricity | Government monopoly | political power | Baseline is policy |
| Supplier-dominated | Appliances | many suppliers, mass users | marketing, advertising | Monitoring |
| Specialist suppliers | Chemical industry, power plants | few suppliers, few users | Techno-economic paradigms | Integrated systems, „conservativeness" |

The right-hand column is a first suggestion about the CDM barrier. To further investigate this, a series of case studies with different technologies and from different countries are necessary.

## Conclusions

Despite their high profitability (payback around 3 to 5 months), $N_2O$-CDMs appeared surprisingly slow. The technological trajectory of Specialized Suppliers proposed by Keith Pavitt allows to describe how the CDM efforts of $N_2O$ abatement technology suppliers are shaped by their innovation habits. These suppliers avoid to diversify their products and seek to maintain the scope of the privileged relations to their clients from which they have gained crucial insights in the past. Like other technology suppliers for CDM in industrial sectors, the $N_2O$ abatement technology suppliers experiment with organisational solutions to create CDM projects. The first choice is to get CDM advice while using this as a marketing instrument. The second choice has been to align themselves with CDM developers. These CDM developers oblige them to separate the technological from all other aspects which offers them insufficient opportunities to use their technological competence. This latter obstacle is possibly made more severe because it runs counter to Specialized Suppliers' past learning efforts.

While fertilizer is a chemicals branch, the behaviour of companies involved in CDM development corresponds to the Specialized Supplier trajectory. The trajectory explains both the routes chosen by suppliers, the respective success and the default solutions to which they refer when problems appear. The trajectory sheds light on the behaviour in a Public-private Partnership that allowed the suppliers to go beyond their "traditional" roles. Specialized Suppliers are marked by their past success of learning from their clients, the plant operators. Management in Specialized Suppliers view their CDM challenges as similarly reliant on plant operators. This is a crucial weakness that CDM developers such as Ecosecurities and N.serve have exploited to their advantage.

The Specialized Supplier who gave an exclusivity to a CDM developer and the Specialized Supplier that tried to buy a CDM methodology for its technology both failed to use their technological mastery to their advantage. The creation of CDM methodologies, notably the publicly documented argument between the AM028 and the AM034 methodology proponents, seem to be direct prolongations of the same technology provider – CDM developer *"rapport de force"* in the CDM project development. N.serve's use of Johnson Matthey in an Uhde plant in India, and the one exceptional Heraeus technology among the Mitsubishi CDM in China are the cases that underline this. Were the Methodology Panel to anticipate the role of proprietary knowledge between technology providers and plant operators, the methodology submission process might allow to challenge the CDM developer dominance, but this is only a speculative interpretation. Later methodology submissions NM0176 and NM0284 are only skirmishes of some CDM developers that have lost out to the first movers.

The Specialized Supplier category among 4 types of technical change has been brought to the fore by analysing R&D expenditures across all economic sectors. Specialized Suppliers avoid to grow in scope because the cooperation with their clients is the crucial factor for the business success. That prevents them from building in-house competence for CDM and a further expression of the Specialized Supplier category, relate to CDM developers similarly to their other technology cooperations even so CDM development has no resemblance to those cooperations. The PPP $N_2O$-CDM is the main evidence here since the negotiations were always confidential. Looking at this case alone, one would come to infer that the weak patentability of de-$N_2O$ catalyst and the high profitability of CDM projects are at work. Pavitt's conclusion that Specialized Suppliers are focused on product innovation close to their preferred costumers appears to be a superior explanation. Instruments, software and machinery in particular in power plants would fall into the same category and CDM projects for supercritical coal-fired power plants would be the most obvious technology of this type of technical change.

## Bibliography


Benecke G., Friberg L., Lederer M., Schröder M.(2008) „From Public-Private Partnership to Market", Sonderforschungsbereich Governance Working Paper Series, FU Berlin
http://www.sfb-governance.de/publikationen/sfbgov_wp/wp10_en/sfbgov_wp10_en.pdf

Cowan R., David P.A. and Foray D., 2000, „The Explicit Economics of Knowledge Codification and Tacitness", *Industrial and Corporate Change*, 9/2: 211-253.

Grammig T., 2003, "Sociotechnical Relations and Development Assistance", *Technological Forecasting and Social Change*, 70/6: 501-523.

Grammig T., 2002, *Technical Knowledge and Development: Observing Aid Projects And Processes*, London: Routledge.

Grammig T., 2001, "Technology Co-operation and the National Context", *Entwicklungsethnologie*, 10/1-2: 61-78.

Grammig T., 1993, "Unterstützende Empirie in der Projektimplementierung", E*ntwicklungsethnologie*, 1/1: 21-37.

Grubb M., 1999, *The Kyoto Protocol. A Guide and Assessment*, London: RIIA.

Pavitt K., 1992, „Some Foundations for a Theory of the Large Innovating Firm", In Dosi G., Giannetti R. and Toninelli P.A., *Technology and Enterprise in a Historical Perspective*, Oxford: Clarendon Press, pp. 212-228.

Pavitt K., Robson M. and Townsend J., 1989, "Technological Assumulation, Diversification and Organisation in UK companies, 1945-1983", *Management Science*, 35/1: 81-99.

Pavitt K., 1984, „Sectoral Patterns of technical change: Towards a taxonomy and a theory", *Research Policy*, 13: 343-373.