



## Employment-oriented Industry Studies

### Resource-based Technology Innovation in South Africa

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# **RESOURCE-BASED TECHNOLOGY INNOVATION IN SOUTH AFRICA**

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**RESOURCE-BASED TECHNOLOGY  
INNOVATION IN SOUTH AFRICA**

**CHAPTER 1:**

**Mines and Medicine – Lodox Low-dosage X-ray**

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Yfm

## 1. Introduction

*We [South Africans] are extraordinarily unsuccessful at converting innovations from academic research into commercial companies (Goldblatt, 2002).*

*The fact is there are many, many good ideas in South Africa that just don't make it (R. van der Watt, interview, December 2003).*

*There are excellent R&D-driven technologies in South Africa that get nowhere (B. Strydom, interview, December 2003).*

This is the story of a South African idea that is in the process of 'making it', that looks as if it might just 'get somewhere'.

The introduction to a story on CNN.com/Health, dated 12 June 2003, reads: 'A digital X-ray system once used to search South African miners for stolen diamonds will now allow Baltimore trauma doctors to scan a patient's entire body in 13 seconds.' This paper tells the story of how this technology was developed and brought to market over the course of the last 13 years.

At the most superficial level it is an outstanding story of how the prevention of theft of a rather valuable stock – diamonds – created a technology that has revolutionised emergency room treatment. At a deeper level it is a story of how a confluence of regulatory and institutional dynamics, together with intellectual networks and personal dynamism, created a unique set of events that led to the emergence of a technology that substantially increases medical staff's ability to save lives.

The Lodox story is a story of innovation, but perhaps more importantly a story of commercialisation, in other words, of the process by which the idea became a technology, which became a product. As will become clear in the telling, the innovation challenge lay not so much in the creation of new technology but in its commercialisation. The initial 'eureka' moment set a series of events into motion, but there were others events that were vital too: if they had not occurred we would not today be examining the innovation in Lodox. It is for this reason that this paper will explore the innovative journey from the sound of 'eureka' echoing through the halls of a South African mining house to the operational use of Lodox in a Baltimore emergency room.

It is hoped that, by both telling the story and peeling back the layers of events, coincidence and personality, this paper will provide some insights into the drivers and facilitators of innovation in South Africa's resource and mineral energy sector.

This paper poses the following questions:

- What were the drivers of the initial innovation, that is, the low-dosage x-rays?
- What provided the organisational impetus to explore the medical innovation that we now know as Lodox?
- What were the institutional, personal and environmental conditions that encouraged the innovation?
- Did government policies and supply-side measures make a discernable difference to the innovation process?

By posing these questions, this paper hopes to advance an understanding of:

- The organisational conditions that foster innovation;
- The processes of interaction between government and the private sector in innovation;
- The extent to which the existing policy and supply-side environment actively foster innovation;
- The relationships between government, academia and the private sector in fostering innovation; and
- The key elements in the journey from innovation to commercialisation.

The paper is divided into three broad sections, the first two of which constitute the bulk of it. The first section describes the events that led to the appearance of Lodox in US emergency rooms. It highlights critical factors that impacted on the development of Lodox. In so doing it provides a context for the analysis that follows in the second section. The second section turns attention to these factors and analyses the way in which they drove and facilitated the process described in the first section.

The concluding part of the paper puts forward some hypotheses as to key variables in the innovation and commercialisation process. It is hoped that in so doing the paper will lay the foundations for a more thoroughgoing analysis of the innovation process.

## 2. From ‘eureka’ to ‘it’s sold’

### 2.1 What is Lodox?

Simply put, Lodox is a low-dosage x-ray device that takes x-rays both quickly and with comparatively low x-ray exposure. It takes a full body image in 13 seconds; compare this to conventional x-ray procedures, which would take up to 45 minutes to generate the same detail. Furthermore, the conventional approach would generate multiple x-ray photographs of body parts that would ultimately have to be pieced together, as opposed to the single image generated by the Lodox device.

The fast low-dosage x-ray scans that are possible with Lodox could potentially revolutionise emergency-room treatment, as doctors are now able to obtain extremely rapid full-body images of trauma patients, which:

- Provide them with a detailed picture of the patient’s internal injuries; and
- Enable them to identify where the patient needs the most immediate intervention.

These advantages, in turn, mean that the survival chances of trauma patients are considerably increased. It is to understanding how this remarkable technology made the journey from South Africa’s diamond mines to the emergency room that we now turn our attention.

### 2.2 The beginning: from Scannex to Lodox

De Beers, the world’s leading diamond mining and marketing company, has always struggled to find ways to control diamond theft. Indeed, Brian Ainsley, operations director at De Beers, was quoted in a Sunday Times (25 July 1999) story, ‘Rays of Hope’, as saying, ‘During the ’80s, the viability of some of our mines was being threatened by the theft of diamonds.’ To combat this stock theft, De Beers used a mixture of physical searches and conventional x-rays. However, in the later 1980s, the International Commission on Radiological Protection (ICRP), a multilateral agency that promulgates international standards on safe levels of radiation exposure, reduced the level of what constituted safe levels of radiation exposure by 80%. In effect this meant that De Beers’ ability to search its employees was reduced fivefold. Put differently, the new legislative environment increased De Beers’ exposure to diamond theft by 500%. In reaction, the De Beers Research Laboratories were tasked with finding a solution to the risk now faced by the diamond mining industry.

At this point in the story two critical factors enter the equation. The first was Herman Potgieter, who was the catalyst for the think-tank searching for the innovation that became Scannex and who, over time, became the champion who drove Lodox’s technological development. For a while he was CEO of Lodox Systems, the company

that today houses the Lodox device, before taking the decision to become Chief Technical Officer, thereby giving himself the freedom to continue focusing on innovation instead of the administration of running a business. The second was the creation of an intellectual community that inspired the De Beers project team to explore the medical applications of the technology that they were to develop.

However, at this stage, i.e. *circa* 1990, Lodox as it is described above had not yet been thought of. The challenge facing Potgieter was to find a low-dosage x-ray device that would enable De Beers to detect efforts by employees to smuggle diamonds out of the mines.

The project team assigned to this problem defined the nature of the challenge confronting them as essentially one of human imaging. They needed to be able to generate an image of the entire human body that would be clear enough for the easy identification of smuggled diamonds. At the same time, this image needed to be generated within the parameters set by the ICRP, in other words it needed to be a low-dosage x-ray. At first, the De Beers team attempted to source technology that would be able to do this for them. Potgieter approached all the major medical equipment manufacturers with a project brief in an effort to entice them to manufacture such a device for De Beers. However, he was unsuccessful, as the manufacturers felt that the market for such an application was too small to justify the R&D expenditure.

After this failed attempt at purchasing the technology, Potgieter then led a fact-finding mission to assess the availability of human imaging equipment and technologies globally. At that stage, he was looking for a technology that could meet three key criteria (Interview: H. Potgieter):

- It had to give a picture of the full body (full body acquisition);
- It had to produce this picture at relatively low x-ray dosages; and
- It had to do so rapidly.

It is a critical part of the Lodox story to recognise that its uniqueness rests in the fact that these three criteria (essential to De Beers in the development of the Scannex technology) had never been recognised as important in the medical world.

This attempt at sourcing led the fact-finders to interact with a whole array of medical experts both internationally and domestically. Among these were medical experts and medical engineering experts from the University of Cape Town who worked at Groote Schuur, the academic hospital associated with the university. It was this group of people who were ultimately to convince the De Beers team that in addition to the security applications of the device that they had invented, there was also the possibility of very definite medical applications. Nevertheless, these efforts too were unsuccessful and Potgieter was compelled to build a team within De Beers to develop the appropriate technology.

The original technology developed within De Beers was able to produce an upright full-body image within the ICRP requirements, and to do so rapidly. This system was called Scannex. Because the system had implications for people's health, De Beers was required to get it medically accredited. This brought Potgieter back to Groote Schuur in about 1995. It was at this stage that the medical possibilities of Lodox were first discussed in earnest.

Professor Gerhard de Jager at UCT captures the dynamic as follows: 'It was really the need to have medical certification that led Herman [Potgieter] to the medical potential of Scannex' (Interview G. de Jager, February 2004). However, for the medical possibilities of the device to be realised, it needed to be re-engineered. Potgieter also explains that 'this was the days before "core business" was a priority, and it was thought that the medical imaging possibilities offered the potential to build a nice strategic business'. It was this confluence of forces that created the space for the conversion of Scannex to Lodox.

### **2.3 The development stage: enter SPII and the IDC**

Inspired by the enthusiasm of Groote Schuur's medical experts and also by the possibility of commercial returns, during 1994–5 the R&D team re-engineered the Scannex device and ultimately renamed it. The new prototype was called Lodox, and was placed in the Groote Schuur trauma unit, where it underwent three years of testing. Prof. Steve Benningfield, head of radiology at Groote Schuur, says that this version later became known – in a somewhat tongue-in-cheek way – as Oldox. He notes that Lodox at this stage 'showed promise, but didn't quite meet the grade'.

It now became clear that further development of Lodox would be required – a cost that De Beers was unlikely to bear on its own, despite the enthusiasm of the medical experts. Accordingly, the De Beers project team applied for funding from the Support Programme for Industrial Innovation (SPII) a programme established by the Department of Trade and Industry (DTI) and administered by the Industrial Development Corporation (IDC) to assist companies in the commercialisation of industrial innovation.

At this stage, three new important factors enter the Lodox story:

- Government supply-side measures, which facilitated further development;
- Bertie Strydom, the Industrial Development Corporation (IDC) manager, who was to become an important champion of Lodox and today represents the IDC on the Lodox board; and
- The IDC itself, which became the first investor in Lodox besides De Beers.

Bertie Strydom describes Lodox at this stage as 'having shown innovation and demonstrated the ability to succeed, but being very far from a commercial operation'. The SPII was the first step down the commercialisation road. SPII is a supply-side measure established by the Department of Trade and Industry (DTI) and

administered by the Industrial Development Corporation (IDC) to assist companies in the commercialisation of industrial innovation. Typically this means assisting in the funding of prototype development. Having secured this funding, the De Beers project team, together with the medical team at Groote Schuur, re-engineered the original Scannex device, and so an Advanced Demonstration Model of Lodox was born.

The Industrial Development Corporation, anxious to secure the intellectual property (IP) rights within SA, then approached De Beers with a joint venture proposal that sought to unlock the capital required to take Lodox to the next stage of development.

However, nine years into the process, with a considerable investment of human and intellectual capital (and the associated costs), and no returns in an area that was not their core business, De Beers were feeling ambivalent about their future with Lodox. Accordingly their priority was to dispose of the business and recoup their investment in its development.

The De Beers management approached all the big original equipment manufacturers, attempting to sell them the Lodox technology. However, they had invested so much in the development of Lodox that the upfront capital costs were too high for a direct purchase and so no-one would buy the technology. De Beers, driven by their desire to generate a return on their investment in Lodox, simply wanted too much – ten million US dollars for the technology. In Potgieter's words, 'It looked like the adventure was over.'

At this stage the relationship with the IDC, which had been forged during their role as the administrator of the SPII funding, became critical. De Beers' desire to recoup some of their investment, together with this relationship and the IDC's desire to secure the technology for South Africa, meant that they were able to reach an agreement that would see the further commercial development of the Lodox system. This agreement laid the foundations for the emergence of a new company, Lodox Systems, which would attempt to further the commercialisation of the Lodox technology.

## **2.4 An independent company is born**

One of the first steps taken by the IDC in its new role as investor was to co-fund a market study and also some actual marketing of the product at international trade shows. In both cases the results were positive, giving De Beers, the IDC and Herman Potgieter – the leader and champion of this technology – the confidence to forge ahead.

As the technology developed, two factors came into play. First, the IDC's continued investment in the refinement of the technology had led to a situation in which its equity was increasing to above 30% – the IDC's maximum threshold for a stake in a company. Second, it was becoming clear that it was necessary to find a partner who understood the medical equipment market. The IDC and Potgieter both felt that the company would benefit from having a partner that was able to provide input into end-

users' purchasing criteria. So started the search for a partner with knowledge and understanding of the medical market.

This search resulted in the entry of a third shareholder into Lodox Systems. This was Netcare Hospital Management (Pty) Ltd, which is a wholly owned subsidiary of Network Healthcare Holdings Limited, Africa's largest private hospital and doctor network. Netcare is the final piece in the explanation that appears in the following section of this paper.

Riaan van der Watt, Group Clinical Engineer at Network Healthcare Holdings, describes Lodox as being 'unique. It addressed a critical part of the emergency room workflow. It meant that x-rays could now happen simultaneous to resuscitation.' This innovation was of critical importance to the Netcare group, a specialist in tertiary healthcare provision, and the operator of some of South Africa's largest emergency rooms.

With Netcare's assistance and expertise building on the considerable work that had gone beforehand, Lodox Systems was able to place its first fully operational unit in Netcare's Milpark hospital, home to one of the busiest emergency rooms.

The major challenge that then confronted the company, and still does so, is penetrating the USA market. The US accounts for over 50% of total sales of medical imaging equipment, and thus success in that country is a prerequisite for success in this market segment. Given this challenge Lodox launched a marketing initiative. The marketing of the Lodox technology at international trade fairs was ultimately to lay the foundations for the opening of a Lodox subsidiary in the USA. This was a critical step in the product's development, as the US is the world's largest market for medical imaging equipment. Following Potgieter's participation in these trade shows he was contacted by William Greenway, who was the engineering head at one of the big and ambitious original equipment manufacturers (OEMs), and Kevin Oakley, a specialist in marketing medical technology, with a proposal to represent Lodox in the US. Thus the first steps towards establishing a US subsidiary were taken.

However, getting access to the USA market required that Lodox receive Food and Drug Administration (FDA) approval. By all accounts, obtaining FDA approval is an exceptionally time-consuming and costly exercise.

Bertie Strydom estimated that the average cost of conforming to FDA requirements is in the order of \$1.5 million – a cost large enough to put a halt to many attempts to commercialise medical technology.. Here again, the relationship with academia proved to be essential and Professor Steve Benningfield of UCT drove the clinical trials that underpinned this application. The unique of skills that now constituted the Lodox ensured that the technology sailed through the FDA process in eight months, at a cost of less than R1 million.



## **2.5 AMI: the Lodox child**

Running parallel to the birth of Lodox as an independent company was the creation of a second company, African Medical Imaging (AMI). AMI was created as a joint venture between Lodox Systems, National Accelerator Systems and the University of Cape Town. Professor Kit Vaughn, head of bio-medical engineering at UCT, was critical to acquiring the Innovation Fund support that led to the establishment of AMI.

It had two aims:

- To further explore the medical possibilities of Lodox with a view to advancing the technology's commercial possibilities; and
- To obtain and properly administer government supply-side support, in the form of the Innovation Fund.

Although Potgieter says of AMI that 'in the business sense it was not that successful', the AMI 'experiment' made its contributions elsewhere. Most notably it resulted in 12 postgraduate degrees being awarded to students who had worked on the Lodox project. Indeed, some of these students went on to work for Lodox Systems, and thus the project contributed to the country's intellectual capital.

## **2.6 Where is Lodox today?**

Today the Lodox device is operational in a number of US emergency rooms. The company, Lodox Systems, has established a US sales and marketing competency and in Strydom's words, 'Everyone is now watching closely. The next 12 months will be critical.'

## **2.7 Summary**

In the course of the last few pages, we have traversed approximately 13 years in the history of a technology, a business, the people and the social and institutional processes that led to what is tantamount to a revolution in emergency healthcare provision. This section of the paper has:

- Given a brief synopsis of the milestones in this process; and
- Highlighted the factors that are of significance in understanding the development of Lodox.

We now turn to trying to understand how these various events, role-players and institutions all interacted to bring about the emergence of this new technology.

### **3. The drivers of innovation**

In the first section of this paper, I attempted to highlight what key participants have identified as defining moments in the Lodox story. In this second section of the paper we turn to analysing those moments and their contribution to the innovation process in greater detail. In doing so, we face the enormous challenge of analysing and understanding what drove the development of Lodox, while extracting some themes that may inform a broader understanding of innovation, for, as Riaan van der Watt said, and as will become clear below, ‘It was a very very specific set of circumstances that drove this development.’ Nevertheless, as the reader will observe from the other case studies in this series, there are a number of general processes that they all have in common. The second analytical challenge that we face is that this story in fact represents a double innovation. First, we have the innovation that led to the creation of Scannex. Second, we have the innovation that transformed Scannex into Lodox. Associated with this second innovation are a series of events, forces and individuals that have been integral to its commercialisation. Much of this next section is focused on the second innovation and the commercialisation processes associated with it.

#### **3.1 Necessity is the mother of invention**

Regulatory changes and the risk of diamond theft were the first drivers of this innovation. This could be coupled to the fact that no medical equipment manufacturer has developed appropriate technology to meet De Beers’ needs. This initial driver contributed more to Lodox’s medical innovation than might be initially apparent. Van der Watt explains the impact that driver had:

To understand Lodox, you need to understand two things. The first was that the principles behind Lodox were not new; it was their application that was innovative. The second is that that innovation was driven by the fact that the De Beers team was working with a very clear objective. They had to generate a good image with as low as possible a dose. This meant they were operating with a completely different set of rules to those that normally applied to x-ray technology. The normal medical rules were that you had to generate an ‘as clear as possible’ image. As long as the radiation levels were within medically acceptable norms they were not an issue, as it was unlikely that the patient would be receiving regular exposure to x-ray (unlike the mineworkers, who would be x-rayed regularly).

In other words, the initial business driver changed the conditions under which the De Beers project team approached the question of human imaging. Because of these changed conditions, which meant that they had a different set of standards that they had to comply with, they came up with an entirely novel solution. The circumstances under which the De Beers team was operating led them to ask questions and search for solutions to the problem of quick, efficient, low-dosage, high-resolution images in ways that were fundamentally different from those taken by medical technologists in

the same field. Perhaps it is precisely because engineers drove the innovation team in a mining company rather than a medical company that Lodox came into being.

The lessons for innovation are twofold. The first is the self-evident part of the equation, namely that regulatory pressure, risk or any other form of environmental pressure can create the conditions under which innovation occurs. It is probably fair to say that there is no profound lesson for studies of innovation in this first point. However, the second part of the ‘necessity’ equation is more interesting. As Van der Watt points out, the principles were not new; but the project team was thinking about them in a different context, applying different rules to the medical environment. They were able to generate a unique solution. The changed ICRP regulations created the pressure for innovation, but it was the second aspect, the change in the rules and the context within which one thought about the challenges of human imaging, that led to the innovation, namely Scannex, which became the bedrock of Lodox.

### **3.2 A liberation of talent**

Like almost everything else in South Africa, Lodox appears to have been shaped by our political transition – albeit more obliquely than in other cases. With the demise of apartheid, many of the military-equipment manufacturing firms that had been supported by the state began large-scale retrenchments or simply closed down as the state’s defence-related expenditure dried up. As a consequence of these retrenchments, many highly skilled engineers suddenly found themselves on the labour market. Herman Potgieter recalls that the staffing levels of the core team surrounding the development of Scannex went from ten to 150 over approximately four years, as De Beers took advantage of the sudden availability of ‘large numbers of extremely smart people’ (as Potgieter puts it) (Interview H. Potgieter). The advantages of this sudden availability of engineering were many, but key to both the initial Scannex development and its later conversion into Lodox was the fact that De Beers employed a community of engineers who all had considerable experience in different parts of the development process. Gerhard de Jager of UCT commented: ‘If you wanted to do that today [develop Lodox] you wouldn’t be able to, because the people simply aren’t around.’ Thus it seems that the process of political liberation and the subsequent demise of the apartheid military complex unleashed a wave of intellectual resources that in some sense gave Lodox the impetus it needed to carry itself through the initial development phases.

Nevertheless the disruption that occurred was not without negative consequences. Potgieter notes that “although the country maintained some of this talent the vast majority left the country”. He tells an anecdote of looking for a specific electrical engineering skill that he knew four South African’s had. Every single one that he knew had by the mid 1990s left SA. So, although De Beers (and ultimately Lodox) was able to reap the benefits of the disruption the country probably experienced a net loss of intellectual capital.

### **3.3 Intellectual communities**

The story of Lodox is the story of a series of key events that simultaneously open up the possibility of new relationships, which in turn have added enormous value to the project. In many respects it is the second moment, the moment when the initial contact is converted into a relationship, that is more important to the story than the actual event is.

The key moment–relationship conversion points in the Lodox story have been:

- The initial contact with Groote Schuur to assess whether the technological knowledge for challenge facing De Beers existed created a community for converting Scannex to Lodox;
- The drive to obtain additional funding for Lodox, which converted into a relationship with the IDC in which the IDC became key to the commercialisation of the project;
- The search for new equity partners, which introduced Lodox to Netcare, the company that became integral to obtaining FDA certification; and
- Participation in trade events, which converted into relationships that formed the basis for launching a subsidiary of Lodox in the world’s largest medical equipment market, the US.

Thus, when we examine the events in the innovation process we need to be aware that they contain a duality of possibilities, one that pertains to the event itself and a second that holds a whole range of other possibilities that follow from the relationships forged through the event. Indeed it is quite likely that it is in the latter part of this duality that the true drivers of innovation lay.

### **3.4 The medical community**

Lodox’s engagement with the medical community is the archetypal example of the duality of event and relationship. Herman Potgieter, himself a key factor in understanding the innovation process, attributes Lodox’s progress from the security checkpoint to the emergency room largely to the encouragement, engagement and support that he received from the medical community. Bertie Strydom of the IDC is equally convinced of the importance of the role of the medical community. He calls De Beers’ ‘discovery’ of the medical application ‘accidental’ and says that it was the relationship developed with medical experts that was the ‘catalyst’ in the further development of Lodox.

Just as the different context in which the De Beers engineers and designers were working enabled them to see applications that medical practitioners had not conceptualised, so the medical practitioners’ own world enabled them to see applications for the security-scanning device that may otherwise not have been pursued by the De Beers team.

In a more abstract sense, it was the interaction of two different intellectual communities that provided much of initial impetus underpinning the innovation. Both intellectual communities saw different possibilities based on their own contexts and it was the meeting of these communities that made Lodox possible.

### 3.5 The role of De Beers

As important as the two previous variables are to understanding the Lodox story, they are – from one perspective – the least important part of the Lodox story. This is because the interesting part is not so much the technological innovation – in a brief interview Riaan van der Watt mentioned at least three other medical technology innovations that he was aware of – but the fact that the innovation has become commercialised. In understanding this it is essential to understand the role of De Beers. The key actors in this story were unanimous in their opinion that Lodox would not have seen the light of day if it had not been for De Beers' initial involvement in the project. Interestingly, though, the role of De Beers was more complex than simply that of the noble benefactor with deep pockets.

#### 3.5.1 *A moment in time*

The reasons for the Scannex innovation are quite clear. De Beers needed such a device; no one else had made one, so they had to make it themselves. The interesting question is really why a diamond mining company decided to invest so much time and money into developing Lodox, a medical device.

First, there was space within De Beers for the exploration of the Lodox project. Potgieter puts it as follows: 'If De Beers was as strategically focused as it is today, Lodox would not have happened.' Steve Benningfield captures it slightly differently by saying, 'Those were the days of lots of surplus cash and lots of staff.'

In addition, De Beers saw Lodox as:

- A potentially lucrative project that might generate some returns on the investment in developing the Scannex technology; and
- An opportunity to demonstrate a broader social commitment. As Gerhard de Jager puts it, 'X-raying people is a bit of a no-no. Lodox was an opportunity for them (De Beers) to show a commitment to the "greening" of De Beers.'

Interestingly, De Jager believes that, notwithstanding all these enabling factors, it was Herman Potgieter who ultimately made the difference to De Beers' willingness to pursue the Lodox project. He argues that because Potgieter had established considerable credibility with De Beers' senior management, he was given the space to explore a project that perhaps other less gifted and credible individuals would not have been given. Thus it was the combination of organisational and individual variables that opened the space to further the Lodox adventure.

### 3.5.2 *Intellectual capital*

Taking a product from concept to market is a complicated, multi-stage undertaking. In its crudest form it follows a path from idea to concept, to prototype, to an advanced demonstration model, to redesign, to commercialisation and implementation. Inevitably each stage in the development process calls on a whole new set of skills, experience and knowledge. For this reason, the fact that Lodox was being developed by De Beers stood it in good stead, as the core project team was able to draw on a wealth of innovation experience and expertise around them as the project developed. Van der Want notes, 'A project of this nature requires a high level of engineering skill, that in turn needed concentrated time to work on the project.' In its De Beers home Lodox had access to precisely this level of skill. Van der Watt went on to say, 'The crux of the matter is that as an engineer you really need to have been involved in a development process three or four times to create the knowledge necessary to take a product through the entire innovation cycle.' In the De Beers laboratories, Herman Potgieter had access to precisely the sorts of people who had such experience. In contrast, most technology start-ups do not have access to such a wide array and depth of skills and so often founder at a particular stage in the development process.

### 3.5.3 *Finance*

De Beers' financial contribution is perhaps the most obvious driver of this process. The terminal illness of most technology firms is brought about by a combination of over-investment in the development process, slowness in getting to market, and, ultimately, choking to death on a lack of cash flow. Because it was part of De Beers, Lodox did not have these problems; as Strydom puts it, 'The development costs were small money in terms of De Beers' overall operations.' Perhaps the costs would have been enough to starve a smaller company to death, but the fact that the development took place in an environment where there was no immediate pressure on cash flow or from shareholders hungry for a return on investment meant that the Lodox team could continue to develop the technology and refine it without too much risk.

Ironically, De Beers' lack of rigour in monitoring the extent of their investment meant that when they ultimately decided to dispose of the technology to recoup their R&D investment they were unable to find a buyer, as (in Strydom's opinion) they 'totally over-valued' the worth of the company.

Because they valued it in terms of what they had put into it as opposed to what the medical equipment manufacturers were originally prepared to offer – keeping in mind that these were the same companies that ten years earlier had thought there was no market for such technology – they were unable to find a purchaser and so were almost compelled to enter a joint venture with the IDC to begin the process of divesting themselves of the Lodox technology.

### 3.5.4 Summary

A series of events facilitated De Beers' involvement in Lodox, the most important of which were the influx of considerably advanced engineering skills into the organisation, coupled with a greater openness to experimentation than may currently be the case in many organisations that have reoriented themselves to focus on 'core' business.

These enabling factors allowed De Beers to have a profound impact on the development of Lodox:

- By giving the project team access to a whole range of engineering expertise appropriate to each stage in the development process; and
- By removing the immediate financial pressures of cash flow and returns to shareholders that have sounded the death knell of other good ideas.

De Beers continues to have a stake in Lodox, but it is seeking to dilute its interest. Potgieter describes the company's continued involvement as a 'goodwill gesture'.

## 3.6 Supply-side measures

In the course of Lodox's development the company had access to two supply-side measures – the SPII and the Innovation Fund. Interestingly, in addition to the financial assistance that they provided, both played an important 'signalling' role. In other words, the fact that Lodox was able to access this money gave it credibility both with existing and potential investors and with possible clients.

### 3.6.1 *The Support Programme for Industrial Innovation (SPII)*

SPII played a dual role in the Lodox story. After three years of testing the Lodox prototype in Groote Schuur it had become apparent that the product would need to be re-engineered if it was to take the next step towards being a commercially saleable product. At this stage, it seems that the De Beers senior management were already having second thoughts about the medical road that they had taken. The awarding of the SPII facility provided a valuable injection of cash into the project, but equally importantly, it was a vote of confidence in the viability of the product. SPII is only awarded after the IDC has conducted a comprehensive assessment.

Herman Potgieter says, 'I am two-thirds sure that it was the fact that we received SPII that gave De Beers the confidence to go forward with Lodox. It said to them that other people believed in the project.' Over and above playing the role of log-jam breaker, the SPII money also advanced the development of Lodox to a point at which the IDC could get involved in the project, by providing assurance that it had moved beyond the R&D stage and was ready for industrial development. Thus SPII provided De Beers with the security to continue their investment in the technology, and ultimately it took it to a stage where the product was attractive to other potential investors.

Perhaps as important as the money that SPII brought and the confidence that it created, its location within the IDC added a whole new dimension to the Lodox story. The IDC were the administrators of the SPII fund, but by virtue of their role in industrial development they soon took on a more proactive role in Lodox than simply asking for report-backs on the expenditure of supply-side money. The IDC, through its representative Bertie Strydom, developed a ‘hands-on’ relationship with the De Beers team leading the development of Lodox. Potgieter says that the IDC’s involvement was key to encouraging the further development of the project and providing valuable direction in furthering the commercialisation of the Lodox technology. Strydom describes the IDC’s role as playing ‘the catalyst of marrying everybody’. Importantly, though, he goes on to note, ‘We can only play that role if we know what’s out there. I think that 50% of these big companies are sitting on technologies that could be converted into good products.’ In this respect the location of SPII within the IDC was a critical decision as it provided an environment within which industrial development is a key organisational imperative. Accordingly, the administrators are interested in more than merely ensuring compliance with the terms and conditions of the fund, but are in fact capable of pursuing the industrial development potentials of the technological innovation, and, in a sense, they have an incentive to do so.

### *3.6.2 The Innovation Fund*

The Innovation Fund was less critical to Lodox’s commercialisation drive, as it primarily drove the exploration of new potential, that is, it was trying to break new ground for the project rather than furthering the primary thrust of the innovation and commercialisation. Nevertheless, there are some interesting insights to be derived from examining the role of this supply-side measure in the Lodox story.

As with SPII, it seems that the Innovation Fund provided an important signalling role in the life of Lodox. Herman Potgieter says that the Innovation Fund was ‘nice to have’, but more significantly he believes that it was ‘incredibly important to give us international credibility’.

However, aside from this benefit, it is important to keep in mind that the SPII and the Innovation Fund also have different objectives, with the latter seeking to support collaboration between the private sector and universities with a view to increasing the country’s intellectual capital. In this respect, it appears that the Innovation Fund was a success, as it generated a number of postgraduate degrees. Lodox benefited directly from this, as it was able to employ graduates from the programme.

## **3.7 The shareholders**

In addition to the intellectual support provided by the medical community, Lodox’s shareholders have been integral to advancing the product from a prototype to a saleable product.

### 3.7.1 *The Industrial Development Corporation*

The IDC differentiates itself from many institutional investors in the South African context by the fact that '[i]t has a higher tolerance for risk' (Interview: B. Strydom). As described above the IDC played an integral role both in facilitating the migration of the technology out of De Beers and in introducing new investors to the undertaking. Undoubtedly the presence of the IDC on the South African institutional landscape provided an important exit strategy for De Beers while simultaneously ensuring the continued development of Lodox. One has to ask whether, without it, Lodox would not have simply died a quiet death in the De Beers Labs, given the failure of De Beers' attempts to sell the technologies.

However, the IDC's role was broader than simply that of a provider of finance. As discussed above, its initial role as administrator of SPII and its commitment to the Lodox project gave the Lodox management much-needed moral support to continue tackling the challenges that they faced. Over and above these two roles, the IDC introduced what Strydom calls 'a business urgency'. He recalls that De Beers was characterised by a 'strong R&D mindset', but had less understanding of the commercialisation process. The IDC brought this expertise to the project. Here again we see the 'double movement' of an event or process leading to the emergence of new social, intellectual and business relationships that move beyond the immediate event. Riaan van der Watt says that the IDC's role was 'massive, except for the miracle of Herman convincing De Beers ... this was the second half of the miracle. Lodox would not have happened without the IDC's involvement.'

Indeed, it is after the involvement of the IDC increased that market feasibility studies, attendance at trade shows and an aggressive search for appropriate partners become part of the Lodox story. Before the IDC's involvement the story is very much one of prototype development, exploration and improvement. Strydom identifies this as a generic weakness of companies driving technological innovation: 'There is a tendency to over-engineer, to invest too much capital in the development when really you need to get it to market as quickly as possible.'

Thus it was the marriage of the innovation in the De Beers Laboratory with the commercial mindset, expertise and instincts of the IDC that enabled Lodox to take the next step in the commercialisation process, a critical component of which was the introduction of Netcare as a shareholder.

### 3.7.2 *Network Healthcare Holdings (Netcare)*

Netcare's involvement brought a valuable understanding of the medical business to the Lodox project, enabling those involved to develop more effective market penetration strategies and was thus a critical element in furthering the commercialisation of Lodox.

## 3.8 Summary

Both of Lodox's new shareholders have been critical to furthering the commercial viability of this innovation. Undoubtedly the fact that the IDC is slightly less averse to risk than conventional investors is an essential component in understanding Lodox's development, as it is that tolerance of risk that enabled it both to assist in the commercialisation process and to introduce Netcare as a key shareholder. Thus it would appear that having partners that understand commercialisation is an integral part of a successful innovation process.

### 3.8.1 *The champions*

The final drivers of this innovation that are worth considering are the people who made Lodox happen. Importantly, there appear to be different champions at different stages of the Lodox story. Their status as 'champion' is in large part derived from the fact that they brought particular skills, enthusiasm or resources to the project at appropriate times.

Undoubtedly the figure that looms largest in this story is Herman Potgieter, the person who drove the original search party that culminated in De Beers' first developing Scannex and subsequently Lodox. His role was that of the archetypal champion, driving the concept and the vision of this new product. His own explanations for his role are his intellectual curiosity and his desire to innovate and to drive a development that he believed in. However, it appears that it was also his credibility within De Beers that gave him the space to be a champion. Gerhard de Jager notes that 'Organisations give you space when you exercise discretion and have technical competence. Herman had established both so he had greater freedom to pursue things.'

Potgieter himself does not cast himself in the champion role, preferring instead to give that mantle to Bertie Strydom. Strydom, similarly, does not accept the title, preferring to explain that all he did was to bring a set of skills to bear at an appropriate time in Lodox's evolution.

Although it is tempting to explain the responses of both these champions as simple modesty, there is an interesting truth in both of them. In the quotation in the section on the Industrial Development Corporation above, Van der Watt refers to the two men as equal parts of the Lodox 'miracle'. Therein perhaps lies the key to the 'championship' role – it is about having the appropriate skills at the correct moment in the company's evolution. No doubt there are deeper and more profound individual reasons that drive people to adopt this role – in Potgieter's case it was intellectual curiosity, an explorer's mindset – but equally important is the fact that different cycles in the process of innovation and commercialisation require different sorts of champions.

This section concludes the discussion of the drivers that are critical to understanding the evolution of Lodox from a solution to a stock theft problem to an integral part of emergency room treatment. The journey appears to have been characterised both by

happenstance and by some systematic pursuit of commercial opportunity. Now that we understand both the Lodox story and how the various elements of the story got Lodox to where it is today, the paper will attempt to derive some potential lessons for innovation, which it may be possible to interrogate further as the RBTC project unfolds.

## **4. Lessons for innovation**

The previous sections of the paper have reviewed the specifics of the Scannex and Lodox stories and have also sought to identify the key drivers of this innovation and commercialisation. In this concluding section of the paper, an attempt is made to abstract from the specifics of the Lodox case to broader trends that may be of use to the development of policy, process and institutions for driving innovation.

### **4.1 Multiple networks**

If anything, this story is one of multiple networks. Because of a particular set of demands, the De Beers laboratory transformed existing technologies in a way that had not been conceptualised by the medical community because they thought about human imaging within a particular set of rules, the rules of their network. The De Beers network had different rules and conventions, which created the space for the original innovation. Their relationship with a medical network ensured that Lodox's medical possibilities were identified and realised. The relationship that emerged with more commercially oriented role-players – the IDC and Netcare – meant that Lodox was able to migrate from technological innovation to product. Each of these networks contributed something unique to the Lodox story, and if either of them had not been present, it is unclear whether Lodox would have advanced as far as it has. So clearly the creation of multiple networks, and the encouragement and perhaps support that they give, appear to be critical to the overall innovation process. We have already quoted Bertie Strydom as saying that there are no doubt many technologies whose commercial potential has not been realised because they are housed within big companies' research divisions. The lesson for policy has to be that if we wish to reap the benefits of technological innovation we need to find ways to foster multiple relationships to ensure that all the possibilities of an innovation are realised.

### **4.2 The duality of events**

In the second part of the paper much was made of the fact that each event in the Lodox story in fact triggered the development of a series of social relationships that became integral to Lodox's development. If we take seriously the above policy lesson, that we need to find ways to foster multiple relationships, then we need to find out what triggers those relationships. In other words, key drivers of the National Innovation process need to guide events with the ultimate objective of building social relationships that may advance the innovation process. There are a number of existing opportunities in the public space; two examples are Trade and Industry South Africa's (TISA's) Export Marketing and Investment Assistance (EMIA) scheme, which sponsors participation in trade fairs, and the DTT's Innovation Awards. Such schemes and a myriad of others offer a platform for the advancement of social relationships or the creation of intellectual communities that ultimately underpin any innovation process.

### 4.3 The ‘signalling’ effect of supply-side measures

Indisputably the supply-side measures were a key component in the creation of relationships that fostered the development of Lodox. However, just as importantly, they played the role of signalling to potential and incumbent investors that the project was potentially worthwhile. Therein lies an important lesson for policy processes surrounding innovation. Often the call for support is a call for increased public-sector funding of the innovation or commercialisation process, but intriguingly the Lodox story shows that there are two elements to the supply-side story. Obviously the money is critical but equally critical is the signal that the supply-side provides to investors that a project might be worth investigating. For this reason it seems essential that supply-side support only be awarded after a fairly rigorous assessment process, the nature of which is also communicated to the investment community. This would mean that the award of a supply-side measure was a mark of approval for a project, thus making it easier to obtain private-sector support.

### 4.4 Institutions matter

For both of the reasons that constitute the ‘duality of events’ and the signalling role that can be played by supply-side measures, it is essential that supply-side measures and related events are located within institutions that have the organisational skill, capacity and imperatives to advance the project. The location of SPII within the IDC is a critical component in the Lodox story. The relationship forged with the IDC by virtue of SPII ultimately led to the introduction of two new shareholders, who have been critical to ensuring the migration of Lodox out of De Beers. SPII location within the IDC ensured that its role was not simply one of funding but also one of catalysing. It would seem that the process of innovation could be furthered by creating relationships between government supply-side measures and institutions that are able to play an active role in commercialising the undertaking. As Herman Potgieter put it, ‘The IDC didn’t just give us the money, they were continuously involved.’

Conversely, the Innovation Fund experience, although a substantial success in that it created considerable intellectual capital, seems to have contributed less to the major South African challenge, namely the commercialisation of good ideas. Although it is beyond the scope of this paper, it seems fair to hazard a guess that this may in part derive from its institutional location within the National Research Fund, an organisation that has little experience with the commercialisation of innovative technologies, and little reason to acquire such experience, as its purpose is different. Accordingly, it would seem that if the *raison d’être* of the National System of Innovation is to advance this kind of commercialisation, the system of incentives and rewards should ideally be closely aligned to or linked with organisations that have the desire and capacity to add value to the commercialisation process.

## **4.5 The money**

The key participants in the Lodox case all refer to its uniqueness. The overwhelming sense one gets is that it would be exceptionally difficult to replicate the processes that led to this innovation. One of the main reasons for this is the role of De Beers. De Beers was exceptional in that it provided the process with enormous intellectual capacity, and was also a fairly flexible shareholder, providing the company with strong cash flow. Without this initial support it is doubtful whether Lodox would have made it as far as it did. The policy implications are difficult, because they mean that one needs to find instruments that aid cash flow or enable companies to reduce their financial risk by providing some kind of compensation. The difficulty of this is the risk of supporting harebrained schemes that may never contribute in any way to the creation of national wealth.



## 5. Conclusion

This paper has explored the development of Lodox from the conception of the idea through to its current attempts at achieving large-scale entry into the USA market. The innovation was driven both by design and by accident. However, what is most apparent is that there are two periods, each of equally critical importance, in the innovation cycle – the initial technological innovation and the long road of commercialisation. The irony is that if too much is invested in the first process then the second process is doomed from the outset.

In closing, I wish to return briefly to the various areas of understanding that we explored through the prism of this case study.

This case has clearly shown that the primary **organisational conditions that foster innovation** are:

- A willingness to explore ideas outside of the immediate core business;
- A depth of intellectual resources that enable the project to advance from one developmental stage to the next;
- The presence of a key individual or individuals that have the passion to pursue the project and, importantly, the trust of their organisations; and
- Broader social relationships that deepen the intellectual base on which the project is founded.

In the Lodox case, supply-side measures played an important role in the **processes of interaction between government and the private sector in innovation**. The most important aspects of this were:

- The introduction of the IDC, which played a critical role in the commercialisation of the project; and
- The signalling effect of the SPII fund, which enabled Potgieter to secure De Beers' continued engagement in the project.

Perhaps the central lesson that emerges from the interaction between government and the private sector in this case is the importance of ensuring alignment between the measures and institutions that can aid the innovation process.

The findings of the case study are unclear as to whether the **existing policy and supply-side environment actively fosters innovation**. In the case of SPII it did not so much foster innovation as further it. The involvement of the Innovation Fund falls more squarely into the 'fostering' environment, as AMI was deliberately structured in order to access Innovation Fund money. In other words Lodox and UCT responded to the policy imperatives encapsulated in that supply side. However, one is left with a sense that there was lost potential because of the institutional housing of the

Innovation Fund. Although it did achieve successes, it perhaps was not as successful as it might otherwise have been.

This paper's final objective was to discern the **key variables in the journey from innovation to commercialisation**. It has discussed each of the key variables for Lodox. It is crucial to recognise that there are a series of 'do or die' moments along the innovation path, and the failure to seize these moments can destroy the innovation, no matter how compelling the idea. Lodox is currently faced with such a challenge as it attempts to build and consolidate a critical presence in the US market. Only if this is achieved will we truly be able to say that Lodox is the Charlize Theron of South African innovation.



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**RESOURCE-BASED TECHNOLOGY  
INNOVATION IN SOUTH AFRICA**

**CHAPTER 2:**

**Multotec Process Equipment - dense medium cyclone  
for materials separation**

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## **1. Introduction: background on Multotec**

Multotec Process Equipment (MPE) manufactures various types of machinery for the separation of different media, such as ores and coal. Its largest area of operation is the manufacture of cyclones. These machines use centrifugal force coupled with fluid dynamics to separate media of different densities. MPE is a leader in the development of cyclones, and, in addition to dominating the local market, it also exports a substantial proportion of its output. The research and development that is the focus of this case study relates to two activities. One is the product development which has placed it in a leading position. The second is its construction of a full testing facility, which received financing from the SPII.

MPE is an interesting case, partly because it has used the SPII twice, once with a successful development and once with a development which did not meet its goals. The successful development is the testing facility for cyclones for dense-medium separation. The unsuccessful development is also for materials separation, but this time related to a new spiral for the processing of coal. The manufacture of spirals and the manufacture of cyclones fall under separate divisions. As will be seen, the SPII support for the spiral did have positive spin-offs despite not ultimately meeting its main objective.

Multotec Process Equipment is part of a large group, which has majority German ownership (though MPE is not integrated into the German firm).<sup>1</sup> It has several divisions, including the one that manufactures cyclones. Seventy-five people are employed in MPE overall, with 31 employed in developing and manufacturing cyclones. Of the turnover, 64% is from cyclones.<sup>2</sup> (Seven hundred people are employed globally by the German parent company.) MPE's total turnover has grown strongly in most years (Table 1), reflecting its strong position in the local market, and growth in its exports.

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<sup>1</sup> Multotec Pty Ltd is 66% owned by Stafag Holdings AG and 34% owned by local shareholders. Stafag Holdings and Multotec Pty are each 50% owners of Multotec Manufacturing, which in turn holds 75% of Multotec Process Equipment Pty Ltd.

<sup>2</sup> Calculated from 2002 data, which are given in Table 2 for cyclone sales.

**Table 1 – Multotec Process Equipment: turnover and R&D expenditure**

	1999	2000	2001	2002	2003	2004*
R&D Exp. (Rth)	439	660	960	560	450	550
Turnover (Rth)	56,343	70,892	60,800	65,300	82,000	90,000
Turnover growth, %		25.8	-14.2	7.4	25.6	9.8
R&D, % of turnover	0.7	0.9	1.5	0.8	0.5	0.6

\* *projection*

MPE's main motivation for developing firm-specific capabilities and making ongoing innovations is the local demand from industries, principally mining, for equipment to meet their specific needs. This demand has provided the base for export capabilities. At present, approximately 30% of output is exported. The main markets are Norway, Russia and Australia. The firm is also looking at breaking into the South American market.

Although MPE does not have a separate R&D division, a significant proportion of its resources, efforts and people are directed towards research, and it has good links with institutions such as universities. Although R&D expenditure has remained at 1.5% of turnover or less (Table 1), this does not include the expenditure on the testing facility supported by the SPII. The money spent on R&D also does not include the salaries of MPE staff who are responsible for ongoing product development and customisation of products to meet the needs of users. Altogether, MPE employs seven qualified process engineers.

Despite the apparent success of MPE on the back of quite low levels of R&D, its experience nevertheless raises a key issue concerning the need for more responsive facilities able to undertake or support shorter-term research to complement fundamental research. This directly talks to the need identified by Department of Science and Technology to define and take forward a new R&D vision and follow through to commercialisation of the outputs.

## 2. Overview: the innovation

### 2.1 Cyclones

A cyclone is a machines used for separating materials according to density through the action of centrifugal force as they are fed into a cylinder at velocity (created by pressure). A strong vortical flow is created within the cyclone, resulting in the heavier material being moved outwards towards the wall, and downwards in a spiral path to the lowest point, where it is discharged. The lighter material is taken upwards by the reverse vortex created and is removed through an outlet at the top.

Cyclones have generally been used for separating a little waste from a majority of 'good' material. The important thing that makes the high-density cyclone different is that it separates a majority of waste from a small amount of 'good' material. This makes it useful, for example, for the reprocessing of mine dumps, where a large amount of waste material has to be sifted through.

The challenge of processing large amounts of waste with a cyclone is that the exit at the bottom for the higher-density waste material constrains the speed of operation, as the great majority of material now has to exit via this route rather than from the top. The cyclones developed by MPE experiment with faster exits at the bottom of the cyclone, including a side exit.

The innovation and product development in cyclones requires a combination of advanced computer modelling capabilities together with the ability to test different designs. The manufacturing of the cyclones themselves has to meet specifications, but does not require especially advanced manufacturing capabilities in itself.

Most of the cyclones made by MPE are for use in the mining of gold, platinum, diamonds and coal, although some are used in the processing of chemicals. There are also potential applications in areas such as separation of foodstuffs. The materials to be processed largely determine what the cyclone is made of. Cyclones are mainly made of steel, and lined to be more abrasion-resistant, although MPE also makes some cyclones out of polyurethane (this is set to develop further).<sup>3</sup>

The cyclone division has been engaged in a series of incremental, and more radical, developments to the cyclone, driven largely by the lead process engineer, who was until 1994 head of Iscor's research and development section. The development involves computational fluid dynamics – applying advanced mathematics in computer modelling, experimentation and testing.

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<sup>3</sup> The research programme on the spirals involved experiments in casting polyurethane. These techniques are now being applied to cyclone manufacture.

## **2.2 Product lifecycle and ongoing innovation**

The product (the cyclone) lasts for two to three years and the life-cycle of the technology is estimated to be around five to eight years. Small changes in the specifications of the cyclone can have quite large impacts on the efficiency of its operations, which have potentially very large returns for customers processing valuable metals. This means that customers are going to be continually looking for the best specifications.

These factors together mean that ongoing product development is crucial for the success of the firm. This is also reflected in profit margins, which are very good relative to the material input costs of making cyclones.

Multotec's two main competitors are a South African subsidiary of the major USA manufacturer, Krebs, and a second firm, Linatex, which has used the Krebs designs and empirical results in its own manufacturing.<sup>4</sup> Linatex produces almost entirely for the local market and sees itself to be mainly competing in terms of price, as it does not have ongoing R&D related to cyclones. Krebs undertakes extensive R&D work in its USA home base.

## **2.3 The innovation**

Rather than one single innovation, it is MPE's ongoing capabilities in product development which are evaluated here, including the radical innovations in the design of the shape and structure of the cyclone. In recent years these have changed the shape of the cyclone to increase velocity and lead to a better flow. As explained in the introduction to this section, a side exit at the bottom has also been introduced for the heavy material.

For the SPII, Multotec's key innovations are those that advance the dense-medium separation capabilities, precisely because of the potential linkages with the reprocessing of mine material. The development supported by the SPII is the construction of a full on-site testing facility. The test rig was completed towards the end of 2003 and is the only one of its type in southern Africa. It stands three storeys tall and enables controlled testing of different types of cyclone, changing variables such as pressure and flow. It will enable Multotec to develop a new generation of more efficient cyclones.

The R&D expenditure, at around 1% of turnover, consists of approximately R100,000 per annum on experimental work, and R600,000 per annum on the modelling of

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<sup>4</sup> Linatex is a subsidiary of a UK-listed firm, with operations in several other countries. Its technological strengths in process equipment are focused on the manufacture of screens for sorting ores. Its other main operation is the manufacture of high-quality rubber, which is used to line the cyclones, giving it a specific edge.

computational fluid dynamics, which is mainly conducted at the CSIR. In addition to these expenditures, there is the construction and operation of the testing facility. The construction cost was R540,000 (half of which was financed by the SPII under matching finance arrangements).

## 3. Incentives and drivers of innovation

### 3.1 Motivation for internal capabilities

As will be seen in section 4 below, the commercial returns to MPE's investment in R&D capabilities appear to be very good. Obviously, financial returns are an important driver for innovation. Yet firms differ greatly in their success in innovating and the path followed in developing their production capabilities. In the case of MPE, analysed here, financial returns do not provide a strong explanation of why innovation was pursued and was successful. Rather, there are particular salient factors which have underpinned MPE's decisions.

Although MPE's commercial returns have been very good, they also partly derive from the relatively low production costs in South Africa. Several competitors produce under license or are local subsidiaries of international firms like Krebs. These firms have a fixed range of products and do not undertake the same level of in-house design (in South Africa) and ongoing development as MPE.

The key motivation for local in-house capabilities has been the specific demands of South African mines. MPE has emerged as the leader in making customised products to order rather than 'off-the-shelf' products. This itself requires design capabilities. Ongoing innovation has therefore been mainly driven by MPE's objective of building and then maintaining its domestic market position, based on in-house capabilities.

The innovative dimension, however, did not originate as an explicit firm strategy determined by senior management. Rather, it derives from the group of people employed and their backgrounds. Instead of a defined research function, the development of an engineering team was motivated by the strategic decision to provide extensive after-sales support to customers. This team became involved in R&D as a natural consequence of solving customers' problems.

MPE did not identify R&D as a separate function until recently, and had no R&D division or section, nor did it have a development manager. Development tasks were assigned on an *ad hoc* basis. The R&D spend is no higher than 1.5% of turnover, but 10% of employees in the cyclone division are involved in R&D (most of the skilled/professional staff), and in MPE as a whole there are seven qualified process engineers. Recent appointments also include an engineer with a PhD. Staff involved in research and ongoing innovation therefore represent a significant proportion of the total, given that a good many of MPE's activities are fairly routine manufacturing functions. R&D expenditures are therefore higher than the 1.5% of turnover the firm itself identified.<sup>5</sup>

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<sup>5</sup> And, for example, the manager of the spiral division estimated internal and external R&D spend to be equivalent to 4.5% of turnover when the salaries of research-related staff were included.

At an individual level, the senior process engineer, who has now been appointed development manager, was more experienced than might have been expected for a firm of this size. This was as a direct result of the declining R&D spend in large South African companies during the 1990s, which has been widely observed. Until 1994 the MPE development manager was the head of Iscor's Research and Development department. When Iscor was restructured, its research activities were dramatically cut back, enabling MPE to attract a very experienced research manager.

The evolution of research capabilities can therefore be seen as a combination of 'push' influences internal to MPE and demand-side 'pull' factors from mining in particular. Each of these influences implies the importance of testing facilities. Such facilities are required for the customisation of designs to different customers' specific needs. The internal employee-driven interest in R&D also requires testing facilities in order to progress. Before the testing site was constructed in 2003, the lack of suitable facilities meant that prototype cyclones had to be tested *in situ* (generally in a mine), following the computer modelling. The identification of a specific development path around capabilities of design and customisation led to MPE's plan to construct their own testing facility and the application to the SPII concerning this.

Demand for the testing facilities is indicated by the fact that MPE already has more than a year of testing planned, in the form of 12–15 potential projects, even before the testing facility is complete.

### **3.2 The Support Programme for Industrial Innovation (SPII)**

In interviews the availability of SPII funding was reported as a major motivation for the testing facility that MPE required in order to build its innovative capabilities. Questions about the counter-factual remain, however, as the returns appear to justify investment in a facility by the firm itself (i.e. without support from the SPII or other programmes). But the size of the investment, and uncertainty about the quantifiable benefits, plausibly suggest that without the SPII support it would have taken much longer to realise the testing facility. In MPE's case, therefore, the SPII programme appears to have played a reinforcing and encouraging role.

MPE's SPII application for the cyclone testing facility was made in September 2002 and provisionally approved in December 2002. The last milestone (the operation of the testing facility) was reached at the end of 2003. The provisional acceptance of the proposal by the SPII was conditional on the ending of the unsuccessful SPII-supported development of a new spiral column for the processing of coal (see section 3.3 below). This had been overly ambitious and had failed to progress as expected.

There are four elements for qualification for a SPII grant:

- The project must be innovative (either in its products or its processes), and marketable;

- It must be financially viable. The company must fund both its own portion of the project and the SPII portion, as the SPII grant is made retrospectively;
- The firm must show that it has the necessary technological and human resources, including managerial ability in product development; and
- The research project must be designed to serve more than one customer (as the research cannot be for within-group purposes, nor can it be basic research which is not targeted at commercial projects).

Crucial to the success of MPE's application for the testing facility was the fact that it would allow the development of dense-medium cyclones suitable for reprocessing mine dumps. The financial viability and firm capabilities were well established, and the research was clearly directed towards products that would serve more than one customer.

The SPII rationale of supporting risk-taking means that failures are expected. As the case of MPE's spiral development programme demonstrates, the failure of a project also does not prevent a firm accessing SPII funding for other innovative ventures.

### **3.3 The coal spiral case as a comparison**

Spirals are used to separate heavy minerals from shales and sort them into different sizes. While the principle is relatively simple – that if a mix of material is churned the smaller sizes will move towards the centre and up the spiral – the effectiveness depends on the exact profile of the spiral itself. Multotec conducts ongoing research in order to refine its spirals, and it patents its incremental improvements. It is a major producer, rating itself the second-largest supplier of heavy-mineral spirals in the world, and the largest supplier of coal spirals. Exports are approximately 35% of output.<sup>6</sup>

The spirals are currently manufactured by spraying polyurethane onto a metal mould. The polyurethane spiral, once hard, is wound off the mould by hand and fibreglass is applied to the back of it to give it greater strength and rigidity. Some polyurethane is lost in the spraying process, and the application of fibreglass is time-consuming and labour-intensive. It is these two concerns which motivated a programme of research into the possibility of casting the polyurethane with a fibreglass core inside a closed-mould system.

The SPII application supported the process – mainly in the form of building prototype moulds and part-funding the development time required. Progress was slower than initially expected: the SPII schedule was not always met, and in the meantime the firm also worked out a way of applying the fibreglass by using an

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<sup>6</sup> This does suggest that they may be overstating their relative size internationally.

automated process (thereby greatly reducing the benefits obtained from the research). For these reasons, the project was terminated.

It should be noted, however, that the firm and its German supplier benefited from learning about the moulding of polyurethane, and about adapting different grades of polyurethane. This knowledge has been applied in MPE's manufacture of polyurethane cyclones. The firm is also continuing, although more intermittently, with experiments in moulding spirals.

It is possible to draw conflicting conclusions from the experience with spirals. One interpretation is that the obstacles to success should have been more clearly foreseen in the evaluation of the SPII application, and that the projected gains to the firm did not appear particularly large in the event of success. The SPII grant essentially supported the firm in research activity which it was going to undertake anyway, albeit more slowly perhaps. The alternative interpretation is that the SPII programme supported research which relates to the firm's core production capabilities and that, as such, the knowledge can be transferred to other operations. The early termination of the programme shows the effectiveness of the monitoring and evaluation.

Furthermore, while the particular step envisaged was not achieved, the project did not entirely fail, as may appear at first sight.

Each of these interpretations is consistent with the experience. Research that is not aimed at radical change is nevertheless still uncertain and risky. The SPII's rationale, therefore, is that it was supporting innovative activity of an incremental nature like the development of the spirals, although questions still remain as to the initial evaluation undertaken.

## 4. Gains from commercialisation and the competitiveness of the firm

MPE is highly profitable and appears to have a strong platform for continued growth. Profits are approximately 30% of sales – a very healthy margin. This figure is based on production costs of approximately 50% of sales revenue and fixed costs of a further 20% of revenue. Based on estimated sales of cyclones (Table 2), the returns easily reward the investments in R&D and in the testing facility in particular. Indeed, it could be argued that the firm may still be under-investing in R&D even on relatively narrow and short-term commercial criteria.<sup>7</sup> While the projected sales growth is steady and incremental, the financial rewards from this growth are substantial relative to the R&D spend.

**Table 2 – Estimated sales for the cyclone division of MPE**

	2002	2003	2004	2005
Local market (R-million)	30	35	40	42
International market (R-million)	12	15	16	18
Total	42	50	56	60

The low R&D spend (relative to its apparent returns) and the development of production capabilities reflects a number of influences on the strategic direction of the firm. Historically the firm (through its owners) did not see itself as R&D-focused, as is suggested by the lack of a specifically defined R&D function. In the 1990s, however, it was decided to provide customers with a very strong service function. This entailed having an engineering capability that would provide customers with support and problem-solving as they needed it. In this the company differed from its main competitors, including the operations of its main multinational competitor in South Africa (Krebs).

Luck (or at least coincidence) played a role at this point, as the availability of good engineers due to retrenchments in the big upstream industries like Iscor meant that MPE could build up an engineering team who were able to move forward with development and design improvements, which effectively amounted to R&D. A belated recognition of the value that this accorded to the firm led to the identification of R&D as a key driver of the firm's commercial success. The low recorded R&D spend therefore belies the capabilities built up. Valuing the time of the engineering team as partly R&D would increase the spend, while their success has led to recognition of the importance of technology.

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<sup>7</sup> However, the low R&D spend is partly a question of certain activities not being identified as research.

## **4.1 Market shares and growth**

The commercial imperatives of R&D reflect the mixed basis of the firm's competitiveness. On the one hand, MPE has built its dominance of the local market on its responsiveness to the needs of South African mines in processing gold ore, platinum ore, and diamonds and coal. For this reason, one of its major concerns is to be defensive, so that it can protect its local market from other firms, both local and international, that seek to copy it and customise products as it does. Only by maintaining ongoing improvements can MPE ensure that it stays ahead. The company estimates it has an 85% share of the market in its particular product areas, and the remainder is largely supplied by imports.

On the other hand, there is the more growth-oriented focus on building export markets. Exports account for approximately 30% of output. The export markets have developed gradually, aided by the internationalisation of South African mines. The next target is to break into South American markets, including the copper market, as well as the processing of iron ore in existing markets such as Australia (where the South African firm Kumba has a mine). Export markets therefore involve new product niches in the sense of different minerals, as well as straightforward expansion of existing production. There is ready capacity for expanded production. At present MPE only runs one shift, with overtime as required. It can also quite easily contract out some of the work (such as casting) and so greatly increase throughput with existing facilities. Its competitiveness in international markets depends on being able to customise its main models, which in international terms can be viewed as 'mid-range' in terms of design and effectiveness, to the needs of different customers.

With the completion of the new testing facility in late 2003, Multotec is working on a new range of cyclones, which, due to better modelling and design, will have significantly better production efficiencies and enable the company to build a stronger brand and market share internationally.

The cost competitiveness of manufacture can be viewed as militating against an R&D-oriented strategy, as firms can manufacture relatively standardised products under license. In the South African context, two factors make a price-and-cost-based competitiveness strategy difficult. These are economies of scale and the needs of local customers. First, the size of the South African market means that firms cannot do the large orders and production runs that are required in order to use installed machinery most efficiently. This pushes firms towards a focus on product niches with small runs to particular specifications, which require many changeovers and are not so price competitive. Second, such a focus is reinforced by the gains to the local buyers of having customisation to particular needs.

It is the interaction with local buyers, and the ongoing learning-by-doing resulting from it, that appear to have been crucial in MPE's move towards an R&D-oriented competitive strategy. We now briefly discuss the firm's competitiveness in more detail.

## 4.2 Competitiveness

The competitiveness of South African manufacturing costs can be seen in relation to those of the main international manufacturers, in the USA, the European Union and Australia. Despite abundant local materials (largely iron and steel), the import parity pricing and relatively high local scrap prices (scrap being used for much of casting) mean that South Africa does not have a significant materials cost advantage. The cost competitiveness derives instead from labour and other costs including electricity, land and additional fixed costs. Despite being ‘knowledge-intensive’ in the design and development phases, the manufacturing of cyclones is quite labour-intensive. Labour accounts for between 35% and 40% of production costs. In South Africa the costs of the semi-skilled labour required in production are very low compared with those in industrialised countries such as the USA.

Perhaps more surprisingly, MPE reported that the ‘computing power’, mainly skills and capabilities of people employed in modelling and product design, was both readily available and cheap in South Africa. Again, the international comparisons that are used are important here. Presumably, other industrialising and developing countries like India and Malaysia have similar or cheaper skills in this area, but the nature of the product being made and the demand from mining have meant that the main competitors are in industrialised countries in Europe and North America. This still represents a threat in that multinational cyclone manufacturers are able to locate production functions in countries where these skills are even more cheaply available – India, for example – as firms in other industries have already done.

While it draws on these sources of cost competitiveness, which ensure a healthy profit margin, non-price sources of competitiveness are going to be increasingly significant for MPE. These encompass continued technological capabilities together with design and customisation. As noted above, in the case of MPE the design and customisation functions have led the development of technological capabilities. The availability of skills in process engineering preceded the establishment of a defined R&D function.

The importance of the demand-side stimulus to design and research, in the case of MPE, suggests that the weak R&D expenditure of South African firms in general is related to the lack of a deliberate mission or focus in supporting new industries. The apartheid government support for the then new chemicals and defence industries (and earlier, the iron and steel industries) evidently stimulated R&D and technological capabilities. Without such a demand-side motivation from industry, coupled with appropriate support measures, the natural barriers to R&D inhibit the development of capabilities. Similarly, the decline in R&D activity in the now ‘old’ industries has meant available skills for firms such as MPE, but without new skills development this aging (and white) skills base is too narrow for a prolonged expansion of industry founded on improved technological capabilities.

### **4.3 Potential**

MPE itself has considerable potential. The possible returns from a ‘lateral migration’ of cyclone technology to applications in chemicals and food products (e.g. cleaning starch) have also yet to be properly explored. Mintek is reported to be involved in some of these developments, which are still at an early stage. Exploiting such potential will also rest on computational power and ability to design and test cyclones. It will also benefit from further use of other materials such as plastics, which MPE is already developing with polyurethane cyclones.

## 5. The role of institutions

The fundamental factors which inhibit research and innovation – appropriability, positive externalities and risk – all require institutions to undertake initiatives that are in the collective interest, as such initiatives may not be taken by individual firms or, if they are, will not be shared.

Multotec has relatively well-developed links with the various institutions responsible for supporting research and innovation. The case illustrates the roles of these institutions and suggests where there are overlaps or gaps. As discussed above, the Support Programme for Industrial Innovation was an important consideration in their decision to move ahead with the testing facility. In interviews, the role of the CSIR was also explored in some detail, and so too were links with universities.

### 5.1 IDC/SPII

It is important to note that the SPII's successful operation is partly due to its being housed within the IDC. This gives it a measure of autonomy, including the ability to draw on a pool of consultants and industry experts to appraise projects and monitor their progress.

The SPII is intended to fill a gap in government support between basic research and programmes and incentives to support capital expenditure. Therefore SPII applicants cannot get other government funding for the same project. The SPII evolved in 1993 from the Innovation Support for Electronics Scheme, which the DTI introduced in 1989. It is managed by the IDC on behalf of the DTI.<sup>8</sup>

There are two schemes under the SPII, the Matching Scheme and the Partnership Scheme.

#### 5.1.1 *The Matching Scheme*

This provides a non-repayable grant of 50% of the actual direct qualifying costs incurred and paid for in development activity, up to a maximum grant of R1.5 million per project.

#### 5.1.2 *The Partnership Scheme*

This provides a conditional grant of 50% of the actual direct qualifying costs incurred and paid for in development activity, with a minimum grant of R1.5 million per project. The grant is repayable upon successful commercialisation of the project, in

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<sup>8</sup> Note that firms are required to provide data for three years after the end of a SPII grant, so there is an important database of firms which could be drawn on in assessing innovative activity.

the form of a levy on sales. Should the project be unsuccessful, the conditional grant is converted into a non-repayable grant.

In 2002/03 there were 61 approvals under the Matching Scheme, with an average grant of R910,000, and three approvals under the Partnership Scheme, with an average grant of R7.9 million. This represented a slight fall in the number and value of approvals from the previous year. The constraint on the growth of the scheme is the number of good applications rather than the availability of funds. This suggests either that the scheme is not being marketed effectively, that it is not useful to firms, or that factors other than finance inhibit innovative activity. The requirement for firms to fund the activity initially, before being reimbursed under the matching scheme, was not reported to be an obstacle to potential applicants.

Disbursements are made in three tranches as performance milestones are achieved. This means that firms are reimbursed as they make measurable progress. As the SPII is meant to fund high-risk projects promising high returns, repayment is not required. The use of three tranches enables projects to be terminated if thorough investigation proves it to be no longer viable. Thirty consultants are used for the evaluation of proposals and the progress of projects.

## **5.2 The CSIR**

The CSIR has been a key player in technological development – especially in the case of energy and coal. Its role in the support of related research has gone through several stages. It is useful to understand these stages, as they provide an insight into the way public institutions work together with private interests; they also provide the background to the specific current situation of the main source of energy in South Africa, coal.

In the past (up to 1990) there was a levy on coal exports. The funds raised went to the National Energy Council (NEC) so that it could undertake and fund research. In addition, a test facility was constructed in Pretoria West. The levy was essentially part of the very large state role in the coal industry. With the 1990 Coal Act, which deregulated the coal industry, the levy fell away. This led to a fragmentation of research, with firms having to conduct more in-house research (with duplication of research), and the CSIR conducting research on a contract basis. The testing facility was also closed down. Much of the testing, both in the past and the present, has been driven by health and safety imperatives. Improving equipment to make it safer is clearly very important; however, it is necessary to distinguish this from innovations intended to improve the performance of the machinery or equipment in terms of the job it is required to do.

Problems with the declining level of research as a result of there being no structure and funding for collective research stimulated the design of the Coaltech 2020 plan. There are similar plans for gold ('Goldmine') and platinum ('Platmine'). The nature of the plans differs according to the stage of the industry and the requirements of different mining operations. In general, gold and coal are more mature industries, and

the initiatives are engaged in supporting ongoing and incremental research and development. In particular, Coaltech 2020 is motivated by cooperation between Sasol and Anglo-American, two of the biggest coal miners and processors.

Coaltech 2020 is a collaborative research programme for which each of the following provides one-third of the funds: the CSIR (from its parliamentary grant), the FRD through the Technology and Human Resources for Industry Programme (THRIP), and the coal industry. In 2001 the budget totalled R12 million.

Support had been given to a total of 37 students by 2002, of whom six were registered for PhDs and 19 for Master's degrees. 12 students were black and 12 were female.

Coaltech 2020 has six research areas:

- Open-cast mining;
- Underground mining;
- The surface environment;
- Geology and geophysics;
- Coal processing and distribution; and
- Human and social aspects of mining.

Proposals are invited for projects, which are led by CSIR scientists under each of these main areas. In addition, Coaltech 2020 is funding a PhD student at the University of Pretoria; this student will use the Multotec facility.

Under coal processing the main thrusts have been economic agglomeration of fine coal and beneficiation of fine coal.

The proposed new projects in 2002 were:

- Smokeless fuel;
- Kroosh screening technology;
- Control and management of dust;
- Real-time plant efficiency measurement; and
- Hydraulic pumping of ROM coal.

It appears as if, as in the past, the institutional agenda for research support is relatively narrow; it does not seek to develop linkages. The Coaltech programme is very much focused on mining.

More broadly, firms' assessment of the CSIR's activities is that, although the CSIR has been moving towards business development and an emphasis on export orientation, it is still more suited to fundamental research. A key gap that was mentioned both by those inside and outside the CSIR is the lack of capabilities for more responsive

research linked to incremental development. At present there is a pool of consulting expertise, including people who have been retrenched from defence research, but there is a need for coordination and management of expertise to support industry's needs.

Closely associated with more short-term and responsive research is the need for testing facilities. The Multotec facility is an example of the type of facility which enables ongoing research for improved products. However, its use remains limited to one company, and for others to do similar tests will require duplication of the facility.<sup>9</sup> Mathematical modelling is very important in design, but testing of prototypes is also required. Testing cannot be effectively done on site, and so the development of competing local manufacturers requires joint access to a testing facility. Conversely, to the extent to which the main competitors are subsidiaries of multinationals that conduct research and testing in their home base, the lack of open access may be viewed as the support of a 'national champion'.

### **5.3 Universities**

Multotec has strong and ongoing links with universities, including Pretoria, Stellenbosch and Wits. These links include Multotec funding of Master's students through bursaries and funding for their research projects. A PhD graduate from Wits has also recently joined Multotec to increase its own in-house research capabilities.

Although there has been an increasing emphasis on the commercial value of research, it still appears as if much of universities' research funded through programmes like THRIP is very science-driven and the links with business development are not made at the research stage.

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<sup>9</sup> One interviewee from the CSIR believed that the SPII funding will mean that the Multotec facility will be more widely available. But there appear to be no grounds for this. While Multotec may be happy to have a PhD student using the facility for research linked to its own needs, there is no reason why it should make the facility available to other firms wishing to undertake testing.

## 6. Conclusions

The MPE case reinforces the importance of particular local demand patterns in stimulating technological capabilities. In particular, the needs of mining have underpinned the development of firm capabilities, and the case is illustrative of the underlying dynamic driving much of South African industrial development, which Fine and Rustomjee (1996) have termed the ‘minerals–energy complex’. It is, however, also an example where capabilities appear to be transferable to the separation and processing of other materials (and so lateral migration is feasible).

At the level of the firm, the development of technological capabilities does not appear to have been driven by clear strategic decisions, and R&D expenditures have been relatively low, especially given the high levels of profit being made.

Instead, the developments have partly been driven by the core group of technical employees within MPE, who have pursued a research-oriented approach under the guidance of the senior process engineer. The firm’s decision to provide customers with support, linked to their production of customised cyclones, led to the development of an engineering team and the capabilities to innovate.

The case therefore illustrates the importance of broad economy-wide factors – the significance of mining and energy in particular – along with the need to understand internal and firm-specific considerations related to production capabilities and firm strategy. The demand-side pull has underpinned ongoing development of the expertise required for what are arguably world-class capabilities in the necessary activities, including computer modelling.

The importance of mining and energy has not, however, been developed into a coherent strategy to develop wider linkages, and this pattern appears to be replicated in the recent initiatives like Coaltech 2020. These initiatives followed a decade in which the role of the public sector in supporting research was rolled back, but the plans are still quite narrowly focused on mining.

The SPII support given to MPE essentially built on existing activities and did not mean that a different path was followed as a result of the intervention. Support for the test facility appears to have encouraged MPE to take a more research-intensive approach, which in effect had already been embarked upon.<sup>10</sup>

The challenges facing MPE are to accelerate and better plan R&D activities, given the threat from multinational companies and the ability to overcome barriers to exporting. There is also great potential to broaden the applications for which cyclones are

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<sup>10</sup> This also does not provide a solution to the need for shared facilities, especially for small and medium firms

manufactured, especially with the shift to different materials such as polyurethane. MPE's steps in this regard are encouraging; and coincidentally they were supported by the SPII grant for the unsuccessful coal spiral development.

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## **List of interviews**

Pieter Neveling, Process Engineer, Cyclones, MPE

Rohan Biddulph, Factory Manager – Spirals, MPE

Stewart Douglas, Process Engineer, Linatex

George Ashworth, Miningtek, CSIR

Johan de Korte, CSIR, coal division.

Ron Gevers, IDC/SPII

**RESOURCE-BASED TECHNOLOGY  
INNOVATION IN SOUTH AFRICA**

**CHAPTER 3:  
Gunric and RGR Valves**

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## **1. Background: valve manufacture**

The manufacture of valves involves engineering skills in the working of materials, mainly metal, to produce a piece of equipment which can open and close the flow of liquid or gas in pipes. While a valve may seem to be a relatively unsophisticated mechanical device, it can be highly specified depending on the size of the pipe and the pressure and abrasiveness of the liquid.

In large industrial operations, which run on a continuous basis, having to change a valve because of wear and tear is potentially costly in terms of downtime. There are also other challenges in the design itself: the valve should enable full flow when open, otherwise the diameter of the pipe would not be used optimally.

As with the markets for many items of machinery, the market for valves has distinct segments. In addition to differentiating according to the diameter and the type of liquid, there is an important difference between commodity products, which are made in large volumes, and products which are made to a customer's specification depending on the exact usage for which they are required.

Innovation and ongoing product developments are important in both large-scale and small-scale production, but the nature of competitiveness is quite different. The South African industry has developed strengths in the more customised segments, although the availability of material inputs suggests that it could be internationally competitive in the large-volume products as well.

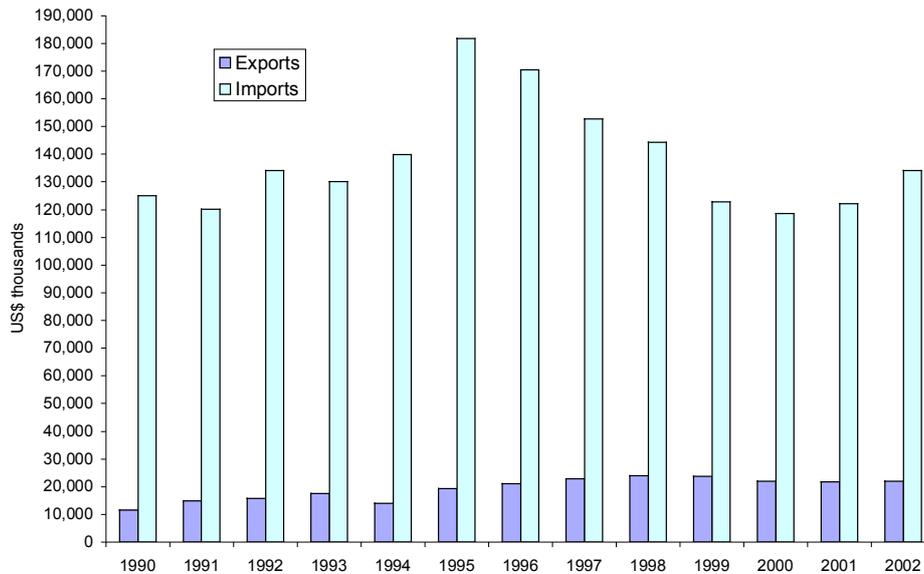
At present, however, it is estimated that local manufacturers supply less than half of local demand. Some estimates put the proportion of local demand met by imports at as much as 80%.<sup>11</sup> This is reflected in the large trade deficits of imports over exports throughout the last 12 years (Figure 1). Exports have improved somewhat, and imports have fallen from a peak in 1996; however, the fall in imports could reflect low levels of capital investment and thus a decline in the demand for valves rather than improved competitiveness of South African producers and import replacement.

Historically, valves have been sourced from European producers, especially German firms. This reflects industrial capabilities, coupled with the importance which the mines and other local customers attach to reliability. The repair of these valves by South African firms, coupled with immigration of engineers from Europe (particularly Germany) provided the impetus for local production. A combination of local demand linkages, reverse engineering and learning-by-doing, and ongoing product development and incremental innovation in making to order has underpinned the development of capabilities. We will return to the conditions underlying successful innovation and commercialisation after describing the two firms studied here.

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<sup>11</sup>Halwindi, 2003.

**Figure 1 – South African trade in valves, taps and cocks for pipes and tanks (HS8481)**



*Source: Trade and Industry Policy Strategies (TIPS) Standardised Industrial Database*

This case study covers two firms in different product niches. One firm makes ball valves for small-diameter pipes, the other makes butterfly valves for large-diameter pipes. Their experiences have been similar in certain respects. For example, both firms are small, with innovative activity based on strong engineering skills. Both firms also demonstrate the importance of the nature of local demand in stimulating the development of production capabilities. There are also important and interesting differences between them such as the choice of whether or not to purchase computer-numerically controlled (CNC) machinery, and the related training decisions.

Little institutional support has been received and testing is done in-house and with customers on site. Key obstacles to commercialisation of developments and exports are the cost of meeting international quality standards (ISO 9000 and PED), and the availability (and cost) of export finance.

Section 2 reviews the innovations made by Gunric Valves, and section 3 reviews those made by RGR Valves. Section 4 makes a comparative analysis of the two companies in order to arrive at insights into the main factors underpinning the innovative activities, their commercialisation, the relationship to firm competitiveness, the role of institutions, and obstacles encountered. Section 5 concludes the report.

## **2. Gunric Valves**

Gunric Valves developed its own metal-to-metal sealing butterfly valve 14 years ago, in 1989, which made South Africa one of only four countries with a manufacturer of such valves. The innovation benefited from the efforts of a Swedish company whose valves it had been repairing. Generally, valves were made with rubber seals, but these could not stand up to very high pressures or heat of more than 70–80°C. The Swedish firm had succeeded in developing a butterfly valve that sealed metal onto metal, but not one that did not leak.

The Gunric innovation enabled import replacement, and three years later, in 1992, Gunric started to penetrate export markets. As other firms caught up (there are now estimated to be around 20 big players, mainly in Europe and USA), Gunric came to specialise in the large-valves niche.

The company employs 50 people. The owner continues to be the main person engaged in ongoing design and innovation. The amount of research and innovation remains high so that incremental improvements can be made. The R&D spending is estimated at 7–8% of firm costs. Much of this is the time spent by the owner and one other design engineer, together with the expense of making and testing prototypes.

### **2.1 Main products**

As mentioned, Gunric specialises in butterfly valves for large-diameter pipes (0.5m up to 2.5m).

Its main markets are:

- Water (40%);
- Petrochemicals (20%); and
- Mining (15%).

Exports have accounted for as much as 35% of its market, although in 2003, with the strengthening of the rand, exports fell to 20%.

The product range includes:

- Valves to withstand high pressure in a water column for South African goldmines operating 2.5 km underground with a pressure of over 200 bar; and
- Valves to withstand extreme heat in the furnace of a platinum smelter operating at a temperature of 950°C.

## **2.2 The innovation**

The specific innovation and the ongoing incremental improvements to the essential design stem from the internal capabilities of the firm and its strategic decisions. These relate, first, to the targeting of specific niches where design gives the firm a greater competitive edge than in products with large production runs; and second, to the commitment of internal resources including management time and expertise to design and product development.

The main innovations were:

- The metal seal;
- A closure mechanism, where the angle of closure as the valve turns shut also levers the valve into place (the particular mechanical leverage that the valve exerts as it seats itself adds an additional pressure to ensure that the valve stays closed); and
- Replaceable seals.

Gunric patented both the seal itself and the action resulting from the angle of closure that creates the seal.

The development of the metal seal was very important for the closure of large valves, which had previously required a rubber seal at the join. The metal seal offers the benefits of:

- Ability to withstand higher pressures;
- Ability to withstand higher temperatures; and
- More durability.

Gunric has further developed a locking pin (also patented) to prevent the valve being opened by mistake. In the very large pipes this has additional safety benefits, as checking the pipe means that people have to spend time inside the pipe making inspections. These people are at great risk if the valve is mistakenly opened.

## **2.3 Incentives and drivers of innovation**

The main stimuli for the innovation were a combination of particular characteristics of the local market, the existence of research and development skills and international links, and the commercial returns. The local market impetus particularly came from the high pressures due to the depth of mines, and also from the need to remove abrasive waste-water from the mines. Although the mines were the main impetus to the development of capabilities, it is important to note that these capabilities are now used to a much greater extent in supplying the water sector. While similar applications are involved, the stimulus from the particular demands of mining underpinned the subsequent 'lateral migration' of technological capabilities to develop products for the

water sector. Research and development skills were largely due to the managing director, who had started as a consulting engineer, and had worked for a valve company.

Of these stimuli, the local market impetus and the presence of R&D skills are the most important. The initiative came from the firm's work in servicing and refurbishing Swedish-made valves. This enabled two processes, the first being a reverse engineering process for the manufacture of the valves, and the second being a research process to solve the problem of a metal seal that would be water-tight under pressure (the Swedish company was also working on this problem), and to guarantee market share through import replacement and also through export opportunities.

This innovation therefore represents an excellent example of the adaptation and adoption of international technologies, together with innovation to develop them further to meet local market requirements. The innovation was a cutting-edge one, as it led to the South African firm being the world leader in the particular niche, but it was not based on fundamental research that generated a completely new product.

As will be discussed below, the impetus and information flow from local demand was crucial to the learning-by-doing process, yet the commercial returns were not as large as might be expected, nor did the firm view possible large returns as the main reason for the product development. This partly reflects the differentiated nature of valves, with the innovation representing an important advance in one specific segment of the industry which required valves to close in a particular way. This segment, however, has been the fastest growing in the valve industry internationally in recent years. The firm itself has decided to limit itself only to customised, made-to-order products within this segment.

## **2.4 Firm capabilities**

Firm capabilities are very important in two respects besides the ability to conduct research. The lack of support facilities for such activities meant that prototypes had to be built and tested in-house. The capabilities to do this building and testing could be burdensome for a small firm to develop, yet the size of the South African market means that most machinery manufacturers are small and engineering-oriented.

An important part of the innovation process is therefore the commitment to build an ongoing culture of in-house R&D, using available engineering and design skills, together with the financial commitment to carry out in-house testing. R&D expenditure was estimated to be a very large commitment, equal to 7% to 8% of production costs.

Ongoing skills development is an important part of the firm's capabilities. Much of this consists of in-house training for artisans and operators, including ensuring that the skills required for product testing are available. ISO 9000 certification requires this to be recorded and systematised. The company is also drawing back money from the skills development levy for the training of artisans and operators. In addition, it

has recently employed a trainee from Technikon Witwatersrand with financial support from the SETA.

## **2.5 Strategic choices, commercialisation, and competitiveness of the firm**

As set out in the theoretical framework, technological capabilities are part of the strategic orientation of the firm. These choices are closely linked to decisions about the markets to be served and the firm's competitive positioning.

Gunric's main innovation provided a platform for growth through import replacement and penetration of export markets, which began three years after the innovation in the early 1990s. However, the firm is now operating at just under 70% utilisation of capacity. Its experience also usefully illustrates other factors affecting commercial success, which raise questions of whether industrial policies are consistent with goals of building technological capabilities.

The costs of investment decisions and economies of scale, rather than the firm's capabilities, were reported to be the key factors in Gunric's decision to target the large-valve market in particular. In other words, the strategy adopted was in some sense forced on the firm by the nature of demand, with lots of different orders making it difficult to yield economies from long production runs. Because CNC machinery is so expensive, it is important to have a high level of usage for the investment to be commercially viable. The relatively small size of the South African market meant that the returns might not be high enough to justify the initial investment. However, CNC equipment is necessary for the consistency required by international standards.

The combination of these factors led the firm to specialise in the manufacture of particularly large valves. This continues to be a process of making to order in cases where the valves required are too large to manufacture with typical CNC machinery. Being competitive in this specific niche does not therefore require CNC machinery but very good engineering capabilities. It is important to emphasise that it was the upfront costs of CNC machinery which drove the considerations of the market focus, rather than markets or products driving the choice of technology.

Making to order also involves more intensive interaction with customers, links which support research, and development activities to improve customisation of the product continuously. Gunric's main customer is Rand Water.

## **2.6 Cost competitiveness**

The niche product capabilities are therefore a strength but they are also a result of prior decisions based on competitive conditions.

Not only have concerns about economies of scale inhibited investment in machinery; more and more international competitors are making similar products, which means that the costs of inputs and price competitiveness are becoming increasingly important. It was estimated that there are now approximately 20 competitors, mainly in the USA and Europe, although none make exactly the same product.

These manufacturers are located in the main markets, where quality standards and international certification are determined (complying with these standards places an added cost burden on South African firms). At the same time the manufacturers have increasingly outsourced component manufacture to countries like South Korea and India. As with products like watches, the firms maintain the 'made in Germany' certification while lowering input costs considerably by using locations where manufacturing costs are low.

South African manufacture of the most important input materials, like steel, is very competitive but the prices charged to local customers by firms like Iscor are high, which means that none of the local cost competitiveness of the steel industry is passed on to the machinery manufacturers.<sup>12</sup> For example, it was estimated that a casting in South Africa costs as much as the fully machined part purchased from India.

Like European and US valve manufacturers, Gunric is now exploring the possibility of sourcing components from India and South Korea, owing to the difference in cost. However, there are scale economies associated with this in terms of bearing the costs of the transactions; it requires strong links with component manufacturers to satisfy the full traceability of material required by safety standards; and it adds logistics problems to the other difficulties of making to order on a job-by-job basis.

## **2.7 Certification**

The other major cost is that of the certification required to enter export markets in Europe and the US. Separate steps are required in order to meet the international ISO 9000 standard and the specific European standard (PED).

Building the ISO 9000 system from scratch cost Gunric R100,000 ten years ago (approximately 5% of turnover at the time), and an annual audit is required, costing approximately R30,000. A full audit is required for each certification every three to four years, at a cost of R40,000 to R50,000 per certificate.

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<sup>12</sup>Basic iron and steel and non-ferrous metals account for 27% of input costs (excluding the costs of production, capital and labour). More than an additional quarter of input costs are due to machinery components, like gears, and fabricated metal products which themselves are metals-intensive. (Statistics South Africa, 1998.)

Complying with the systems requires keeping detailed records on each product made and on the training undertaken, and proving all calculations. Maintaining the system therefore adds to the expense.

It should be noted that while the certification process involves payments to international consulting firms,<sup>13</sup> the expenses required to maintain it (staff time, etc.) are probably not greater in South Africa and may be a source of competitive advantage over competitors in industrialised countries.

## **2.8 Strategy**

The key strategic focus of the firm is internationalisation. It focuses on this in order to be more successful in export markets and more cost-competitive by sourcing inputs. Expanding the export markets requires considerable marketing and tendering expenses, given that, according to Gunric's own estimate, they win fewer than the 1% of sales bid for.<sup>14</sup> Quotes for export business are typically given one to two years in advance, as they concern supplies for major projects (dams, mines etc.). This lag, together with the volatility of the exchange rate, increases the risk associated with the returns from exporting.

Gunric is pursuing alliances and joint ventures with firms in India and Brazil to market one another's products. It is also exploring the sourcing of machined components from India.

The internationalisation therefore relates to market access, the marketing costs of exporting, and cost competitiveness. In the technology literature on developing countries, international linkages are usually understood as important, as they enable firms to learn, copy and adapt technologies from more advanced countries. The Gunric case is a little unusual in that improving technological capabilities is not the aim of the internationalisation developments.

The second strategic thrust has been black economic empowerment through the formation of a separate company, Isizwe Valves, targeted at refurbishing operations and business from government and the mines. This company is owned by a black investor and by a trust of black employees who had worked for Gunric for more than ten years.

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<sup>13</sup>For example, Gunric uses TUV Rhineland, an international company based in Germany.

<sup>14</sup>This is very low, and the firm confirmed that it really was its estimated success rate.

## **2.9 The role of institutions and policies**

In the past, Gunric Valves has drawn on institutions like the CSIR and DTI. The CSIR has been used specifically for fire-testing, and Gunric has also received support from the DTI under the General Export Incentive Scheme. More recently, DTI support was given for attending an exhibition in Holland. A government grant has also been received for obtaining ISO environmental certification.

The firm is thus well aware of the operations of different institutions and what is on offer. The use of incentives, however, masks the lack of deeper interactions with a network of institutions to support research and development, and the improvement of skills and technological capabilities. For example, at the most basic level all the testing (apart from fire-safe testing) has to be done in-house. R&D takes place in-house with apparently few, if any, links with universities and other research institutions.

Like any other firm, Gunric is affected by the range of policies related to employment, trade liberalisation, investment, etc. It is beyond the scope of the present project to explore the impacts of these policies, except for the impact on the firm's innovative activities. The greater openness of the South African economy is perhaps the most important factor here. As already noted, the firm does also draw back the skills development levy, and the new skills development framework has been one consideration in its employment of a trainee from a technikon, in supporting increased training at the artisan/operator level, and providing more in-house training to support its product testing.

The significance for the firm of policies directly aimed at supporting technological development is that there are no such policies.

## **2.10 Obstacles**

The main obstacles identified were related more to commercialisation and competitiveness than to research or innovation. These obstacles were the difficulties and costs of building export markets, and of gaining access to large projects. Both of these obstacles, and also the effect of input costs on competitiveness, highlight the importance of a trade and industrial policy which is consistent with exploiting technological capabilities.

The main issues in exporting are:

- Export marketing costs (which are being addressed through joint ventures, although these themselves are risky, and rely on the parties to the agreement differentiating their products to reduce overlap);
- Risks in returns due to volatility of exchange rates and input costs; and
- Export finance.

Exports also have an important role to play in sustainable growth, by ameliorating the effects of highly cyclical local demand. Expanding and reducing capacity by large amounts is difficult and costly: exports provide a means for maintaining steadier output levels.

The main obstacle to supplying large projects is that such projects are generally managed by international turnkey contractors, often linked to international sources of funding. Turnkey contractors receive support from their home governments on condition that they source inputs from their home country as far as possible. This has had major and direct impacts on South African firms:

- For Saldanha Steel, the turnkey contractor was an Austrian company, First Alpine. As First Alpine was 'required' to source within its region, Gunric eventually supplied valves for Saldanha via a German company.
- A similar thing happened with Mozal, for which the turnkey contractors were French and Canadian companies. They also supported producers from their home countries.
- In the case of an Algerian refinery built by the French company Technik, business went to another French company, even though Gunric was technologically better and cheaper.

Inducements to use South African materials could be specified by financiers like the IDC. Rand Water is notable for using South African suppliers, for example, in tendering for a contract for a pumping station in Jordan.



### **3. RGR Valves**

RGR won a prize in the Technology Top 100 for its innovations in developing high-pressure ball valves. The company manufactures a range of ball valves and piston-type non-return valves. These valves are used for pipes approximately 22 cm in diameter in high-pressure pumping systems. The company started as a general engineering shop that was taken over by two brothers in 1990, and now employs 24 people.

The innovation was mainly due to meeting local requirements, particularly those of deep-level mines, which wanted to replace imported valves that did not meet specific South African needs. The developments started as the repair of imported valves followed by reverse engineering and the development of prototypes. RGR is now custom-making valves for the chemicals and pulp and paper industries, continuing to focus on high-pressure systems. It developed three new products for the pulp and paper industries in 2003.

#### **3.1 The innovation**

The valve developed does not disrupt the water flow when open, lasts much longer than substitutes, and meets the requirements for:

- Working at depth (and being able to cope with the consequent pressure);
- Coping with corrosive and abrasive substances, like the waste water from these industries;
- Coping with extremes of temperature; and
- Coping with large volumes of water.

The two major steps taken were the development of a high-pressure ball valve (isolating valve), and a non-return valve designed specifically for the particular conditions in South African mines. These developments prevent 'water hammer' from pressure surges which damage pipe work. The imported valves used by South African mines were in fact made for the oil industry, and not specifically for the needs of deep mines.

In addition to engineering, design and development, an important step was the process developments that arose from the decision to buy CNC machinery, even although the company was doing customised jobs that required many changeovers, and which traditionally were seen as unsuitable for CNC. This decision to invest in expensive machinery despite not having long production runs meant that changes had to be made in the organisation of production.

Essentially, RGR has followed a multi-skilling route in order to introduce processes that halve the changeover times between jobs and maximise the time for which the CNC machinery is working, even although there are many small jobs being done.

## 3.2 Incentives and drivers of innovation

The innovation has been driven almost entirely by a niche opportunity arising from the specific needs of deep-level mines (in which South Africa is the world leader) for high-pressure valves. This opportunity was seized by two entrepreneurial brothers, one with an engineering background, who had been working in mines, and the other with a financial background. Initially RGR undertook repair work on imported valves: the opportunity arose from this. The main incentives were the relatively high prices that South African mines were paying for imported valves and the relatively cheap costs of manufacture compared to the USA and Europe. This is a classic entrepreneurial story: for working capital both brothers had to mortgage their homes.

In the reverse-engineering and innovative design the work was done in-house, including the building and testing of prototypes. Pressure testing is done in-house but more extensive testing is done by installing valves on site. The company has developed very close working relationships with the mines in order to do this. This was made possible by its existing relationships with the major mines, and its reputation for success, which means that mines would install untested variants for *in situ* studies. Mine decision-making on such equipment is localised, and much of RGR's marketing is done through and with consulting engineers responsible for delivering systems to the mines.<sup>15</sup>

The core capabilities in making ball valves for very-high-pressure systems have provided a foundation for diversification, so that the company now produces customised valves for other industries. As discussed, the constraints due to small orders and the cost of machinery forced RGR to make innovations in its work organisation. RGR can now set up CNC machines in less than one hour, while most other firms take between two and three hours to do this. This focus on work organisation and efficiencies in producing small batches is further reflected in the stability of the workforce and the high rates of pay (by South African standards) to staff such as the senior setter. More than 80% of the workforce have been with RGR for above five years. Furthermore, an estimated three months is spent on retraining recruits from other firms.

The strong focus on product development has meant that the R&D spend has remained relatively high at 3% to 5% of turnover.<sup>16</sup>

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<sup>15</sup> This is changing as the mining companies centralise their procurement.

<sup>16</sup> This is fairly close to Gunric's spend, as it is measured out of turnover, while Gunric's R&D spend was given as a proportion of costs.

### **3.3 Strategic choices, commercialisation and competitiveness of the firm**

As RGR has replaced imported valves (which were very expensive), it has good margins and a competitive edge owing to the cheap costs of manufacture in South Africa relative to the EU and the USA. After a financially difficult period during which RGR was developing the product it is now established as the leading local manufacturer.

Competitors import or make under license, which means that price competition is keen. Increases in materials prices have also affected RGR's costs. For example, the price of forged bar from Iscor increased by 50% over 18 months, and even though the rand has appreciated, the price has not decreased.

It is RGR's ability to deliver to particular specifications, and its ongoing product development, that places it in a strong competitive position. This allows it to earn a return from those of its competitive advantages that are not related to prices.

Because of the company's narrow focus on valves for deep-level mines, exports have also been limited to these users. Most deep-level mining takes place in South Africa. In recent years RGR has delivered large orders to Konkola Deep in Zambia, and to gold mines in Ghana.

### **3.4 Certification**

RGR has faced similar issues with regard to certification to those faced by Gunric. At a similar cost it has obtained ISO 9000 certification and is currently going through the process for PED with the help of the same international firm, TUV of Germany. It is also planning to apply for certification from the American Petroleum Institute in 2004.

While SABS used to test products and certify that they complied with standards, RGR believes that it is cheaper and more effective to go the international route of EU and USA certification.

Fire-safe tests have been done at CSIR in the past but the effective privatisation of the CSIR facilities means that RGR is looking at other options.

### **3.5 Strategy**

As already discussed, RGR's strategy can be characterised as flexible, high-value manufacture for a quality niche. This strategic approach is reflected in its decision to buy sophisticated CNC machinery early and to train employees to use the machinery effectively. It is also reflected in the employment retention and pay levels noted above.

### **3.6 The role of institutions and policies**

Little direct support has been received in recent years. As a member of the Capital Equipment Export Council, RGR has been contacted by the DTI. However, little of practical value has come from the interactions to date. The Small and Medium Enterprise Development Programme was explored but rejected on the grounds that it does not support incremental growth, but only discrete investments in new and expanded production capacity. The firm did receive support from the Small Business Development Corporation initially.

As with Gunric, state institutions could play a major support role by helping RGR to overcome obstacles connected with testing, certification, and obtaining finance for exports. The DTI's export credit facility at interest rates of 2% per month is viewed as expensive, and it does not effectively provide support for exports when payment terms are sometimes 60 days after delivery.

In terms of the broad policy framework, the major effect has been greater openness resulting from trade liberalisation.

### **3.7 Obstacles**

The main obstacles to growth are cited as:

- Obtaining export finance;
- Obtaining finance for expansion; and
- The expense of certification.

Notwithstanding the success of RGR, financing the working capital has been difficult, in particular for a business where the time from order to design and delivery is long. Commercial banks have lent money for the purchase of machinery as the machinery itself constitutes collateral; but the working capital was only obtained by borrowing against the owners' private property.

Export finance is very expensive, especially as some deliveries to EU firms are on payment terms of 60 days after delivery. The importance of exporting for firms that are learning and upgrading, coupled with the risks, the high transaction costs and the high information costs strongly suggests that it would be sensible to provide ways of supporting or subsidising exporting for small firms entering export markets. Export finance is an obvious way of doing this.

There are more fundamental obstacles, which are illustrated partly by RGR's success in overcoming them. These are the lack of supporting institutions for building capabilities, the fact that many South African firms are dependent on technologies controlled by multinational enterprises, and the weak value-chain linkages, particularly with suppliers of raw materials.

## 4. Comparative analysis

The two cases highlight the relatively well-known gaps in research support under the apartheid system. The apartheid government's strategy was to support fundamental research, research in upstream production capabilities and research in specific strategic industries, notably defence and petrochemicals; it largely ignored support for industrial research. An important part of a broad-based manufacturing strategy is building capabilities in value-added items and developing the engineering skills base which can be applied to many different product groupings.

Valves were, and remain, largely imported. Yet their cost competitiveness depends on materials, mainly metals, in which South Africa is internationally competitive, and mainly mid- to low-skilled labour, which the case studies here do not suggest is a constraint. The necessary manufacturing capabilities are certainly not beyond South Africa's power, as it has demonstrated very successfully in industries such as defence, chemicals and, more recently, automobiles.

A major issue is certainly the economies of scale necessary to be internationally competitive. While there is significant demand in South Africa, the local market remains small by international standards. Economic growth in the southern African region will add to local demand for valves, especially in areas like water supply.

The premise underlying the studies is that a key constituent for industrial development is the development of technological capabilities. Case studies provide insights into specific firms and their developments. By studying success stories, the cases can illustrate the importance of different factors in technological capabilities. The cases also point to weaknesses. The comparison of the cases here seeks to identify similarities and differences, and also to relate the cases to broader questions of innovation and technological capabilities.

### 4.1 Innovation and commercialisation

There are striking similarities between the experiences of the two firms described here. They are as follows:

*The importance of the specific nature of local demand.* Demand-side inducements have been the single most important impetus for the innovation and the reason for the niche competitiveness of the firms. The specific requirements of deep-level mining and the fact that the demand is not big enough for the major global manufacturers to target the market directly have provided a window of opportunity for infant valve manufacturers to grow.

*International linkages and exposure.* In each firm, interaction with international manufacturers was an important element. In the case of Gunric this included a close relationship with a leading Swedish manufacturer. It highlights the importance of

international relationships for access to technological know-how, alongside local advantages enabling the learning-by-doing to take place, sheltered to some extent from international competition. These local advantages are specifically those referred to above: the combination of specialised local demand and a requirement for small volumes only.

*Reverse engineering* was in both cases the second step (after valve repair) in developing particular products which would be leaders in their specific applications.

*Research and design capabilities* are of a general engineering nature. In both cases, while experience in the industry was crucial, the internal design capabilities reflected the willingness to pursue an opportunity, rather than skills of a unique nature.

*Testing strategies* are similar in both cases, with firms investing in the internal systems necessary for international certification and testing of products as part of ongoing innovations being done largely in-house (due to the lack of other facilities) and by customers themselves.

Products have been successfully sold to *export markets*, despite a lack of particular advantages in terms of *cost competitiveness*. This is highlighted by South Africa's comparative disadvantage, a trade deficit in valves, which it has in common with many downstream manufacturing sectors. The recent huge increases in the price of steel illustrate the fact that the steel-using firms do not benefit from low steel production costs in the form of competitively priced steel. When the rand depreciated at the end of 2001, import parity pricing led to sharp increases in local steel prices. With the recovery of the rand, prices have not come down, however.

## 4.2 Firm capabilities and strategies

There are similarities in the capabilities of the firms, each being centred around an owner/manager with the necessary engineering and design skills. These individuals have innovated by using their own resources and facilities. The firms' strategies have also differed in important respects, although it is not clear that one approach is necessarily superior to the other. The key features of the different strategies and their implications are described in the following paragraphs.

Gunric's avoidance of the expense of CNC equipment on the grounds that it was not viable given the scale of operations and small orders in turn led it to focus on valves with very large diameters, for which CNC is not appropriate.

RGR's approach placed it on reinforcing circular dynamic, although it made the opposite choice to that of Gunric. Early purchase of CNC machinery coupled with the fundamental problem that was also faced by Gunric, that of low economies of scale, led to radical and internally driven changes in workplace organisation, including an approach to training. Organising the workplace to ensure rapid changeovers between jobs, achieving high efficiency levels while producing small batches, means that shop floor workers and tool setters will assume greater responsibility and

initiative; it also means that there will be a need for teamwork and greater flexibility. This is strikingly similar to the flexible specialisation and multi-skilling models which are associated with Japanese production systems and small firms in Germany or the 'Third Italy' region. The strategy appears not to have been influenced by exposure to these types of organisation but instead to be an internal response to production challenges.

The changes in workplace organisation and production systems instituted by RGR represent major and fundamental elements in its production capabilities. As explained in the case study, they are integral parts of the firm's ability to undertake product development and can be viewed as process innovations in their own right. RGR was, indeed, more innovative in this case as the production systems changes were not instituted as an explicit copying of 'best practice' or 'world class' processes from elsewhere but as a result of internal innovation in response to a key challenge facing the firm.

### **4.3 Institutions, policy and implications for RBTC**

Quite concrete findings emerge from the two cases in terms of obstacles and related institutional issues.

Certification is an important barrier to entry to international markets. It imposes a cost on firms (the cost is fixed, and hence is more onerous for small firms) and highlights weaknesses in terms of local institutional support for developing the appropriate production systems and advice on obtaining the certification itself. An important gap is the availability of facilities for testing products. This is necessary for ongoing incremental product development and is also important for marketing to local customers.

Risks and market failures in integrating with the international economy (for example, through a greater export orientation) suggest the need for targeted support measures. Exporting requires access to finance and a willingness to take risks. In the absence of direct measures, exports are therefore likely to cause firms' capabilities to lag rather than to move forward, notwithstanding the incentive schemes already in place. It is evident that interaction with international firms is also important for ongoing technological development. This is reflected in the reverse engineering undertaken by both firms. South African firms may be falling behind international developments once more. While learning from international firms is part of catch-up it does not prevent falling behind. Measures that help firms to draw on international developments on an ongoing basis are important.

The existing institutions have been drawn on by the firms, but they are generally not seen as responsive to the practical needs of firms undertaking continuous incremental product development. Nor does the shift towards an approach which makes more use of consultancy help deal with the intrinsic issues of technology (including positive externalities and informational problems) which are briefly outlined below.

These issues suggest a possible gap in the institutional framework, namely technical centres of exactly the type envisaged in the AMTS. Given the ‘public good’ dimension to much of what they would do, with government support, such centres could address the lack of shared facilities for testing, and the need for support for certification if it is to be readily overcome as a barrier to exporting. They could also serve as a source of information on best practice in work organisation, production systems and approaches to exporting.

It is important to be clear that there are separate and reinforcing rationales for such facilities arising from economies of scale and scope (avoiding the duplication that would result if each firm sets up its own in-house testing equipment and machinery) and from the positive externality and public-good aspects of technology and information. The latter point refers to the fact that the gains to the economy from a firm investing in improving technological capabilities are greater than the gain to the firm itself as there are spill-over effects – other firms learn and copy. There is therefore a tendency for private agents to under-invest relative to the economic gains. Public funding to support such activities (for instance, by providing information) is one solution. A private fee-for-use approach does not provide the support (or subsidy) to remedy the intrinsic problem of private under-investment.

The cases reinforce the rationale for the RBTC programme. In both firms, the role of local demand from mining and energy was crucial in developing manufacturing capabilities. These insights are important for a strategy for broader-based industrialisation, as such an approach needs to build on existing strengths. At the same time, a changed orientation in itself will stimulate new areas of capabilities – just as demand from mining stimulated a production response, so may different sources of demand going forward stimulate appropriate responses. However, the development of production capabilities is evidently dependent on the path chosen. To put it as simply as possible, what we can do in manufacturing now depends on what we aimed to do in the past. A new trajectory cannot start from a clean slate.

The cases also point to the need for consistency between industrial and technology policy, such as is envisaged when a value matrix is used. The cases examined show that technological developments at the level of the firm are part of production strategies. These strategies in turn have evolved owing to the position of the firm in terms of markets, main competitors, availability of competitively priced inputs, etc.

The industrial policy concerns from a firm perspective are effectively indistinguishable from the technology policy concerns. If there is not a ‘joining up’ of policy from the government side then there is a risk that the policy instruments will not be well coordinated from the point of view of the users (firms).



## 5. Conclusions

The development of capabilities in valve manufacture is a very good illustration of the production capabilities that have been driven by mining demand. It is the particular requirements of deep-level mining which have served as the platform for both of the firms studied here. In a sense this local demand advantage provided a level of natural protection for the firms. The development of capabilities in both cases involved reverse engineering, learning and innovation.

The decision of both firms to focus on specific niches also illustrates the importance of demand-side factors in driving technology. Neither firm has the levels of exports necessary to achieve the economies of scale which would allow them to lower production costs and move beyond quite narrowly defined product niches. There are several reasons for this, including the difficulties and risks involved in exporting, as well as relatively expensive material inputs. At a broader level this is manifested in the very large ongoing trade deficit in valves and related products.

The different strategies adopted by the two firms in response to the same core difficulty of achieving effective usage of expensive machinery are reflected in each firm's innovations. RGR has made important process innovations in its work organisation. These are additional to the particular product developments which have been stimulated by the problems faced by South African mines. Gunric chose a niche in which it could build on its ability to customise without the necessity of CNC machinery.

In both cases there are also indications of significant challenges. Internationalisation of standards means that firms are being required to invest in certification. A separate but related issue for firms involved in incremental product development is the availability of testing facilities and appropriate institutional support. These weaknesses in the local environment pose a threat to the improvement and retention of capabilities as large multinationals increasingly outsource production to low-cost destinations and provide full installation and after-sales support in markets like South Africa.<sup>17</sup> This is a reversal of the pattern which underpinned the development of both of the cases here, where the firms started up by providing repairs and support for foreign-manufactured valves.

The policy implications of such patterns are relatively clear. There is a strong rationale for government-supported programmes and institutions to ensure that firms' activities in upgrading technological capabilities reflect the returns to the wider economy from such activities. In the presence of narrow private incentives alone, firms will under-invest in such activities, as they will not take the positive externality effects into

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<sup>17</sup> The FRIDGE study (2003) noted these patterns and a shift to firms becoming importers and agents for local sales by multinationals.

account. In addition, information on different production systems, better work organisation, etc., can be provided as a 'public good' through such programmes and institutions. This can be thought of as analogous to public parks, which are available to all, while each individual is also free to plan his or her own private garden. Public investment in the park provides everyone with a large, shared benefit.

Lastly, the cases illustrated that the ability to access export markets for capital equipment like valves often requires breaking into the organisation of large projects. Turnkey contractors providing total project management solutions are very influential in the sourcing of machinery and equipment. There is a need to foster local project management capabilities, which will enable greater linkages with local firms manufacturing machinery and equipment. A second level of influence is the conditions often imposed by governments on projects for which there are public funding or other support.

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# **RESOURCE-BASED TECHNOLOGY INNOVATION IN SOUTH AFRICA**

## **CHAPTER 4:**

### **Innovations in South Africa's Off-grid Concession Programme**

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## **1. Introduction**

This case study deals with South Africa's off-grid concessions programme, an important component of the government's National Integrated Electrification Programme. This programme was aimed at offering access to photovoltaic solar home systems in deep rural areas, pending the supply of grid electricity throughout the country. Like the other case studies in this volume, it is aimed at deepening analysts' and planners' understanding of processes of innovation in the South African energy sector, and identifying key lessons that may be applied elsewhere.



## 2. Electrification in South Africa

The Reconstruction and Development Programme (RDP) of 1994 stated that:

*Although energy is a basic need and a vital input into the informal sector, the vast majority of South African households and entrepreneurs depend on inferior and expensive fuels... Although Eskom has excess generating capacity, only 36 per cent of South African households have access to electricity, leaving some three million households un-electrified. Furthermore, some 19 000 black schools (86 per cent) and around 4 000 clinics are currently without electricity. Little attention has been paid to utilising sustainable energy sources such as solar power (RDP 1994:31).*

It further noted that:

*An accelerated and sustainable electrification programme must provide access to electricity for an additional 2,5 million households by the year 2000, thereby increasing the level of access to electricity to about 72 per cent of all households (double the present number). Both grid and non-grid power sources (such as solar cells and generators) must be employed. All schools and clinics must be electrified as soon as possible. Communities must be involved in the planning and execution of this programme. Micro, small, and medium-sized enterprises must be given support and shown preference in the tendering process.*

Thus began a new era of electrification. Until this time, rural electrification had been largely ignored, except for white-owned commercial farms (RDP, 1994:32). In 1994 the government and the electricity distribution industry, mainly comprised of Eskom, but also local authorities, signed a compact in terms of which 2,5 million households would be electrified in the five-year period from 1994 to 1999. It was felt that access to electricity would significantly benefit previously disadvantaged South Africans. This was seen as a prerequisite for modern development. Importantly, electrification was also seen as an important means of reducing indoor air pollution.

A National Integrated Electrification Programme (NIEP) emerged. It was initially funded by the electricity industry itself, with Eskom cross-subsidising the electrification undertaken by municipalities. The Eskom funds were transferred to the NER, which allocated them to local authorities. Eskom also funded its own electrification programme from internal cash flows.

It was assumed that new customers would consume enough electricity to make the programme financially viable. Very soon, however, it became clear that consumption by rural households was very low (100 kWh a month and less). Typically, poor households cannot afford to use electricity for thermal activities (cooking and heating), and thus tend to use it only for lighting and social communication (including TV and radio). In response, Eskom intensified its technical development

programmes, including pre-payment meter options. It also began to diversify its services, which allowed it to limit electricity supplies to rural households.

Despite these important and valid attempts to contain the real costs of electrification, it quickly became apparent that a large sector of the rural population could not be electrified at 'reasonable' cost. For many communities in sparsely populated rural areas, the on-grid electrification programme (entailing relatively high connection and ongoing costs) would not provide an avenue to changing the quality of their lives.



### 3. The start of the off-grid concessions programme

In 1996, the government established the Renewable Energy Fund of South Africa (REFSA), tasked with establishing a national programme for installing photovoltaic (PV) solar home systems. In 1997 it announced a subsidy of R1 500 per system; however, it was disbanded soon afterwards without having financed a single deal.

According to the DME, it would have been uneconomical to provide such a service in the deep rural areas (Kotze 1999). Importantly, the two value chains necessary to create a viable rural PV market, namely a network of shops providing access to off-grid solutions, as well as micro financing institutions, were almost non-existent.

The government had to find a new way forward. In the past, public utilities had successfully provided services to low-volume users, and involving them in solar energy as well seemed to be the most logical solution. Nevertheless, Eskom was reluctant to become involved; it argued that it wasn't familiar with the necessary technologies, and that a non-grid programme would probably encroach on its core business.

At that stage the government had not thought about involving the private sector, but did take note of the fact that the private sector was successfully selling PV systems, mainly for telecommunication/transmissions, water pumps and lighting systems.

The DME recognised that if it were to rely on the private sector to deliver PV systems at scale, it would need to offer this sector some special incentives, since it was unlikely to do so on its own. In 1998 the government began to consider a concession-type model in terms of which it would identify franchise areas, grant the franchises to companies, and also provide some financial support.

In December 1998 it released the White paper on energy policy for the Republic of South Africa which stated that:

*[i]n many cases, grid electrification is simply uneconomical. In such cases an off-grid supply can often provide an adequate electricity service. The government therefore recognises the need to level the playing field between grid and off-grid electrification.*

Annual connection targets and related subsidies will be allocated for off-grid electrification in accordance with the national electrification strategy. Soon after the release of the White Paper, Eskom (Research) and Shell Solar jointly launched an off-grid solar PV programme in the Eastern Cape. Despite the fact that the government had not yet formulated detailed policies in this area, the programme was launched by then president Nelson Mandela, which lent added new momentum to the haphazard development of the off-grid electrification programme.

In 1999, the government invited the private sector to establish technically competent commercial off-grid operators in rural areas. The advertisement described the envisaged off-grid programme in very broad terms, and without specifying technology, business models, and so on in any detail. Importantly, though, it did state that public–private partnerships should be forged, that the programme would not be fully subsidised, that private companies should establish a presence at the local level in their concession areas, and that fee-for-service arrangements should be made between the concessionaires and their customers.<sup>18</sup>

Given that typical rural households use a mix of fuels, and that electricity is rarely used for thermal purposes, the government also asked concessionaires to start providing alternative thermal fuels to wood and coal such as liquid petroleum gas (LPG) and paraffin at the local level.<sup>19</sup>

More than 25 responses were received and evaluated by the National Electrification Coordinating Committee (NECC). Six consortia of local and international partners (see table 1) were short-listed, and added to the Eskom Shell joint venture, called Eskom Shell Solar Home Systems.

Two more years elapsed before implementation began. Indeed, in August 2003 the government stated that the programme was still in a pilot phase. The pre-implementation process was difficult, and involved numerous interested parties and lengthy negotiations. A DME official later acknowledged that the department did not always know where it was headed.

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<sup>18</sup> At the time, local and international experience suggested that a fee-for-service arrangement would be the most cost-effective solution. The government did not favour the other major option – direct sales (for cash or credit) – because of concerns about after-sales service and the maintenance of solar home systems. The government was particularly keen for concession companies to provide a service and maintenance function to customers. In order to effect this, concession companies would need to maintain a local presence, hopefully establishing rural outlets for their products and services reasonable walking distance of their customers.

<sup>19</sup> Concessionaires have never been contractually obliged to offer these additional services. All that has been established is a broad agreement that they will work on widening their business scope.

**Table 1 – Consortia recommended by the NECC**

Consortium	Members
Renewable Energy Africa	Renewable Energy Africa (Pty) Ltd Wakowa Development cc Kopano Project Managers (Pty) Ltd Milani Investment Holdings (Pty) Ltd
BP SA/Emtateni	BP Southern Africa (Pty) Ltd Emtateni Investment Holdings (Pty) Ltd Eskom
SolarVision	SolarVision (Pty) Ltd Khatima Engineering Services cc Lebone Engineering (Pty) Ltd
Nuon/Raps or NuRa	NVE (North Zealand Energy, Denmark) Nuon (Energy utility, Netherlands) Rural Alternative Power Systems (Pty) Ltd
Spescom	Spescom (Pty) Ltd Phambili Nombane (Pty) Ltd Vantage+
Electricité de France/Total	Net Group Electricité de France TENESA (Pty) Ltd Total Phambili Nombane (Pty) Ltd The Sirius Foundation

*Source: Africon (2004)*

## 4. The off-grid concessions programme today

By June 2004, four of the seven public–private consortia, namely Rural Area Power Solutions (RAPS)/NUON, the SolarVision/Renewable Energy Corporation of Norway, Electricity de France (EDF)/Total, and Eskom/Shell Solar, had reached the implementation phase. A fifth concessionaire, Renewable Energy Africa, was gearing up for implementation, but was struggling to secure adequate finances. The German government (through Kreditanstalt für Wiederaufbau, KfW) was preparing tender documents for a sixth concession.

Selected service providers were allocated exclusive rights to provide off-grid electrification in particular geographic areas (called ‘permission areas’). These are situated in broader areas or regions earmarked for off-grid electrification, called ‘concession areas’. The rights last for a period of five years; however, the service contracts remain binding for a period of 20 years. Besides solar home systems and mini-grids, service providers are encouraged to distribute alternative thermal fuels such as gas or paraffin. The concessionaires are largely active in former ‘homelands’ areas, notably two areas in KwaZulu-Natal, two in the Eastern Cape, and one in Limpopo.

Initially, Eskom defined permission areas, but more recently there has been a move towards establishing these areas in negotiations involving local authorities, Eskom and the concessionaires. The rule is that off-grid systems should not be installed within 2 kilometres from a gridline.<sup>20</sup> However, some concessionaires have installed solar home systems as close as 1 kilometre from existing gridlines.<sup>21</sup>

By October 2003, about 16 000 solar home systems had been installed.<sup>22</sup> At that time, the government estimated that there was an electrification backlog of 3 million households in the former ‘homelands’ areas (Kotze 2003). It was hoped that the off-grid programme would reduce this backlog by 300 000 (and grid connections the balance). This meant that each of the six concessionaires would need to install about

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<sup>20</sup> This rule is one of a set of criteria that are used to allocate areas to non-grid service provision.

<sup>21</sup> Areas where households are dispersed owing to low densities or large stands are not likely to become Eskom electrification projects, although if they fall within the 2 kilometre zone they should not, according to this rule, be considered by concession companies. There are two choices here: (a) concession companies can ignore the 2 km restriction and supply a SHS (solar home system) or (b) they can let the customer apply to Eskom as a rural customer on normal commercial terms. This would cost the customer approx R3 000 upfront and it would entail a monthly account of more than R250. This is obviously unaffordable to the poorest of the poor (Van der Merwe 2003).

<sup>22</sup> This figure must not be confused with the one appearing in the National Census of 2001, which states that there are solar home systems in 23 000 households in South Africa. Active accounts as of October 2003 were: NuRa (4 680), SolarVision (3119), KES (2 526) and ESSHS (5 733) (Africon 2004).

50 000 systems during the initial contract periods of five years, and then continue to service them for 20 years. However, it also appeared that the public funds to do so might be lacking: from 1 August 2003, concessionaires were only permitted to install 300 solar home systems a month, and in January 2004 they were informed that subsidies would cease entirely until a comprehensive review of the programme then under way had been completed, prior to the signing of final contracts in March 2004.

## 5. Customer perceptions of solar home systems

A number of studies have been done to review customer perceptions of the PV solar home systems. These reviews include community submissions to parliament in 2003, as documented by Yaw Afrane-Okese and Jocelyn Muller of the Energy and Development Research Centre, a review by SolarVision in its concession area in Limpopo in October 2002, and by the RAPS Group, which commissioned an independent report on its customer's views (Gothard 2003b). Finally, the DME commissioned a comprehensive national review of the off-grid electrification programme in November 2003 – January 2004, which was conducted by Africon.

The findings have been relatively consistent, and can be summarised as follows:

- Although households would have preferred to be brought into the grid system, the PV solar power systems were very popular in households. They were seen as easy to use and that generally they worked well. However, DME's survey found that many customers did not understand how the solar home system worked.
- While extending energy to rural households, the PV solar systems do not specifically benefit the poorest of the poor, even in the context of subsidies. Household income must be sufficient to pay for the service. Only households that could produce proof of regular incomes tended to be eligible for solar home systems. Beneficiaries of the systems were typically wage earners, pensioners, and civil servants. Unlike grid-electrified households, solar-electrified households were unable to vary their expenditure by varying their electricity consumption. Households objected to paying R58 for only 6 kWhs a month. (This was the full monthly tariff; of this, about R40 was subsidised by the state, leaving households to pay about R18 a month). In some areas, solar system recipients had to travel to pay points to buy monthly credit, while in others monthly fees were collected at their homes. Thus some households were incurring additional transport expenses. The more sophisticated the service delivery mechanisms, the higher the costs to households tended to be. The SolarVision survey found that 41% of users could not pay the monthly user charge of R58.
- Repairs to systems could be slow, as access to rural households could be difficult. Where installation and repair was done locally, these tended to be "men's jobs" – women were not sufficiently drawn into the programme.
- Most households used electricity for lighting and radio/TV, and not for cooking, heating or for income generation. This meant that women still had to collect wood for cooking and heating, and that the systems did not ultimately have the effect of reducing indoor pollution.



## 6. Innovation in the off-grid concessions programme

As noted earlier, this study is aimed at gaining a better understanding of innovation in the off-grid concessions programme, and to identify key lessons. This section seeks to identify where innovation has occurred. Broadly, it is argued that innovation has occurred in process and products, while experiences in institutional and financing arrangements largely point to barriers inhibiting innovation. However, the concessions programme is still evolving, and no final conclusions can be drawn.

### 6.1 Institutional and programmatic arrangements

#### 6.1.1 *Public–private partnerships*

As noted earlier, the South African government was eager to create an off-grid electrification programme involving a partnership between the public and private sectors. Broadly, this has been achieved in the sense that the private sector has expressed a willingness and a commitment to install solar home systems in rural areas, on the understanding that its efforts will be subsidised.<sup>23</sup> The system costs are about 80 per cent subsidised, and the concessionaires contribute the remainder.

Both international and local experience indicates that there is nothing novel about public–private partnerships, in this sphere or others. Furthermore, it is too early to tell whether the partnerships in this sphere will be sustainable. The contracting process preceding implementation has taken several years, and it has been very difficult for the concessionaires to remain ‘on board’ in such uncertain conditions. Their greatest concern is future certainty.

By early 2004, the concessionaires were still operating in an official pilot phase, and their final contracts with the government had not yet been concluded. Their involvement in this programme also seems tenuous from a financing and risk point of view. Without the capital and consumption subsidies from the government, concessionaires would probably find it impossible to sustain their involvement in this area, and this is proving difficult even with the subsidies at their current level. Typically, these operations will break even (the point where income will exceed expenses) in five to eight years.

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<sup>23</sup> Officially, however, the off-grid concessions programme is not a public–private partnership. As set out in the National Treasury’s regulations, the core values of a public–private partnership include affordability, risk transfer, and value for money. Transactions that do not possess these values are not classified as public–private partnerships.

Spokespersons for most concessionaires have explained that their participation makes little sense in the short term, but that they see medium- to longer-term potential. A social commitment to improving rural energy provision has kept them in the programme in the short term. Among other things, they have had to live with unstable government funding. Concessionaires have been gearing up to put 50 000 systems in place over a five-year period; however, in August 2003 they were informed that capital subsidies would be limited to 300 installations a month. This ceiling had sharply negative implications for ordering and stocks, staff and training, morale, insurance cover, and so on, not to mention the programme's broader goals.

### *6.1.2 Contractual process and arrangements*

The DME initially presented a time line of 28 November 1998 for private sector applications, 11 December 1998 for a debriefing session, 29 January 1999 for the awarding of contracts, and 1 March 1999 for implementation. It soon became clear that this time frame was completely unrealistic. Indeed, 'interim arrangements' were eventually finalised between March 2002 and July 2003 and were extended up to 31 March 2004, when final agreements were due to be put in place (Van der Merwe 2003).

There were various reasons for these delays, which have been documented in Okese and Thom (2003). For example, major delays developed in the DME's negotiations of pilot contracts with concessionaires. Also, its electrification directorate did not have enough staff to integrate the grid and off-grid programmes; as a result, it was decided that the NER should drive the process until the progress had been brought up to date. While able to administer and oversee the financing of the programme, the NER had neither a legislative mandate nor enough staff to enter into contracts with private sector companies. As a result, Eskom was called in to help administer the off-grid programme. The DME supported this: it did not want Eskom to be excluded from the process for fear that this would give Eskom the space to impose its views on the concessionaires. For some time (nine months or more) Eskom officials were reluctant to play any role in the off-grid programme, as they felt that it competed with their own grid-based electrification programme.

Finally, when Eskom was brought on board, key interim agreements were made with the DME as well as the concessionaires. The government would assume overall responsibility for the programme; Eskom (as a government agent) would enter into and administer contracts with concessionaires, demarcate off-grid areas, monitor performance, and report back to the DME and NER. The NER would be the interim caretaker of off-grid electrification funds; establish and enforce a light-handed framework for regulating the programme, establishing standards, and managing disputes. After these contractual roles had finally been clarified, the programme was further delayed because the concessionaires took some time to agree to the provisions specified in the contracts. Given the high degree of uncertainty and risk, it has been suggested that this delay on the part of the private sector was to be expected.

The contracting process was complicated and slow. As a result, one concessionaire withdrew from the programme, and another fell prey to the march of grid electricity.

Also, various concessionaires were forced to diversify in order to remain afloat while the concession areas were being identified, contracting parties identified, and the contracts finalised.

These delays have damaged the programme, and adversely affected its potential beneficiaries. Lengthy periods of uncertainty about whether or not the programme would go ahead have done little for investor confidence. Lost opportunities and associated opportunity costs for customers must also have been substantial.

Indeed, this aspect of the programme does not display any positive innovations. On the contrary, contractual delays and institutional buck-passing have shown how innovation can be stifled, and how not to go about establishing a programme of this nature. Nevertheless, the process is still evolving, and it is hoped that, once final contracts have been signed, the off-grid programme will go from strength to strength.

#### *6.1.3 Programme and procurement process*

The concession-type model adopted is not innovative, when compared with other infrastructure delivery programmes in South Africa or energy programmes in other developing countries. Granting concessions for energy delivery in South Africa is, however, a pioneering step. Traditionally, energy has been delivered by public sector utilities, or offered by the private sector on its own terms.

International experience has highlighted the benefits of using a competitive bidding process to secure private sector partners. It has been shown that the burden on public funds can be significantly reduced and the programme made more sustainable, if potential concessionaires are required to propose subsidy amounts, and those proposing the lowest amounts are chosen. The fact that the DME and the National Electrification Coordinating Committee (NECC) did not adopt this approach has been seen as a lost opportunity.

#### *6.1.4 Electrification planning*

Box 1 outlines how electrification is planned at a macro level. There is little evidence that this has been innovative, but innovation should not necessarily be expected here. One area of concern is the extent to which grid and off-grid electrification planning is being integrated at this level. There is currently very little communication between the two programmes at this level. Generally, electrification is planned on the basis of need; it is assumed that grid will satisfy this need, and that off-grid investments should only be made where this is not the case. However, this is meant to change – when the off-grid programme is implemented at scale, the INEP BP (Integrated National Electrification Programme Business Planning) Unit will begin to plan off-grid projects in the same way as grid projects.

Possibly more relevant is the way in which electrification has been planned on a local or regional basis. Initially, concessionaires waited for Eskom to identify concession areas. Alternatively, they could install solar systems for applicants living no less than one kilometre from grid infrastructure. In some concession areas, planning is now

more collaborative and progressive; consultants are helping to draft electrification plans, and local/district municipalities are working with Eskom and the concessionaires to identify appropriate grid and off-grid areas. Again, while these integrated approaches are certainly worthwhile, they cannot really be regarded as innovative.

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### **Box 1: Macro-level electrification planning in South Africa**

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Electrification in South Africa is currently planned on a macro and micro level. Micro planning is undertaken at the local or district level. It involves (or should involve) extensive discussions between local authorities (which have a constitutional right to deliver electricity within their jurisdiction), Eskom, and concessionaires. Local authorities must produce an annual integrated development plan (IDP) which includes proposals for grid and off-grid investments.

Macro planning is currently undertaken by the Integrated National Electrification Programme Business Planning (INEP BP) Unit. Previously housed within Eskom, this unit is now separate from it, though most of its staff have been seconded, on ministerial request, from Eskom.<sup>24</sup> This unit is tasked with country-wide electrification planning. It has undertaken performance planning, programme management, business planning, audits, and database modelling in order to support the planning process. Business planning includes data modelling supporting processes, aerial photography, statistics/data analysis, and data co-ordination. With support from the DME, the Development Bank of Southern Africa (DBSA), and Eskom, the unit has developed a tool for identifying grid or off-grid electrification requirements and the estimated cost of new connections. This leads to a business plan, which is used to distribute funds for annual grid and off-grid electrification investments. The unit is also working on South Africa's electricity infrastructure needs.<sup>25</sup>

The INEP BP Unit has been focusing on grid electrification needs, but has also been assessing and earmarking funds for off-grid requirements. The idea was that when the off-grid programme emerges from its pilot phase (which was expected to happen in 2004), the INEP BP Unit would start with truly integrated electrification planning.

Most decisions about electrification investments and planning are made by the National Electrification Advisory Committee (NEAC), successor to the National Electrification Co-ordinating Committee (NECC). While the NECC was established to advise the Minister of Minerals and Energy on the way forward for electrification in South Africa, the mandate of the NEAC (a far more streamlined, action-oriented group) is to guide the implementation process.

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<sup>24</sup> This team was seconded from Eskom to support the DME with electrification planning. The idea is not to lose Eskom's competency in this area. It is unclear what will happen to this unit in the future – it may be housed within the EDI Holdings Company (the new structure being established to facilitate the rationalisation of EDI reform, or it might be assimilated into the DME.

<sup>25</sup> Its latest assessment is that an investment of R900 million is needed.

### 6.1.5 *Off-grid regulation*

The NER has established a light-handed regulatory framework for off-grid regulation, based on international best practice. It includes a technical standard – NRS 052 – that broadly specifies which technologies are acceptable. By early 2004, a new service standard – NRS 070 – was being developed. It was said to be fairly demanding of rural energy service providers, and thus likely to be revised downwards.

## 6.2 **Financing arrangements**

### 6.2.1 *Public–private partnerships*

The financial aspects of the off-grid electrification programme also involve public–private partnership arrangements.<sup>26</sup> As noted earlier, one of the key objectives of the partnerships between the public sector and private off-grid service providers has been to foster new investment in this area, and to eventually reduce the financial burden on the public sector. Interestingly, the government has adopted a phased approach: it acknowledges that, until each concessionaire has substantially increased its customer base, it will not be feasible to reduce the current capital subsidy. As noted earlier, public–private partnerships have been successfully adopted in other sectors of the energy industry, and can therefore not be regarded as innovative in this one, but again the arrangements made here are appropriate and effective.

### 6.2.2 *Capital subsidies*

Off-grid service providers have exclusive access to capital subsidies aimed at helping them to install solar home systems in specified rural areas. Initially, these subsidies were to be provided from the national budget via the DME. When it became clear that adequate state funds would not be available, the NER agreed to provide them from interest earned from electrification funds it has been administering.<sup>27</sup> At present, the subsidies are provided by the fiscus via the National Electrification Fund and the DME.

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<sup>26</sup> Technically, and according to the Treasury's definition of a PPP, the model adopted here does not constitute a true public–private partnership. This term here is used broadly and loosely to describe a situation in which both the public and private sectors participate in a particular venture, as designed and initiated by the public sector.

<sup>27</sup> For some time, the NER had been handling funds received from Eskom for grid electrification projects by municipalities and local authorities. These funds had been raised by Eskom in the period 1994–1999 through a small surcharge on the wholesale tariff. When the NER agreed to administer the interim contracts between the government and concessionaires, it also agreed to use the interest from these funds to support the concessions programme financially. The idea was that once these contracts were in up and running they would be transferred to the DME, which would then assume full responsibility for the integrated electrification programme.

This capital subsidy covers about 80 per cent of the cost of the solar home system; the remaining 20 per cent is financed by the off-grid service providers themselves. All the current concessionaires are either international utilities, or have international partners contributing substantially to the programme. This is one of the main reasons why they are able to sustain their participation in the programme. In fact, without international support it is questionable whether the off-grid programme would have existed today.

Public capital subsidies for solar home system installation by the private sector are not a new or innovative concept; it has been tried and tested in many other developing countries.

### *6.2.3 Operating subsidies*

In December 2002 the cabinet finally approved the government's long-awaited plan to provide free basic electricity (FBE) to the poor. FBE is currently offered to grid as well as off-grid electricity consumers. While poor grid customers receive 50 kWh of free electricity a month, off-grid customers are meant to receive an operational subsidy of about R40 a month (expected to be about 80 per cent of off-grid operating costs). They do not receive these subsidies themselves; to date they have been transferred directly from the DME and NET to concessionaires, in partial payment for their fee-for-service arrangements with off-grid households. This fee covers operational costs such as servicing, replacing and maintaining batteries; replacing special bulbs; maintaining solar panels and replacing them where necessary; and maintaining control systems. At the time of writing, the idea was that, when the off-grid programme moved out of its pilot phase, the government would pay subsidies to service providers via the Department of Provincial and Local Government (DPLG), local authorities, and the Equitable Share mechanism.<sup>28</sup> Indeed, this funding mechanism was already being piloted.

Recently, there has been an active discussion about the feasibility and sustainability of the off-grid programme, focusing on the operating subsidy. One of the concessionaires has argued that it makes better business sense for the government to allow companies to sell the solar home systems to households outright and then to use the operating subsidy to service and maintain those systems. The subsidy would incentivise the concessionaires to maintain a long-standing local presence.

This company argues that it does not make financial sense for it to collect R18 a month from its customers (the difference between the total monthly fee of about R58 and the operational subsidy of R40), and it is also concerned that the government is not providing enough of a guarantee that the capital and operating subsidies will

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<sup>28</sup> This is cause for additional uncertainty for off-grid service providers, which are not necessarily assured of receiving the full R40 for services rendered. While local authorities are obliged to establish a clear set of rules for allocating Equitable Share subsidies, they have the discretion to decide whether or not to allocate these amounts to off-grid service providers.

remain available in the short to medium term. The other concessionaires argue that they have established themselves as utility companies in order to provide a continuing service to rural customers. They believe it is important to maintain the fee-for-service model, particularly because it is unclear for how long the government will be able to sustain the distribution of operating subsidies. These companies also contend that it is important for them to encourage a culture of payment among their customers, even if it does mean collecting an additional R18 a month which, they also say, helps play a significant role in making the programme more sustainable.

It is not uncommon in developing countries for small monthly amounts of free electricity to be offered to grid-based customers. The value of requiring customers, the private sector, and the public sector to contribute to either capital or operating expenses is also fairly well accepted. However, it is indeed novel and progressive for free electricity to be offered to both grid and off-grid customers. This forms part of the government's attempt to 'level the playing field' between its grid and off-grid electrification programmes. It will be interesting to see whether this initiative can be sustained.

### **6.3 Process innovation**

The business models of four concessionaires which had begun to operate by early 2004 are presented in Figures 1 and 2.

All the models differ from one another, though not significantly. All the concessionaires maintain a local presence, as required by the government, but to different extents. The Eskom/Shell JV, perhaps the most established of the off-grid service providers, has chosen to work with established spaza shops or other retail outlets in deep rural areas to create a local presence. Customers travel to these outlets to purchase credit units. They are supported by five regional centres (RESCOs), which also accept applications for new systems. EDF/Total has established two energy centres in the permission area in which they are currently working. Again, customers travel to these energy centres to purchase credit for the following month, or to apply for a new system. While the Eskom/Shell JV relies on established outlets to sell credit, NuRa has established its own energy stores in deep rural areas. These stores are reasonably accessible to customers, who can purchase units in advance or apply for new installations. By contrast, SolarVision is contracting local-level vendors who visit customers for payments for the following month's usage. SolarVision also employs local 'runners' to collect applications for new systems. Interestingly, both SolarVision and the Eskom/Shell JV require that vendors, spaza shops, or other outlets pay for units, which they then on-sell. In this way, sales are incentivised and malpractice discouraged.

Figure 1 – Business models currently adopted

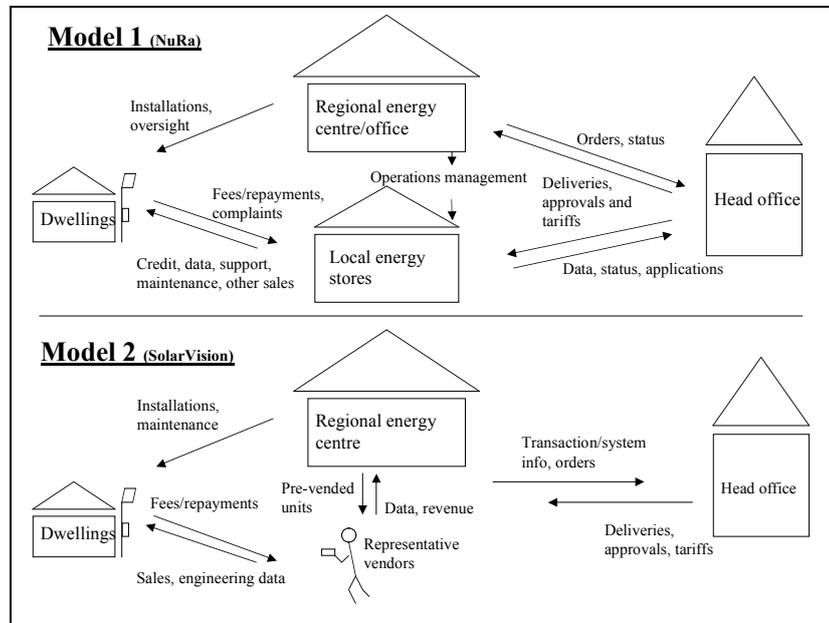
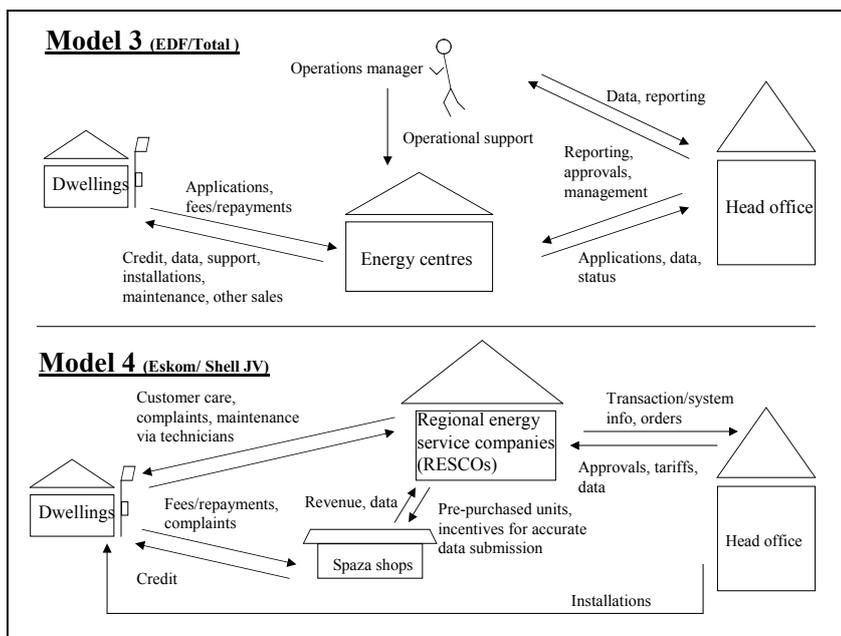


Figure 2 – Business models currently adopted



Both these approaches emphasise participation and ownership by communities. For example, NuRa eventually wants its energy stores to be owned by local entrepreneurs. EDF/Total and SolarVision try to buy poles and cables from local businesses, and EDF/Total have invested significantly in training technicians to install and maintain its systems. The Eskom/Shell JV relies heavily on established rural outlets, including spaza shops, and rewards good performance. SolarVision works with traditional leaders to identify vendors, and is currently trying to build up vendors' businesses so that these primary rather than secondary sources of income.

Each of the concessionaires relies heavily on data communication with its head offices. These are all in Gauteng, except for that of Eskom/Shell, which is closer to its concession area in the Eastern Cape. Lines of communication among regional centres, local stores, vendors, technicians, and so on are all very important for the efficacy of the concessionaires, which explains their continuing quest to improve or refine them.

NuRa has recently achieved tremendous success with selling LPG through its local energy stores. It is the first concession company to do so, and it claims that its revenues from selling other products, LPG in particular, are higher than those from installing solar systems. SolarVision is planning to investigate the feasibility of doing so as well, though its model will need to be different, given that it has not opened local energy stores. Indeed, it believes one approach might be to encourage and assist its vendor representatives to open distribution outlets in deep rural areas. The Eskom/Shell JV is not considering the sales of other energy solutions: it argues that it first wants to get the fundamentals of its business working well. Finally, EDF/Total acknowledges the importance of providing a solution to households' thermal requirements. It is currently extending one of its energy stores for the purpose of selling LPG. Total is able to produce a mobile unit to assist with this, and to set the price at which the gas will be sold. Importantly, this means that it can cross-subsidise sales in rural areas. This consortium also plans to sell LPG appliances, and is looking into more efficient and effective cookers. Until it can be shown that paraffin can be used safely, it will not sell it.

Thus, viewed broadly, these models display fairly similar characteristics, including the establishment of a local presence, the encouragement of local participation and ownership, business diversification, attention to business principles, and a quest to improve rural energy provision. These are challenges that most developing countries continue to grapple with. The ideas behind the models chosen by these concession companies are not novel; beyond the energy sector, these types of models are fairly common. For instance, the Coca-Cola company's method of penetrating deep rural communities is fairly similar, as is that of other popular consumer products.

Therefore, the emerging models 'make sense' rather than being innovative. They involve elements of programmes implemented in other countries, and have been adapted to the challenges at hand as well as government requirements. The models chosen are not static; indeed, they continue to evolve to achieve the best results. The manner in which solar home systems are being installed is a useful example. Initially, head offices expected to rely on local entrepreneurs to install these systems, but, even though these entrepreneurs have received the required training, this has not usually

happened. Over time, several of the concession companies have chosen to install the systems directly on from their head office or regional offices.

Interestingly, the models currently being adopted seem to be converging. All the concessionaires started off with their own models; now, a best practice model seems to be emerging. Other developing countries are closely watching this process, in the expectation that the results will be good enough to warrant similar business models to be adopted in their own deep rural areas.

## **6.4 Product innovation**

### *6.4.1 Background*

Before assessing the nature of innovation in respect of the products evolved for this programme, aspects of its background need to be recalled.

The DME initially intended to give concessionaires room to develop their own technologies. Thus the reference document sent out to prospective concessionaires in late 1999<sup>29</sup> stated that, ‘as an interim measure, it will be a requirement that solar home systems provided as part of the National Electrification Programme satisfy the specification NRS 052 Photovoltaic systems for use in individual homes, Draft 7. Deviations from this specification may be accepted, provided such deviations are clearly explained, reasons for the deviations given and support warranties issued.’

The NET argued that benchmarks should be set, which the concessionaires would need to adhere to. When the concessionaires argued that they needed more ‘space’ in which to operate, the NER chose to ‘stand back so as not to restrict the innovation process’ (Banks 2003b). He goes on to say that ‘the concessions do operate within the constraints of a national specification, but have sufficient motivation and lobby capability to explore reasonable deviations from the specifications’ (2003b).

As noted earlier, the contracting process dragged on for years. The interim period, between establishing a memorandum of understanding with the government and signing interim agreements, was very difficult for the concessionaires. Because of the uncertainties surrounding the programme, and funding in particular, they were understandably reluctant to start implementation.<sup>30</sup> Yet they knew that as soon as the

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<sup>29</sup> These terms of reference are presented in Appendix B of this document.

<sup>30</sup> However, two concessionaires did begin installations prior to official approval of the programme. Eskom Shell Solar Home Systems launched its off-grid programme in 1999 before it started receiving capital or operating subsidies. It achieved a great deal during the initial years (installing 6 000 systems in the Eastern Cape), but at great cost to shareholders in the joint venture. Indeed, the JV has incurred considerable losses in the four years since start-up. Shareholders are now demanding evidence of positive returns before investing further in this venture. NuRa secured funding from the Dutch government which covered the cost of the first 400 solar home systems, installed from December 2001 onwards.

contracts were signed, they would be expected to perform. This presented them with a significant challenge: before any installation took place, staff had to be identified, teams trained, bank accounts opened and insurance organised, premises established, equipment commissioned and purchased, and so on. All of this took time.

The RAPS Group was outstandingly active during this period of uncertainty. It took this opportunity to diversify into other areas, including consultations on rural energy, and to develop products and technologies that would be required upon when installations began. As noted by RAPS Group personnel, they ‘realised from an early stage that the success of these utilities would be based on sound business principles incorporating among other things: energy service delivery, customer service, revenue management and asset management. All of this had to be provided in a cost-effective manner’ (Banks & Niemand 2003). This led to the development of the ENERGYStream™ product range.

#### *6.4.2 Evolution of innovation*

The story behind ENERGYStream™ is not particularly complex. In essence, as RAPS Group staff note, it involved a process of ‘taking certain ideas and moulding them to work in a particular space’. That ‘space’ was rural energy provision and its associated challenges, as well as the terms of reference for the programme, as published by the DME.

The RAPS Group rose to this challenge. Perhaps it was able to do this so effectively because of the outstanding entrepreneurial spirit and drive of its founders and staff. They were able to see the challenge, delve into the details through developing a strong understanding of the rural energy challenge, develop concepts, tinker with technologies, and come up with this product. A team worked on the ENERGYStream product range for more than a year. RAPS invested about R2 million in this activity, and also took a loan from a fund specialising in solar energy development. This loan has now been repaid. The team sought advice from industry specialists (including specialists in the electronics and pre-payment metering industries). In some instances, these specialists were subcontracted to develop elements of the system. In return, they earn royalties per system sold. Restraint of trade agreements have enabled the group to retain control over these products.

This investment in development has begun to pay off: three of the four companies actively installing solar home systems, namely NuRa (the Nuon RAPS utility), KwaZulu Energy Services (KES) (EDF/Total utility) and SolarVision, are using ENERGYStream products. RAPS Technology also offers its clients some product variations. Elements of ENERGYStream are illustrated in Figure 3 and described below.

### 6.4.3 ENERGYStream product range<sup>31</sup>

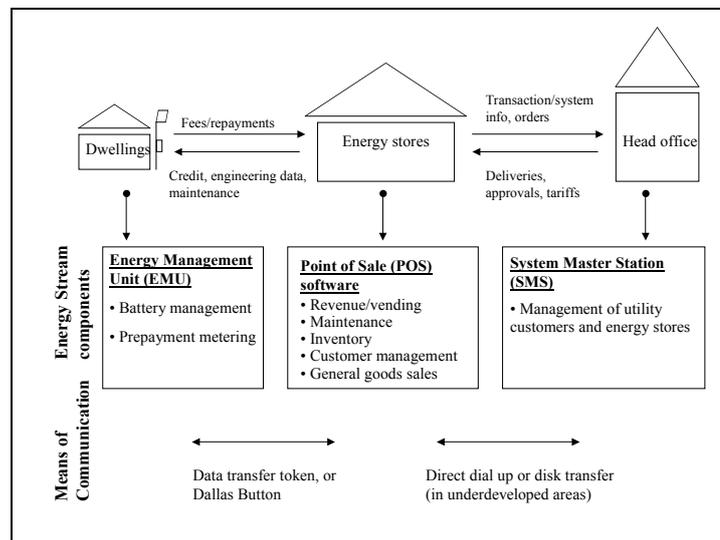
Broadly, ENERGYStream consists of key components: the Energy Management Unit, the Point of Sale, and the System Master Station.

### 6.4.4 The Energy Management Unit

The Energy Management Unit (EMU) manages household credit as well as the battery required to power the system. It is situated within the household, and is effectively a prepaid meter that disconnects the customer's load when the credit has expired. The EMU continues to act as a regulator when credit has expired, to ensure that the battery remains adequately charged. Additional credit purchased from the point of sale (the energy stores in the case of NuRa and EDF/Total, and mobile units in SolarVision's case) is loaded from the Data Transfer token, or a 'dallas' button, which carries electronic data (credit units) from the vendor to the household. The EMU incorporates a unique tariff methodology which allows the management of arrears payments.

Should a customer not use the system, he or she is still responsible for payment (because of the principle of fee-for-service rather than fee-for-energy). The patented ENERGYStream tariff gives the utility the flexibility to impose no penalty for arrears, or to impose extreme or intermediate penalties.

**Figure 3 – ENERGYStream from RAPS Technology**



<sup>31</sup> This section draws extensively on Banks and Niemand (2003).

Once credit has expired, the load can be reconnected every day for about five minutes. The purpose of this is to remind the customer of the system's value. The system incorporates numerous other technical innovations.

Importantly, the EMU records specific information about the operation of the charge controller, the battery, and the customer in general. This information is loaded on to a data transfer token, and transferred to the POS (Point of Sale) when the customer buys new credit. This facility provides vital information about the state of the customer's system, and allows preventive maintenance.

The EMU also contains an anti-tampering switch. Should the circuit be broken, the unit will go into tamper mode. This unit can also drive an electro-magnetic lock. Interlinked with these two features is a maintenance token, which is initialised at the POS and used to open meters for maintenance. Inserting the maintenance token operates the lock, allowing access to the battery. The maintenance token also records the date and time when the meter was opened and the remaining credit. This information is then downloaded at the POS for analysis.

Finally, the EMU has a simple interface to help customers manage credit and battery life.

#### *6.4.5 The Point of Sale (POS)*

The POS was developed primarily to sell solar credit. It also provides a total solution for managing local energy stores. The inventory master list and prices are defined at the system master station. The software provides for full inventory management, which includes receiving material, logging material movement (used for installations/maintenance), generating low stock notifications to the SMS (System Master Station), and so on. The software also simplifies stock-taking.

The POS helps the energy store to manage customers. Applications received are logged at the POS, and are then forwarded to the SMS for evaluation and approval. Various job cards can be generated at a POS (i.e. energy store or mobile unit). Job cards record new installations, routine maintenance, breakdown maintenance, and other engineering feedback. The software also provides a complete cashbook for accounting purposes, as well as a revenue-control management function that manages non-paying customers in a structured fashion. Customer complaints are logged on the POS, and reports on every customer can be easily generated.

#### *6.4.6 The System Master Station (SMS)*

All Points of Sale are managed from the SMS. Indeed, the SMS can 'turn off' a POS and prevent it from further vending. All customers are recorded at the SMS. Applications received from the individual energy stores are approved at the SMS. At this point, the customer is assigned a controlling energy store as well as a tariff based on the type of system he or she is applying for. Customers can also be assigned to maintenance areas, which facilitate logistical maintenance planning. The SMS controls routine maintenance.

It also manages inventory. Inventory classes can be created, each holding several inventory items. Sales prices and minimum stock levels are assigned to each item, and can vary depending on the energy store in question. Stock levels can also be monitored.

Other functions of the SMS include tariff definition, the flagging and tracking of non-paying customers, financial management/tracking of energy store performance, and interconnectivity with Geographical Information System (GIS) software in order to allow the detailed management of customers.

#### *6.4.7 ENERGYStream™ and other available products*

Three of the four concessionaires use the ENERGYStream product range. The fourth, Eskom/Shell, uses the PowerHouse™ Solar Home System, which includes a tower, a battery with an integrated SmartSwitch™, a PV panel with an integrated SmartSwitch™ and associated mounting hardware, a plug and play harnesses, lights and shades, and an enclosure base and cover. Interestingly, the SmartSwitch™ technology was developed and is owned by Conlog, and may be licensed to RAPS Technologies for integration with the ENERGYStream system.

The PowerHouse system is older than ENERGYStream. Developed by the Eskom/Shell JV in conjunction with Conlog in the early days of its programme, it is regarded as the first prepayment solar home system in existence. The system, which has evolved over time, essentially compares with ENERGYStream's Energy Management Unit (EMU). It uses a magnetic card reader rather than a data transfer token or 'dallas button', thus generating more engineering feedback than the ENERGYStream system. This has proven to be very useful with respect to preventive maintenance. Both the EMU and the PowerHouse system manage credit and battery charging with digital/electronic components. Both have a feature to cut out the system if it is tampered with. Both also cut out the system if it is significantly in arrears, though how this is achieved is based on different principles and timing. Both have a simple customer interface that allows the customer to gather information on the extent of credit and battery life. PowerHouse switches off households' external light at dawn, whereas ENERGYStream does not. EMU allows the utility to handle customers whose payments are in arrears by varying the penalty, whereas the PowerHouse system does not. PowerHouse identifies customers through barcodes, while ENERGYStream assigns customers unique customer numbers which are also linked to a meter number; thus customers can be identified by both customer and meter number.

#### *6.4.8 Nature of the innovation*

As a member of the RAPS Group notes, ENERGYStream™ is a 'brand new' product. It is unique for two important reasons. Firstly, it seeks to address the rural energy situation comprehensively. The outstanding innovation in ENERGYStream is not so much the individual components, but the system as a whole.<sup>32</sup> It is effectively

designed to link households to local energy stores and the concession head office. If any of the three elements cease to operate, ENERGYStream loses its value.

ENERGYStream also does well to understand the rural energy context. For example, there is very little reliable infrastructure, customers continually struggle to afford energy, housing is informal, and so on. The system is flexible enough to deal with these types of constraints.

Secondly, concessionaires using ENERGYStream argue that it provides a cost-effective solution. When questioned about the usefulness and the drawbacks of this product, a spokesperson for one of them noted that ENERGYStream was ‘a very simple system’ but that this was a strength rather than a weakness, because it rendered the system useable by relatively unskilled personnel. Most importantly, its simplicity enabled costs to be kept to a minimum. Indeed, there are far more sophisticated components on the market, but they are far more expensive.

The RAPS Group says the system is still evolving. This is due partly to the requirements of ENERGYStream clients and partly to continued attempts by RAPS Technology to improve it. RAPS Group staff note that ENERGYStream could still be improved – particularly in respect of effective business and financial management, and the management of information. Since NuRa is now also beginning to swell LPG and related appliances, it also notes a need to better integrate the sales of solar home systems with other services. RAPS Technology has registered two patents: the ENERGYStream™ product itself, and the Revenue Control System (a component of ENERGYStream). It is working on exporting both products to various countries in Africa.

#### *6.4.9 A different perspective on product innovation*

In April 2003, Shell Solar prepared a document for the DME containing suggestions on how policies could be changed to facilitate the rapid roll-out of solar home systems. It suggested that an outright sales approach rather than a fee-for-services model should be adopted. In response, the other operating concessionaires stated a clear preference for the fee-for-service approach. This interaction was one of the reasons why the government decided to commission a comprehensive review of the off-grid electrification programme. Another was that final contracts were due to be signed in March 2004, thus ending the pilot phase of the off-grid programme. The review process was to be completed by end January 2004 in time for analysis before the new contracts were concluded. A team headed by Africon Consulting Engineers carried out the review.

In the document, Shell Solar argued that the fee-for-service model resulted in ‘inconvenience for the customer, entails excessive costs for the rural private sector operator, and will cost the government more money than it needs to’. In August 2003,

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<sup>32</sup> This is not to say that none of the components is new. For instance, RAPS Technology has developed a revenue control system, which it has patented and which the RAPS Group hopes to export to other African countries.

it began to test an alternative delivery model for solar home systems. It still involves a fee-for-service arrangement with prepayment requirements, but seeks to provide the service at a lower cost. The Mnyamana project is testing the installation of 100 solar home systems with different specifications from those of the standard PowerHouse systems. Broadly, these systems are cheaper because they are simpler, and because of this Eskom Shell argues that they are more robust. The fundamental differences between the PowerHouse system and these pilot systems are outlined in Table 2.

**Table 2 – PowerHouse versus Mnyamana PV systems**

PowerHouse System	Mnyamana System
50 Wp module	50 Wp module
Pole mount	Roof mount
95 Ahr battery	95 Ahr battery
Conlog charge controller with card reader and detailed customer interface	Basic 10A charge controller with no card reader and simple LEDs
Electronic security in battery, panel and charge controller	No electronic smart switches
Customers purchase cards for R58 which are then inserted every 30 days to avoid the system from switching off	Customers 'buy' receipts every 30 days but the system never switches off
PowerHouse controller costs more than R600	Controller costs less than R100

*Source: Eskom Shell JV 2003*

The objectives of this pilot project are to:

- Try to reduce the level of panel theft;
- Reduce capital costs;
- Improve system reliability (i.e. reduce maintenance call-outs);
- Introduce a system that does not switch off, thus reducing the need for tampering; and
- Test cash collection without the assistance of technical devices.

By November 2003 the following results had been recorded:

- The roof mount had been introduced at the request of customers who believed that this intervention could reduce theft. No thefts had been reported.
- Cash collection was 100 per cent.
- One customer had complained about an intermittent problem, which was later found to be the result of a faulty installation. There were no other complaints

- Customers were said to be ‘extremely happy’, particularly with the fact that the system does not switch off. They were happy with its general performance and reliability.
- There was considerable further demand for similar systems.

This is a new project, and time will have to tell whether the encouraging results recorded during the first four months can be maintained. If they can, it must be asked whether the systems developed for managing revenues, guard against tampering, and so on are in fact necessary and/or cost effective. If it is found that customers can be trusted to make payments on time, and panel theft can be prevented in simpler ways, perhaps ENERGYStream and also PowerHouse may, in some instances at least, prove to be cases of technology overkill. In the meantime, however, they must be regarded as instances of genuine innovation in this sector.

## 7. Lessons in innovation

As government officials emphasise, the off-grid concessions programme is still in a pilot phase, and the jury is still out on its future and sustainability. Some aspects seem to be solid and moving forward, while others still seem uncertain.<sup>33</sup> Unfortunately, ongoing public funding is one of the uncertainties. Indeed, there is a concern that, especially since the World Summit on Sustainable Development (WSSD) of September 2002, the programme may be losing momentum.

Have the services delivered thus far been worth the investment and effort involved? From a consumer point of view, the answer seems to be yes, because they have already improved the lives of many rural dwellers.<sup>34</sup> This is confirmed by the following excerpts from customer surveys and interviews conducted in each of the concession areas in November and December 2003:

*Khanyisile (Pomeroy) says that her family are very pleased with the solar home system. The lights make her very happy. She says that 'the lights are as beautiful as flowers'.*

*Thembi (Mbazwane) says that the solar home system gives her household good light and that they 'would not like to be without this convenience again'.*

*Landina (Limpopo) says that the lights are better and she does not have to buy candles. Referring to the outside light above the front door, she says that 'it is no longer dark in the yard and no thieves will enter'.*

*Otto Mshibe (Pomeroy) says that his father has installed two solar home systems at the spaza shop. He says that their shop stays open late 'and the customers really like the music'.*

From an organisational, financial, and technological point of view, progress has been mixed. Concessionaires have made significant progress in setting up rural infrastructure, identifying households, and developing, installing, and maintaining systems. Less success has been achieved in delivering a comprehensive energy package, achieving sustainability, and establishing sound procurement procedures and contractual and institutional arrangements. Importantly, there are lessons to be learnt from both the successful and unsuccessful aspects of the programme.

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<sup>33</sup> For instance, each of the concession companies has international partners. Without this external investment – which has been largely in the social rather than private interest to date – the future of the off-grid programme is uncertain.

<sup>34</sup> This is not to say that the programme is without problems. As noted earlier, customers would prefer grid electricity, they would prefer to have a system that they can cook with, and they would prefer to pay less for the service each month, but on the whole, they are pleased with the systems, and would not like to go back to living without solar energy.

The South African off-grid programme is unique; no similar programme exists anywhere in the developing world. Therefore, many people are keenly watching its progress.

Is the programme innovative? Yes, and no. Viewed as a whole, it is. It has used elements of the business models, financing and institutional arrangements, and technologies used in other countries to forge a new approach to off-grid energy service provision. New products, including charge controllers, revenue management systems, battery boxes, module mounts, and lights and switches, have been developed, and new business or implementation models evolved. Financing mechanisms and institutional arrangements have been fraught with difficulties and challenges, and it is hard to make a verdict in these areas. Again, the extent to which the programme can be deemed innovative should be assessed in the light of customer perceptions. These, as noted earlier, are generally positive, though many customers believe there is room for further innovation in each of the above areas.

The principal lessons in respect of innovation include the following:

*Private sector concessionaires have been given the space to innovate, and technologies and delivery models have not been strictly specified.*

This has allowed concessionaires to be innovative about infrastructure, business models, and technology. Without this flexibility, it is unlikely that the private sector would have invested in innovation to the extent that they have.

*The public sector has produced guidelines on the anticipated end state.*

The government has provided broad guidelines for the type of programme it would like to see developed in rural areas. These have played an important role in keeping the programme on track, and within the ambit of government policy. Without them, it is highly debatable whether the programme would look the way it does today. Given, for example, the dissatisfaction of concessionaires with the fee-for-service model, it is probable that without these broad guidelines it would have been abandoned in favour of an outright sales approach.

*The government's approach has allowed for a diversity of approaches that have increased the value of the solutions.*

Diversity has emerged in terms of business and service delivery models as well as technologies (the EnergyStream versus Shell-Solar approach). More diverse solutions increase the potential for economic value to emerge by creating a larger pool of options to choose from. This avoids an early commitment to options that could be inferior, makes it more likely that the solutions that emerge will have greater value.

*Innovation is fostered by a supportive policy, planning, and political environment.*

Private sector players need certainty and reduced risk to involve themselves happily in partnerships with the public sector. If the risks are higher, private sector participants require higher returns on their investments. A supportive government framework

helps to reduce this risk, and increase certainty. The *White Paper on Energy Policy (1998)* highlights the government's commitment to rural electrification through grid investments. It is less clear on off-grid rural electrification, though it does call for a level playing field for grid and off-grid electrification, and states that 'as far as possible, the government commits itself to maintaining stable targets and subsidy levels'. Indeed, the equalising of subsidies for off-grid and grid electrification has boosted private sector interest in the programme. Arguably, the private sector's significant investment in the programme is a clear indication of strong links between a supportive policy framework and meaningful innovation. Interestingly, there is evidence that this relationship also works the other way: that an unsupportive or wavering policy environment and associated uncertainties about funding will quickly discourage private sector investment and associated innovation. This was perhaps the dominant feature of the programme up to late 2003, when the government drastically reduced the number of installations eligible for subsidy, and commissioned a full review of the programme. As a result, installations and development were largely frozen.

*Innovation is best enhanced in an entrepreneurial environment, and requires champions who consistently work at making improvements.*

The South African off-grid electrification programme is a good example of the contribution the private sector can make to the process of innovation. It contributes an entrepreneurial spirit, a drive to succeed, exposure to new models and experiences, and additional financing that are lacking in public sector institutions.

Private sector companies have to innovate if they are to be competitive. Innovation has given at least one concessionaire a significant comparative advantage over the others; indeed, it is now selling some of its products to others which are facing similar challenges and do not have the time and infrastructure to initiate a similar process of innovation. Off-grid electrification does not offer large financial returns in the short to medium term. It takes special private sector institutions, and probably champions within those institutions, to maintain their commitment to the programme, and therefore innovation.

*Protracted contracting periods create uncertainty and discourage investment.*

The South African off-grid programme clearly demonstrates the negative effects that poor and lengthy contracting procedures and delays and uncertainties emanating from within the public sector can have on private sector participation and investment. If not handled properly, these processes can permanently damage the relationship between the private and public sector. In the case of the off-grid programme, two of the seven private sector consortia withdrew from the negotiations, partly because it was taking so long to complete the interim agreements, and partly because the electrification had changed so much during this period. Trusting relationships and co-ordinated effort are key to workable public-private partnerships and sustained investment in product and process development.

*The role of international participation and investment must be acknowledged in an assessment of the overall innovation.*

As noted earlier, it is unlikely that the off-grid electrification programme would have been able to fly had it not been for off-shore investments, which have played a critical role in sustaining the programme. These investments are still critical – indeed, if the international funding partners dropped out of the process it is unlikely that the local partners would be able to carry on operating as service providers in their current form. Assessing the extent and nature of the innovation must thus be viewed in the light of international support. Interestingly, the off-grid concession programme experience indicates that international participation and investment have not defined the kind of technology used or its innovations, or the prevailing institutional and contracting processes. Rather, international involvement and funds have tended to be very supportive of a home-grown programme, defined primarily by local partners.

*An in-depth understanding of the environment/ target market helps to get the innovation right.*

An innovation is ultimately successful to the extent that end-users or recipients of the innovation are happy with it. Thus, the greater the innovators' understanding of the dynamics and needs of the 'target market', the better things will work. In the context of the South African off-grid programme, 'innovators' include both public- and private sector participants.

This programme is currently questioning the assumption that more technology or more complexity is always better. It seems that this may not always be the case: end-users may, in some instances, be more at ease with a simpler product or process. This is not to say then that the product or process is no longer innovative. Indeed, the simpler the product or process, the more innovative it might actually be. This is certainly the case with the contracting procedures currently in place, as well as with the current funding flows.

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## Appendix A: List of interviewees

Name	Designation, Institution
1. Wolsey Barnard	General manager (regulation and compliance), NE R
2. Yaw Afrane-Okese	Renewable energy officer, NER (formerly programme leader, Energy and Development Research Centre, University of Cape Town)
3. George F.C. van der Merwe	Chief consultant to NER on off-grid electrification programme (Ndizani Networks Group)
4. Isak Kotze	Director of electrification, Department of Minerals and Energy
5. Douglas Banks	Director, RAPS Consulting and NuRa Utility
6. Gary Whalley	Managing director, SolarVision
7. Henry Geldenhuys	Eskom Distribution, also director, Eskom/Shell Solar JV
8. Clive Horlock	Managing director, Eskom/Shell Joint Venture
9. Danie van der Walt	Strategic Electrification Planning, Eskom (Megawatt Park)
10. Vicki Mundell	Programme manager EDF, Southern Africa
11. Anton Eberhard	Professor, Infrastructure Industries Reform and Regulation Programme, Graduate School of Business, University of Cape Town.
12. Sarah Adams	ACCESS Programme, EDF, France

## **Appendix B: Update on off-grid electrification programme**

*Prepared by Riaan de Villiers, October 2005*

This study was written in late 2003, and updated in early 2004. A brief update to October 2005, on the Off-Grid Electrification programme seemed worthwhile, given its time-bound character.

In the course of 2004, the DME concluded new contracts with three major concessionaires: KES and NuRA in KwaZulu-Natal, and SolarVision in Limpopo. The fourth operating concessionaire, Eskom Shell Solar Home Systems, closed down, stating that its operation had become uneconomical.

It is understood that, following its successful pilot of an outright sales model, Eskom Shell Solar Home Systems asked the DME to allow concessionaires to utilise other models. When this did not happen, it decided to wind down. Maintenance of its systems in the Eastern Cape has been handed to three SMMEs, which are employing former Eskom Shell personnel.

The contracts with the three major concessionaires will run until March 2006. They provide for a maximum number of new installations which will fully subsidised by DME. Operating subsidies are now paid by municipalities, and are essentially the free basic electricity grants paid for both grid and off-grid electricity.

While the recommended subsidy is R40 a month, subsidies have the discretion to pay less. (In some cases, analysts say, municipalities are paying no subsidies at all, as a result of which the concessionaires concerted have reverted to charging customers the full monthly rates of R85.)

The German government (via the KfW Development Bank) has provided the DME with funding for a new concession in the Eastern Cape. The DME will subsidise installations by 80 per cent, with the concessionaire contributing the rest. This contract will also run for two to three years.

When these contracts expire, the DME will recede, and all concessionaires will have to form contractual relationships with local authorities. Capital subsidies will be drawn from state municipal infrastructure grants, and paid by municipalities as advised by the DME. However, all service providers will remain obliged to maintain the systems in their concession areas for a period of 20 years, or until their business become unviable due to grid encroachment.

In an interview in early October, a senior spokesperson for the DME stated that, while a number of challenges remained, the programme was functioning 'relatively well'. Up until end September 2005, about 29 000 home solar systems had been installed. De-installation rates due to payment defaults varied from 2 per cent to 5 per cent a year in various concession areas. Ways had been found of reducing theft.

Importantly, he stated that the aim of the off-grid programme was to provide temporary access to electricity in deep rural areas, pending the supply of grid electricity throughout the country. In this context, the off-grid programme would probably continue to grow for about three years, and then begin to wind down.



## **Appendix C: International experiences of off-grid electrification**

Over the past few years there has been growing interest in the use of solar home systems in rural areas in developing countries, and numerous models have been explored. Many of these explorations have been well documented. However, the literature contains very few descriptions of the types of technologies used in off-grid concessions programmes. Some key lessons are extracted below.

### **On private–public partnerships, concessions and competitive subsidies**

The Argentine off-grid programme (Covarrubias and Reiche 2000) is interesting and innovative in that off-grid services are to be provided by private companies requiring the lowest subsidy for serving a given area. Because of political and bureaucratic factors this programme has not yet taken off, but the results of pilot studies are very encouraging.

Concessionaires do not have obligatory coverage targets, but are required to serve customers who ask for it. Once a concession has been awarded, the concessionaire chooses the technology best suited to demand and the willingness to pay in a given area. Subsidies cover a share of the installation cost and, for the very poor, a share of the monthly tariff. They are linked to the service level and chosen technology; for example, higher subsidies are paid for renewable energy options. Subsidies will gradually diminish over the 15-year concession period. In the early years, when they will be at their highest, they will be funded by international donor agencies (Covarrubias and Reiche 2000).

Concession systems have also been adopted in Argentina, Benin, Togo, and Cape Verde. In Benin and Togo, monopoly concessions have been granted on a competitive basis. In Cape Verde a regulated monopoly was initially granted, but over time the system was successfully opened up to competition.

### **Delivery methods, business models and financing arrangements**

Martinot (2000) summarises off-grid experiences in South Africa, Bangladesh, the Dominican Republic, Mexico, and Morocco. Implemented by Grameen Shakti, the Bangladeshi system is one of few examples of solar home systems creating income-generating opportunities. These systems are sold on credit. In the Dominican Republic, a fee-for-service approach has been adopted. The aim of the programme is to reach a ‘proof of concept’ where the programme will break even. The business model employed by the US firm Soluz involves 5 000-customer business units, multiple ‘service centres’ serving 1 000 to 5 000 customers, ‘zones’ within service centres of 500 to 750 customers, and ‘collection points’ for 20 to 100 customers. Cost-effective collection management has been an important lesson: collection has been expensive, largely because it has required visits to some households. This programme has also demonstrated the need to educate consumers about the use of

batteries, chargers, and other technical aspects of the system. The Mexican model involves the leveraging of communal funds to pay for solar home systems, and these funds have not always been well managed. A lesson from Morocco is that beneficiary participation is important, as are adequate financing schemes, efficient payment collection mechanisms, and close after-sales service centres.

Martinot, Ramankutty and Ritter (2000) argue that there has been inadequate experience with the service model (involving fee-for-service arrangements) to say conclusively whether the outright sales or service model is preferable. However, they lean towards the service model, primarily because of its after-sales benefits.

After its workshop on financing mechanisms and business models for solar PV in Africa held in Pretoria in May 2003 (see box 2), the UNDP commissioned an overview (Banks (2003c) of the main methods of delivering solar home systems. The main models identified were:

- Supplier/dealer-led models (with or without dealer credit) evolving in response to purchasing capability, with relatively little outside control (eg Kenya).
- Project-focused models, typically providing consumer credit, involving a project management unit and more than one PV supplier or dealer (eg Kenya and Zimbabwe).
- Utility-type models, typically involving a subsidy, with exclusive access to a defined geographical area and a 'fee-for-service' payment method, with longer-term maintenance integrated into the package. Revenue may be collected either manually or via pre-payment systems aimed at reducing the cost of collection.
- Institutional focus models, involving market entry via projects intended to provide energy services to rural institutions such as schools or clinics.
- Productive use-led models, focusing on supporting economic activity in rural communities with renewable energy technology or other modern energy forms. PV energy is generally sold as part of a small business package, or in partnership with a range of village-level entrepreneurial development services (eg Uganda).

## **Box 2: African solar PV workshop: financing mechanisms and business models**

In May 2003, the United Nations Development Programme/Global Environment Facility (UNDP/GEF) held a workshop in Pretoria on financing mechanisms and business models for solar PV in Africa. More specifically, it was aimed at promoting cross-project learning and the sharing of experiences among African PV programmes. The 57 participants included representatives of 15 PV programmes in 13 countries; donor agencies such as the World Bank, GEF, and UNDP; and dealers, consulting companies, and industry associations. Participating countries were Uganda, Kenya, Tanzania, Ethiopia, Ghana, Zimbabwe, Malawi, Mozambique, Botswana, Namibia, Zambia, South Africa, and Lesotho.

Three distinct business models were identified:

- *Cash sales*, where the consumer buys the PV system for cash or via a credit arrangement with dealer;
- *Consumer credit*, involving a specialised finance partner and a maintenance contract during the finance term; and
- *Fee for service*, a large-scale 'utility-type' approach usually involving subsidies. Variations and hybrids of these three basic models are also found.

As regards financing mechanisms, three basic categories -- financing the consumer, financing the PV business, and financing the financiers -- were distinguished, and a variety of financing tools for each category presented. Tools such as hire purchase, salary withholding schemes, co-operative loans, credit lines to companies, risk guarantees, and many others were explained and discussed.

A key finding was that there was no single best business model, financing mechanism, or market development approach for PV in Africa. Careful analysis was needed to determine which models were best suited to particular markets, and other contextual parameters. Depending on whether the market was at a pioneering, emerging, or mature stage, and also on the strength of the local financial sector and a realistic demand forecast, an appropriate mix of financing tools along the delivery chain needed to be chosen in conjunction with the most suitable business model. These and other parameters would determine whether it was more appropriate to finance the consumer, the PV companies, or the financiers, and whether a cash sales, consumer credit, or fee-for-service model should be adopted.

Other criteria and variables also needed to be considered. The choice of the right business approach and financing tools depended, for example, on government policy, strategy, and action on rural electrification. In countries whose governments were strongly committed to providing energy and particularly (subsidised) electricity to rural areas, market development of PV systems and the choice of business approaches and financing tools would be different from situations where the government lacked the commitment and/or financial resources to provide subsidised access to electricity. In the latter setting, developing a fully commercial PV market with a profitable delivery infrastructure and appropriate financing mechanisms was a huge challenge. In the former setting, a large customer base and long-term perspectives were needed to break even using the fee-for-service approach.

In 2001 the UNEP Collaborating Centre on Energy and Environment published a booklet on experiences with PV systems in Africa (Wamukonya 2001). It notes that various small-scale solar PV initiatives have been implemented in different parts of Africa, driven either by governments or the private sector. Responding to a perceived 'information gap' on these initiatives, the booklet outlines experiences in Botswana, Namibia, Zimbabwe, Kenya, Uganda, Ghana, Mali, Swaziland, Zambia, Morocco, Senegal, South Africa, and Lesotho, and discusses business models and financing arrangements for each of the projects.

According to Martinot, Cabraal, and Mathur (2000), there is growing interest internationally in the energy service company (ESCO) model for delivering solar home systems, in terms of which the ESCO owns the system, charges the household or end user a monthly service fee, and is responsible for service. The ESCO may be a monopoly concession regulated by the government to serve specific geographic areas (as in Argentina, Benin and Togo), or it may operate competitively without an explicit monopoly status (as in the Dominican Republic). Combinations of these two forms of ESCO start with monopoly concessions and progressively open up markets to competition after some years (as in the Cape Verde).

### **Approaches to regulation**

As a component of the review of the South African off-grid electricity programme, Clark (2003) also reviewed best practices in developing countries. Based on the findings, she suggested that the objectives of the local programme should be re-evaluated. International experiences pointed to two basic approaches: quick-fix approaches that rapidly helped to alleviate poverty, or those that built sustainable solutions. Both had merits and demerits. Besides this, South African policy-makers and planners should examine the following issues:

- *Whether it is worthwhile subsidising capital and operating costs to the extent that this is currently done.* These subsidies place a tremendous burden on the public sector, and it is debatable whether they create a sustainable solution. Experience indicates the importance of customer contributions.
- *Whether diminishing grants may be a useful tool.* In some cases, subsidies cannot be avoided; they are needed to help poor households to move out of dire poverty, and to help establish a market for solar home systems. Recognising this, some countries are offering diminishing grants, with the diminutions made known up-front.
- *Whether it is worthwhile introducing more competition into the selection of concessionaires.* International experience indicates the benefits of selecting private sector partners competitively or on the basis of the lowest subsidy required for high-quality systems and service. This approach allows the private sector to create innovative solutions for reducing costs. An interesting example of this is where customers are taught to conduct routine maintenance, and service providers are only called out when there is a second-level problem.

- *Whether it is appropriate to distinguish between on-grid electrification projects and off-grid pre-electrification projects.* A distinction between electrification and pre-electrification projects can help the government to get ‘the right message’ across to customers, thus ensuring that expectations are not unrealistically raised. Furthermore, a distinction between these different levels of electrification can help to remove the need for creating a level playing field between grid and off-grid solutions.
- *Whether sales and service models should be implemented concurrently.* Experiences elsewhere show that these models can be implemented at the same time. Customers can choose the option that suits them best, and different policies and regulations can be formulated for each.
- *If the sales model is implemented, whether it is worthwhile working with micro financiers to reduce the costs of debt.* Micro financing has been successfully utilised in several countries to facilitate the sales of solar home systems. Credit risk should be built into the models from the outset. Flexible repayment systems are crucial. The modular purchase of solar home systems has also been successful.
- *Whether adequate public sector resources have been allocated to administering the programme.* International experience indicates that administering these programmes requires significant time and human resources.
- *Whether the private sector’s role in the programme can be protected.* International experience indicates the importance of ensuring that the private sector is able to make a profit from its involvement. Dialogue, co-operation, and trust between public institutions and private entrepreneurs must be prioritised.
- *Whether the programme’s alignment with other aspects of public policy can be improved.* International experience indicates that solar programmes can be permanently harmed when they are not properly harmonised with other aspects of government policy, including grid electrification.

**Box 3: Overview of international experiences (1)**

Programme	Argentina (Renewable energy in the rural market)	Benin/Togo (Decentralised rural energy)	Cape Verde (Energy & water sector reform)	Peru (Photovoltaic-based rural electrification)	Bolivia (Renewable energy-based rural electrification)
<b>Geographic monopoly for concession</b>	Yes; by province	Yes; selected 'project areas'	No; gains market rights and subsidies, but must compete with others	Community-based, but not necessarily monopoly	Community-based, but not necessarily monopoly
<b>Regulator</b>	Provincial governments and existing provincial utility regulatory agency	Newly established national agency 'Agence d'Electrification Rurale'	Project Management Unit during project; thereafter 'independent utilities regulator'	Ministry of Energy and Mines	Municipal governments (also through equity investments in the concession)
<b>Concession term</b>	15 years	15 years	10 years	Not stated	Not stated
<b>Concession renewable</b>	Yes, to 45 years	Yes, to 40 years	No	Not stated	Not stated
<b>Bundling with other services</b>	Possible	No	Possible	Possible	No
<b>Competitive bidding vs negotiated contracts</b>	Negotiate with urban concession, else bidding	Competitive bidding	Competitive bidding	Not stated	Not stated
<b>Purchase vs leasing by concession</b>	Purchase on open market	Lease from govt agency	Purchase on open market	Purchase on open market	Not stated
<b>Technology choice</b>	By concession	By govt agency (regulator)	By concession	By concession	Initially by project/regulator
<b>Initial customer fee</b>	Yes; ± \$100 (for 50 Wp)	Yes	Decided by concession	Yes; ± \$100	Yes; 10% of system cost
<b>Subsidies</b>	Up-front grant of ±65% of installed system costs; GEF grant diminishes over time Low-income: also monthly subsidies	Up-front grant and yearly grant for up to five years, covering up to 30% of installed system costs; diminishes in later years of project	Up-front grants of 30% for 20 Wp household system; 15% for 50 Wp household system; 25% for 50 Wp public lighting system	80% subsidy for installed system costs; constant over life of project	At least 35% for PV projects and 20% for mini-hydro projects
<b>Service standards and monitoring</b>	PV system performance standards Certification procedures for installers	PV code of practice PV technical standards Accreditation programme for technicians Inspections on installed systems Customer surveys	International standards used Equipment meets 'certain minimum standards' Project Management Unit supervision	PV systems standards Recommended certification practices Training for installation technicians Random inspections	Equipment standards Certification programme

**Box 4: Overview of international experiences (2)**

Case study country	SHS delivery model	Implementing agent	Sources of finance	Notes
Argentina	Fee-for-service, regulated monopoly concession, concession granted on competitive basis	ESCO sells, installs and services	Provincial and federal government  World Bank provides grants on diminishing scale	Concession companies must provide services for a period of at least 15 years
Bangladesh	Credit sales, credit extended by non-profit dealer	Grameen Shakti sells, installs, services, collections, providers guarantees and three-year credit	IFC – Business loans	Marketing and education costs are high
Benin and Togo	Fee-for-service, regulated monopoly concession granted on competitive basis	N/a	World Bank provides grants to concessions on a diminishing scale	Diminishing grants entail added administrative burden
Brazil	Fee-for-service/rental scheme	Electric utility selects, installs, sells, services	Utility  International funding	Low degree of subsidy  User pays a service and rental fee
Bolivia (before 2001)	Fee-for-service/rental scheme	Electric utility (CRE) selects, sells and installs	Electric utility  International funding	Fee collection undertaken through local savings and credit cooperatives that have few means and incentives to minimise defaulters (less than 1/2 of end-users by 2001 were making payments)  CRE believes that it is more expensive to set up a strong fee collection system than to cover the losses
Bolivia (2001 onwards)	Cash sales, flexible credit scheme	(NGO) Energetica	Dutch funds  Local credit organisation	Credit organisation allows built in flexible debt rescheduling according to agricultural situation and calendar
Cape Verde	Fee-for-service, regulated monopoly concession that progressively opened up to competition.	N/a	World Bank provides diminishing grants to concession companies	Diminishing grants entail added administrative burden

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Case study country	SHS delivery model	Implementing agent	Sources of finance	Notes
China	Credit sales, then later cash sales	Company (Gansu PV) to manufacture, install and service	Customers Donors subsidising cash purchases	Initially customers did not understand the concept of 'credit' User is responsible for operation and maintenance Customers pay ½ the price before installation, and ½ after installation
Dominican Republic	Fee-for-service, regulated concession (no monopoly status)	Company (Soluz) and subsidiaries and service centres and collection points	IFC – business financing for dealers available	Cost-effective collection has been challenging Customer education important
Gambia	Credit sales	Small private companies	N/a	High risks involved so sales are restricted to well-known intermediaries or customers
Honduras	Fee-for-service, cash and credit sales, dealer credit	Company (Soluz Inc.) and subsidiaries sell, install, service	Rural NGO financier Soluz Inc.	Fee-for-service is most common (maintenance costs included) For credit sales, customers pay for maintenance if past warranty Resolving non-payment problem more difficult with credit customers Soluz has experience in fee-for-service, cash and credit which helps
Indonesia (Phase 1)	Cash sales and hire purchase	ESCO (PT. Sudimara) sells, installs and services	PT Sudimara provides hire purchase facility	Cash flow problems Banks unwilling to give loans as no collateral High overhead costs
Indonesia (Phase 2)	Cash sales and hire purchase	ESCO (PT Mambruk Energy International ) Franchised solar shops install and service	PT Mambruk provides hire purchase facility World Bank/GEF provides grants to dealers who provider credit on sales	Franchising approach reduces costs Slow start-up owing to infrastructural requirements

*employment growth and development initiative*

*HSRC*

Case study country	SHS delivery model	Implementing agent	Sources of finance	Notes
Kenya	Cash sales (modular and outright)	Private dealers but installation advice not common for hire purchase arrangements	IFC – business financing though competitive solicitation and selection of business plans	Very few local enterprises sell higher-quality systems or provide installation services
	Hire purchase		Commercial funding support	Limited government support Modular sales most common Warranty offered
			Cooperative funding	Hire purchase works well due to a well developed credit infrastructure in rural areas.
Mexico	Cash sales and subsidised government programmes	Local government and private dealers	Communal funds Donor support	Coordination between grid extensions and PV programmes necessary
Morocco	Cash sales, hire purchase and fee-for-service	State electric utility (ONE) to design programme and provide some finance	Local councils, end-users and ONE (from levy on electricity sales)	Fee-for-service is most popular User undertakes basic maintenance
		Private company (Sunlight Power Maroc) sells, installs, services and helps to finance.	IFC – competitive solicitation and selection of business plans	For cash sales, customers may agree to a maintenance agreement and pay an annual fee, or they pay for costs linked to each repair.
			Micro-credit organisations	Capital-intensive business
			Small subsidy content	Performance achieved largely without help of financing arrangements
Namibia	Credit sales	Accredited ESCOs sell, install and service.	Peri-Urban and Rural Solar Electrification Revolving Fund	High payment records Sustainability of revolving fund questioned
		National development authority manages revolving fund	International funding	Quality control and maintenance problems Moderate degree of subsidy (35%)

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Case study country	SHS delivery model	Implementing agent	Sources of finance	Notes
Philippines	Credit sales and renting	Electric Cooperatives contract with end-user and collect service fees which are repaid to NEA	National Energy Administration lends to ECs (subsidies)  International funding too	End-user must purchase balance of system components at own cost  High degree of subsidy  Credit: user owns BOS, EC finances solar generator, user pays combined service fees (O&M and debt service)  Rental: user owns Bos, EC owns solar generator, user pays combined service fees (O&M, rental fee)
Sri Lanka	Cash sales and end-user credit	ESCO (SELCO Solar Lanka Limited) markets, sells, installs and services and helps to finance  Micro-financier does collections	World Bank grant (subsidy to financier to reduce monthly payments)  Micro-financier  ESCO (SELCO Solar Lanka Limited)	Monthly collection costs prohibitive when fee for service approach tried. Micro-finance option preferable.  Sales contract states that the ESCO must provide high-quality after-sales service.  ESCOs had difficulties in maintaining service agreements on credit sales

Case study country	SHS delivery model	Implementing agent	Sources of finance	Notes
Tunisia	Energy service (but no fee for service is requested)	National energy authority installs and services for two years  PV dealers sell to AME	Donor and government supported	High degree of subsidy  Customers place a down payment (about 7% of installed system) but do not pay a regular fee for installation, maintenance or replacement  Financial sector is not involved because no credit  Programme dependent on availability of govt/donor funds  After two years, customer is responsible for O&M  Quality problems and poor technical design  PV dealers do not have opportunity to develop market
Uganda	Cash and credit sales	Village bank procures systems through competitive bidding by private dealers who also install	Habitat for Humanity and donors  Solar Electric Light Fund  HIVOS  Revolving credit funds  Village banking – micro-financing	Community-driven approach  Credit funds are not sustainable

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Case study country	SHS delivery model	Implementing agent	Sources of finance	Notes
Vietnam	Cash sales and credit sales, ESCO concession now considered	Private dealer installs and services, provides guarantees  VMU markets and collects payments  Loans provided by VBARD	Vietnam Women's Union (VMU)  Vietnam Bank for Agriculture and Rural Development  Dealer  IFC – business financing for dealers available	N/a
Zimbabwe	Cash sales and dealer credit and some hire purchase  Bulk purchasing of equipment duty free	ESCO (Solar Energy Supplies) store, credit stores or other network partners  Installation by customer	Initially GEF funded.  Cooperative funding  Agricultural Finance Corporation loan	Cost of system is less because of no installation and travel costs  Cash sales are more popular than credit sales  Modular cash purchase is popular (i.e purchasing system over time)

*Sources for above tables: International Energy Agency (IEA) (2002a); IEA (2003a,b), Martinot (2000), Martinot, Cabraal and Mathur (2001), Banks (2003), Hankins (2003)*

**RESOURCE-BASED TECHNOLOGY  
INNOVATION IN SOUTH AFRICA:**

**CHAPTER 5:**

**Pre-paid Metering Technology – Systemic Innovation  
in the South African Energy Sector**

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## **1. Introduction**

In 1989 Eskom embarked on an ambitious programme for the electrification of over 1 million households in previously disadvantaged communities. The socioeconomic conditions in these areas made the use of existing technology credit-based metering difficult and expensive: the targeted consumer base generally had no access to banking, postal or other infrastructure, was engaged in the informal employment sector, and was subject to high levels of crime. Eskom identified Pre-Paid Metering (PPM) technology as a way of mitigating the impact of these problems on the costs and administration of the electrification.

However, at the time PPM technology internationally was still in the early stages of development, and did not meet Eskom's operational requirements. Consequently, Eskom led a strategic alliance of domestic manufacturers for the development of a South African pre-paid metering technology. Once the technology had matured sufficiently, Eskom withdrew from active participation in the technology's development, focusing on driving the cost of the product down. Today, the objective of extending electricity to one million households has been achieved, with 2.6 million South African households using the PPM technology. The South African manufacturers and developers of PPM technology have successfully grown export levels and attracted Multinational investment in the industry. The standard underlying the technology has received international recognition through its adoption as the basis for a new International Electrotechnic Commission standard for pre-paid metering technology.

The PPM industry represents a case of successful local development of cutting edge global technology, based on the creative combination of inherited local technological capabilities, imported knowledge, and strong collaboration of public and private sector actors, incentivised and co-ordinated by the public sector's strategic purchasing pre-commitment for large and long-term purchases of the resulting technology. Many of the elements of this strategy could be replicable on the level of public industrial and innovation policy. It also holds many lessons for private sector actors seeking to upgrade their innovative capabilities and find a growth market in the context of an emerging economy.

The chapter begins by a brief overview of the various components of the PPM technology. I then provide an outline of the different phases of the PPM industry's history. This is followed by a discussion of several aspects of the PPM industry's development, including the institutional environment within which the industry developed the role of inherited capabilities from the military and communications sectors, the role of strategic alliance leader in paradigm-changing innovations, and the role of Multinational entry in South Africa's PPM industry. A brief discussion of the methodology used in this case study is followed by some concluding remarks.

## 2. The prepaid metering system: a brief overview

Most of the readers of this paper will have experienced the traditional *credit-based system* of electricity delivery, where the customer consumes electricity continuously, and makes periodical payments to the utility provider. The amount consumed is measured by an electricity meter. Representatives of the utility company periodically inspect the meter, and the customer is invoiced for the energy consumed. Depending on the terms of payment, customers have various periods of time to settle their accounts. Non-payment may result in customers being disconnected. The basic principle of the *prepayment system* is the reverse of the credit-metering system: customers decide how much energy they require *before* they consume it, and pay the relevant amount to the utility beforehand. The household is then credited with the purchased amount of electricity. After the prepaid amount of electricity is consumed, electricity is automatically disconnected unless the customer makes a further prepayment<sup>35</sup>.

Credit-based metering and billing is still the dominant mode of utilities delivery. The technology involved is mature and relatively cheap, and its organisational procedures are all in place. However, credit metering is also characterised by high labour intensity, high credit and financing risk, and other cost-related factors (which will be discussed at length below). Thus, in principle, prepaid metering offers utility providers the possibility of decreasing the administrative and financing costs of electricity delivery, which in turn will bring down the cost of electricity delivery, or yield higher returns to the utility, or both. Utility providers have long been aware of the *potential* advantages of prepaid electricity delivery over credit metering,<sup>36</sup> but it was not until the mid-1990s that (partly as a result of the technology development led by Eskom) the PPM technology evolved to a level that would allow its widespread implementation.

As illustrated in Figure 1 and Figure 2, the PPM system has several important components. First, there is the prepaid meter (or ‘electricity dispenser’ - ED) which is installed in the household. The ED is activated by the input of a ‘token’, which indicates how much energy the customer has purchased. The token comes in a variety of physical forms, but essentially it represents a string of numbers that are entered into the ED to authenticate the transaction. In the early stages of the industry, the tokens were disposable cards with magnetic strips, but in the late 1990s keypads became more popular as input mechanisms (as shown, for example, on the ED in Figure 3). The token used for keypad activation is just a string of numbers, communicated to the consumer orally, in written form, or even via an SMS or e-mail. A crucial aspect of the non-transferable token system developed in South Africa is that the tokens used are uniquely coded to work with a specific ED. Since the token has value only for the customer who has purchased it, the incentives for theft are

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<sup>35</sup> This is referred to in the industry as a ‘self-disconnect’ mode.

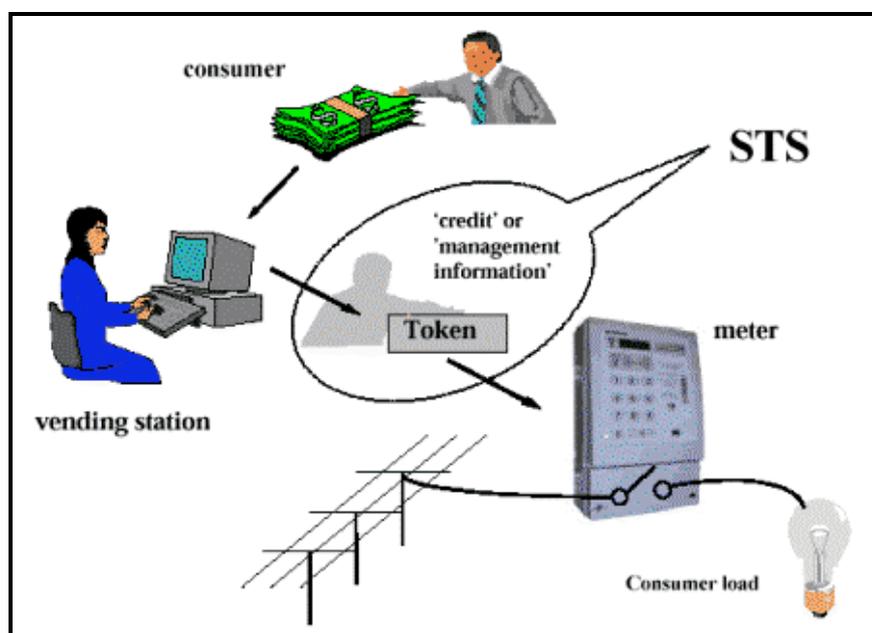
<sup>36</sup> Prepayment is used on a limited basis in the UK. Prepayment is made through coin-operated or magnetic card meters.

removed, thus increasing the security and convenience of the process for the consumer.

The consumer purchases electricity from the vending station, also called the 'cash dispensing unit' (CDU). Given Eskom's monopoly supplier position, the CDU effectively acts as a vending outlet on behalf of the monopoly; it purchases electricity in bulk according to estimated sale needs<sup>37</sup>. Eskom's system master stations (SMS) download the information necessary for the bulk crediting of the CDUs with electricity, while CDU bulk information on individual customer purchases is periodically uploaded to the SMS. The system can operate continually where a good communications network is available, but, if necessary, data can be transferred via a floppy disk (particularly useful in areas lacking good communications infrastructure)

The SMS consolidates the pooled information on the various CDU activities and uploads it to the Eskom's mainframe computers, where Eskom's credit and tariff management system and its information and billing system (CRP system) consolidate and reconcile the figures for the electricity consumed and the amounts paid. This completes the full supply chain, from generation to distribution to final consumption of pre-paid electricity sales.

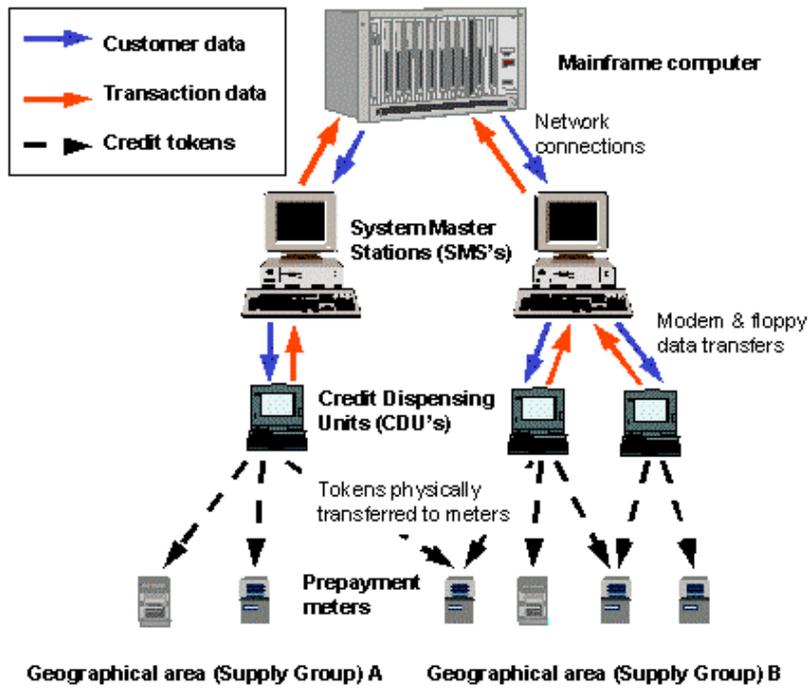
**Figure 1 – The basic process of prepaid metering**



Source: STS Website

<sup>37</sup> Before 2002 CDUs used to purchase electricity on credit, but high financing costs and fraud led Eskom to change to a prepaid system (Eskom, 2002).

Figure 2 – Prepaid metering system structure



Source: Eskom website

## 3. The history of the development of the PPM technology

### 3.1 Strategy development: background to Eskom's choice of PPM

Prior to the 1990s Eskom's electricity distribution activities were limited to direct sale to large commercial and municipal clients. As a vertically integrated state monopoly, Eskom was in a unique position of control of the energy economy from power generation to distribution. As a parastatal, it was also subject to political influence from the government at the time. As a monopsonist in the electricity industry, it was a key market for large segments of the electrical equipment industry. In addition, Eskom's strategic role in South Africa's industrial development lent it a powerful standing in the electricity industry and the economy as a whole. Prior to the 1990s Eskom sold energy directly to large commercial customers and to municipalities. It was municipalities that sold electricity to residential consumers. As municipal electricity distribution was concentrated on the affluent and largely white areas, large parts of the township population were left without electricity. In the context of the political situation at the time, this was identified as a significant problem, and consequently in 1989 Eskom launched the 'Electricity for All' programme, which aimed to extend electrification to one million households in traditionally underprivileged areas<sup>38</sup>.

Electricity-provision involves not only the installation of the physical infrastructure and equipment, but also the effective operation of the administrative infrastructure which would allow the metering, billing and payment for household energy consumption, as well as for maintenance. At the time credit-based metering and payment was the dominant mode of residential electricity distribution (both in SA and internationally). The technology components used in credit-based metering were cheap and widely available, which in turn meant low *per household* installation and maintenance costs.

A combination of factors (summarised in Table 1), such as the high administrative costs of administering a credit-based system, the low income levels of the targeted households, and the lack of physical and communications infrastructure, led Eskom to search for alternatives to the traditional credit-based metering system used in the municipal and commercial markets<sup>39</sup>. Before Eskom settled on PPM technology,

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<sup>38</sup> In rural areas where it was unfeasible to distribute power from Eskom's main grid, an off-grid generation programme was implemented, which used solar power to provide basic electricity to households. This is examined in detail in chapter 5 of this book.

some alternative technologies were considered that could mitigate one or another factor. For instance drive-by metering technology could use radio transmissions for taking meter readings without the need to gain access to the household. Fixed-rate meters could help avoid the credit system administration problem<sup>40</sup>. However, neither of these solutions would have solved all of the challenges faced by Eskom. While drive-by metering decreases the direct costs of inspection, the high administrative and financing costs and infrastructure-related problems noted above would remain. While the fixed-rate meter would have solved Eskom’s problems, it would have done so at the expense of the autonomy of the customers, as the amount they could consume would be restricted<sup>41</sup>. Consequently, Eskom began investigating the possibility of using PPM technology for the electrification programme.

**Table 1 – Credit-based vs. pre-paid metering system**

Credit-based system	Pre-paid metering (PPM) system
<i>General factors</i>	
Meter-reading is labour intensive; need for access to household	There is no need for meter reading in PPMs
Loss of time and resources for clients and distributor due to connection and disconnection	Self-disconnection of PPMs avoids such costs; lower level of customer complaints and communication around re-connection
Credit-based system business processes are very resource-intensive: invoicing, information processing, customer feedback, support, client monitoring, etc.	Self-administration of PPM system cuts many of these costs; PPM provides a basis for the development of innovative revenue management systems
Low-income households have low levels of energy consumption but the same level of administration and maintenance costs	Once-off installation and maintenance costs are only major individual user costs
<i>SA-specific factors</i>	
Debt-management is expensive, especially for low-income parts of society	PPM shifts the income-monitoring cost to the client; extension of electricity to the non-bankable; elimination of the bad debt risk
Politically motivated non-payment culture	Not a problem with PPM
Lack of basic infrastructure (post offices, banks, even street numbers)	Still a problem for maintenance but not a burden for administration
Difficult physical environment for installation” dwellings may consist of mud, corrugated iron, wood, plastic, bricks; electricity brown-outs	PPM Eds were designed specifically to deal with such problems

<sup>39</sup> An early Eskom internal document states: ‘pre-payment metering systems allow the customer to be in control of the use of the electricity purchased and may budget accordingly. This will overcome the misconception which has arisen that there is no relationship between what customers are asked to pay and the amount of electricity consumed.’ (Theron, 1992:2)

<sup>40</sup> These provided the customers with a small amount of electricity, and disconnected when the fixed rate was exceeded (World Bank, 2001).

<sup>41</sup> Respondent 1 explained that Eskom wanted to provide the same quality of service to traditionally disadvantaged areas as it does to affluent areas, and that a flat-rate meter would have been seen as an inferior service. In addition, there would be limited scope for growth in consumption as household incomes grow.

Once Eskom settled on prepaid metering, the availability of appropriate PPM products domestically and internationally was explored. The leading PPM technology was used in the UK, but that was seen as inadequate for Eskom's aims: as the prepayment meters were operated either coin or transferable magnetic strip cards, the security level was low and the fraud risk was seen as very high. Eskom decided that a transferable token system would carry a very high level of theft and fraud risk, and that a non-transferable system would be most appropriate to the market environment<sup>42</sup>. It was recognised that internationally there was no satisfactory solution to Eskom's specific requirements. The crucial decision was then taken that Eskom would co-ordinate the development of a non-transferable token PPM system domestically, with the help of the private sector.

### **3.2 Initial stages of development (1989 - 1992)**

In April 1990 Eskom released the NRS 009 specification which provided the technology concept outline of the basic product features with which potential products would have to comply. On the basis of this specification Eskom issued a call for proposals to industry, in order to gauge the level of market interest and capabilities for the development of PPM technology. To expand the scope for innovation by producers, Eskom kept the NRS 009 specification very short, consisting of 2-3 pages of general functional requirements.

Key aspects of the specification were that the new prepaid meters would be based on kWh measurement, that vendor-user credit transfer would be via a non-transferable token, and a long-term purchasing pre-commitment for over 1 million meters (for 1 million households). The release of the call for proposals resulted in up to 27 different manufacturers expressing an interest for participation in the programme. From this initial pool Eskom started further negotiations with a group of six companies. In July, 1990 Eskom called for a tender for 30 000 EDs, and awarded the contracts to three suppliers, namely Angcontech, Conlog and Spescom (Theron, 1992).

The initial years of the project were aimed at stimulating innovation by the producers, and the development of different technology options around the initial functional specification. To provide the incentives for producers to invest in the development of different solutions, Eskom committed to purchasing early product models of different technological solutions at relatively high prices, as long as these met the basic technological and engineering specification of NRS 009 (1,2,5,7). The following list of producers' credit transfer mechanisms in compliance with NRS 009 illustrates the level of technological diversity that developed rapidly: disposable magnetic card (Angcontech, Conlog), smart card (Altech), bar code/keypad (Ash Brothers), re-usable magnetic card (Cumcon), keypad (Plessey, Spescom) (Theron, 1992). Similar

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<sup>42</sup> In transferable credit systems any meter can use the credit. That is, one household could purchase credit, and another could use it. For instance, a person could 'borrow' a card from a neighbour if she ran out of electricity. Eskom judged that in the context of high-crime areas this would expose households to the risk of theft, as the magnetic strip would have a value.

variety in design existed in the ED's design, support infrastructure and other aspects of the technology.

The first years were characterised by a steep learning curve for all parties. There was intensive interaction between Eskom and the manufacturers. This resulted in the development of strong relationships between the various participants of the strategic alliance and Eskom, with some even describing Eskom as 'grandfatherly'. At this early stage of the technology's development, Eskom played an information broker role, which was important in the rapid diffusion of preferred technology solutions between the different members of the alliance. Eskom's R&D activities benefited the industry, as the company made the results of its research freely available to the participants in the alliance. It also co-ordinated minor technological changes and enhancements by liaising between the producers. The feedback it provided to the producers allowed defects to be corrected before mass production, and saved the industry from having to pay large amounts for replacements and returns.

Eskom's TRI division played an important role in the testing and benchmarking of different manufacturers' models, while also conducting R&D into problems affecting the whole industry. TRI (Technology Research Investigations) is a multidisciplinary science, engineering and technology consultancy focusing on the power sector and related industries, currently with a staff of over 600<sup>43</sup>. As TRI engaged in very frequent and intensive testing of the different model prototypes and the incremental technological changes, it was in a position to compare the different technologies and to encourage early adoption of best solutions by the manufacturers<sup>44</sup>. Where Eskom was the initiator of a testing round, it paid for the tests, and disseminated the results of the tests to the manufacturers, which in turn allowed a rapid diffusion of best practice knowledge. Beyond testing, the R&D activities in which TRI engaged resulted in a number of important innovations that facilitated the growth of the PPM industry (summarised in Table 2). While Eskom allowed producers significant leeway in their design solutions, it expected alliance participants to rapidly adopt its preferred technological solution. The company retained the ultimate right to approve or reject any technological improvement proposed by the various manufacturers, as it could ultimately stop purchasing a particular model.

A good example of the importance of its role is TRI's development of an innovative lightning protection standard through the use of an on-board 5kA gapped arrester. During the early stages of the industry's development, Eskom identified a very high failure rate due to lightning strikes among virtually all manufacturers' models. Even

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<sup>43</sup> After the formation of Eskom Enterprises, it was renamed to Technology Services International (TSI), and it began to expand its activities beyond Eskom (even though Eskom remains its primary client).

<sup>44</sup> For instance, TRI conducted a simple but ingenious experiment to decide between the adoption of the swipe-through and slot-in cards of different manufacturers. A sample of meters were installed at the exit of TRI's building, and a sample of both types of cards were given to TRI's employees, who were encouraged to use them as often as possible. This allowed the TRI to statistically test the superiority of each model, and established the swipe-through mechanism as superior.

though the EDs were in compliance with international standards for withstanding to power surges, impulse, noise and over-voltage for electronic equipment, there was a failure rate of up to 30%. A CSIR investigation subjected several manufacturers' EDs to a lightning test and confirmed that all models shared the problem. TRI's investigations showed that the cause for the failures was due to low-quality installations in the overhead reticulation, clearly not the responsibility of the ED manufacturers (Theron, 1992). In collaboration with the CSIR, TRI developed a novel lightning protection standard, which manufacturers had to integrate in future designs. Consequently, ED lightning failure rates dropped to negligible levels. In addition to solving this problem for the PPM industry, the standard's development resulted in the TSI's development of an internationally leading competence in this area<sup>45</sup>.

An additional example of the standardisation role played by Eskom through the TRI was the development of a software maturity standard in 1993-4. Following an investigation into high-failure rate of meters, the TRI narrowed down the problem to many EDs' on-board software. The different software platforms operated by the various manufacturers, and the lack of systemic quality control led to inconsistent reliability and performance of the EDs. The TRI sought to address this problem by developing a software auditing tool which could identify ED software problems quickly and reliably (in collaboration with Wits University). Simultaneously, TSI pushed manufacturers to increase the levels of 'software maturity' in the ED on-board software<sup>46</sup>. As a result, the level of meter failure due to software problems has declined dramatically.

### **3.3 Standardisation of technology (1993 - 1994)**

Eskom's focus on stimulating a rapid rate of innovation in the development of the EDs resulted in a proliferation of design layouts, vendor systems, as well as widely diverging levels of performance of different EDs. In addition, as the various manufacturers had developed proprietary communication protocols and vendor software, there were multiple standards on a system level too, which meant that different manufacturers' EDs could not operate on each others' payment networks.

As discussed above, diversity in technological solutions was beneficial in the early stages of the technology's development, as it provided a choice of solutions and reduced the danger of developing path-dependence in inferior technologies. However,

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<sup>45</sup> Other important innovations that TRI has introduced in the PPM industry are the development of: an Accelerated Life Testing procedure, which enables the generation of failure modes for EDs under simulated extreme environmental conditions; a methodology for testing the ED software, leading to increased levels of software maturity and standardisation of quality; an improved failure classification system; meter obsolescence planning procedures, which have smoothed Eskom's ED replacement process.

<sup>46</sup> 'Software maturity' refers to the degree to which software modifications are done systematically, and documented. At the highest level of maturity all changes are documented, so that at later stages newcomers or other parties can follow changes and are better able to fix problems (Cf. Engineering GSAM Version 3.0).

as Eskom’s levels of procurement increased, the burden of operating multiple PPM systems and the danger of lock-in increased. In addition, as part of its push for user adoption of PPM, the early design of EDs specified that a faulty ED would go into free-supply mode (so as not to inconvenience the customer). Thus the utility had strong incentives to minimise faults in EDs due to multi-standard operation, due to the additional costs of free-supply of electricity.

There are a number of costs associated with the operation of multiple standards: the duplication of infrastructure, high replacement costs, incompatibility between vending systems and other manufacturers’ EDs, difficulty in performance measurement and control, and higher maintenance costs. Conversely, standardisation facilitates the maturing of the industry, increased specialisation and competition, and the development of economies of scale. By 1992 the number of EDs deployed by Eskom was approaching 200,000, leading to a rapid increase in operational costs due to the parallel running of multiple hardware and software standards.

Eskom decided at this point that the level of understanding of the technology was sufficiently developed to justify a strong push for standardisation in the industry. As standards and designs on both the hardware and software side were multiplying, the push to standardisation would have to take place across several dimensions. On the hardware side, the proliferation of proprietary ED models meant that meters made by the different producers simply had different *physical* designs, and consequently needed different connection and installation layouts in the household. The replacement of a meter model required significant rewiring of client residences, which was expensive and inconvenient. Consequently, there was a need for multiple inventories, to allow the swapping of faulty models. Standardisation of the physical layout of the EDs would allow inter-changeability of faulty EDs, without a need to rewire the household’s installation. Eskom developed a ‘common plug-in base’ standard which it included in its future specifications. It meant that meters could easily be plugged in and out, saving expense and time when they were being replaced.

**Table 2 – The technical and industry impact of PPM standardisation**

Standardisation type	Technical impact	Impact on PPM industry
Standard plug-in base	Interchangeability of meters in households with the same installation.	Less disturbance to households when changing meters; lower installation costs; no need for multiple inventories to be kept; increased competition on performance factors.
Standard Transfer Specification (STS)	Standardisation of the entire vending process and the security of the credit transfer: interchangeability of EDs; high and uniform security of transactions.	Interchangeability of Eds on different vendor networks allows economies of scale to develop; increases competition; increased security of credit transfer; increases international attraction of technology; standardisation of different components of system allows specialisation of manufacturers and software developers; client influences knowledge of encryption key infrastructure; Eskom-controlled key management infrastructure increases confidence in the system.

But Eskom faced a more complex problem for standardisation on the software and systems side of the PPM technology. As the early efforts of Eskom were focused on stimulating the development of the EDs, the support systems were largely left to the manufacturers. This led to a situation whereby each manufacturer developed a proprietary credit transfer and encryption algorithm and vending system. As credit transfer was only possible between EDs produced by the manufacturer of the Credit Dispensing Unit (CDU) installed in the specific area, this meant that ED installation would not be inter-changeable. By 1991 50,000 meters had been installed under five proprietary systems, and by 1993 the number of installed units would grow to over 200,000 (Johnson, 2002). Lack of standardisation of the credit-transfer and encryption process could force Eskom to maintain at least five separate infrastructures, and inventory of the producers' EDs. Standardisation of the credit-transfer mechanism would make the EDs installed independent of the CDU installed in a specific area.

In addition, proprietary software systems made the benchmarking of the quality of different systems' performance more difficult, while the type and strength of the encryption of the credit transfer system differed between manufacturers. This was of significant concern to Eskom, as the whole reason behind developing a non-transferable token system was to achieve a higher level of security. A 1992 Eskom report notes that 'many good systems were developed, but they were all non-standard and not compatible with each other. There is now a definite need from the major users to move towards standardised solutions to address the current operational problems experienced where various different types of EDs and vending equipment have to be operated simultaneously' (Burger *et al*, 1992:2).

Consequently, in 1992 Eskom began a push for the standardisation of the communications process between EDs and CDUs, the security of the credit transfer mechanism, and the vending systems. The company identified two alternative routes to achieving these tasks: (i) a universal credit-dispensing system, which would dispense a number of *different* types of tokens, covering the different payment technologies developed by the market; and (ii) a standardised communications protocol between the various components of the PPM system<sup>47</sup>. The first option would have been best from the manufacturers' perspective, as it would require few changes to their products' design. Eskom would bear the bulk of the standardisation costs, while a multi-standard CDU would also be more expensive than a single standard CDU. The long-term costs of this strategy were deemed as too expensive, so Eskom decided to pursue the development of a new and universal standard, which was named the Standard Transfer Specification (STS).

The development of the STS standard had many advantages for Eskom: it would minimise the need to follow and control multiple standards, lower standard development costs and subsequent running costs, as well as provide it with control over the functionality of the standards. The development and roll-out of the standard

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<sup>47</sup> There are three possible communications combinations: ED-CDU (household ED to Credit Dispensing Unit (CDU)), between different CDUs, and between CDUs and System Master Stations. Integration of the communications protocols over the whole chain ensures that the possibilities for fraud and mismatches are minimised.

had several aims: (i) ensure inter-changeability of ED models (achieved by the standardisation of the format of instructions from the vendor to the meter); (ii) ensuring high and uniform security of the transactions (achieved by the employment of increased quality of encryption keys); and (iii) the provision of encryption-key management infrastructure to industry and clients (Johnson, 2002).

While Eskom retained control over the STS development process, key parts were subcontracted to external organisations or experts. For instance, the encryption key system was developed in collaboration with a Cambridge University academic. Prism Payment Technologies was contracted to develop the security module for the STS-compliant models. Prism's work was facilitated by their previous experience in developing secure transaction mechanisms for the banking industry. Conlog, already a major supplier of prepaid meters and support systems, was contracted by Eskom to develop the communication protocols for the transfer of credit from CDUs to the EDs.

Eskom's leadership and control of the STS development allowed it to retain control over the IP of the standard. When formulating an IP strategy, Eskom was faced with a broad choice of keeping the standard as an open platform (allowing free use of the standard by manufacturers), or seeking to gain a return on its IP asset through licensing. Eskom chose the former strategy, as keeping access to STS open was seen as critical in facilitating the further dynamic development of the industry. The release of the STS standard in 1993 was followed by its successful integration in the manufacturers' models and vending systems. As shown in Table 3, by 2002 proprietary systems accounted for only 14% of installed EDs. This is seen today as a major component of the success story of prepaid metering. (Theron, 1992; Burger *et al*, 1992).

**Table 3 – Composition of installed EDs around 2002**

	Numeric token meters	Magnetic token meters	Total
Proprietary meters	118,000	249,000	14%; 367,000
STS meters	1,480,000	772,000	86%; 2,252,000
Total	61%; 1,598,000	39%; 1,021,000	2,619,000

Source: Eskom website

### 3.4 Maturing of the PPM industry and Eskom’s exit from the alliance

The standardisation of the technology allowed the independent benchmarking of the quality of different components of the system. In particular, it allowed Eskom to adopt a more hands-off approach to procurement, as it was no longer necessary to be closely involved in the design aspects of the different manufacturers. Manufacturers now had to comply with a set of standards around the supply of PPM components, and the burden was on them to ensure compliance. The open standards system allowed the entry of new players in the industry, as well as the disaggregation of the value-chain in the PPM industry.

An additional important factor was the widening of the customer base in the PPM market, since by the mid-1990s SA’s municipalities entered the market, as they began to roll-out PPM infrastructure (and especially as post-1994 municipal authorities began extending municipal services to disadvantaged communities). In addition, manufacturers started seeking an expansion into foreign markets. The exposure to different markets’ competitive pressures increased manufacturers’ awareness of different product operational requirements, the need for flexibility in product and service design, as well as the need for continuous improvements and innovation to the STS standard. The manufacturers’ concern was that if the STS standard and infrastructure (such as the key management centre) remained under Eskom’s control, necessary changes would not take place, while also potential customers could be concerned about allowing a non-accountable 3<sup>rd</sup> party to control the infrastructure.

Manufacturers began pressurising Eskom to release control over the standard, and spin-off the STS management into an independent organisation. However, Eskom was concerned that loss of control over the standard would result in changes in the specification that would impact the operation of the existing metering base, and the backward compatibility of future models. A compromise solution was the joint creation of the STS Association by Eskom and a group of manufacturers in 1997<sup>48</sup>. By this arrangement, Eskom transferred its IP rights to the STS standard to the STS

<sup>48</sup> The founding members of the STS Association are Eskom, Conlog, Energy Measurements (now I&G), and Schlumberger (now Actaris).

Association for free. In return, Eskom gained a permanent seat and a veto voice in the STS Association's management structure. In turn, the manufacturers gained an important influence on the future development of the standards, which would allow them to modify/update the standard in a way that would allow them to enter the international stage.

The STS Association would be in charge of the control, further development, and promotion of the use of the STS standard globally. It would also accredit manufacturers' compliance with the STS standard and maintain a network of approved testing organisations<sup>49</sup>. In addition, the STS Association would control and improve the key management infrastructure, and ensure that accredited manufacturers make encryption keys available to the industry to allow clients to find alternative sources of vendor and metering equipment. Thus the STS Association would become the nerve centre of the PPM industry, controlling the encryption and standards infrastructure, and act as an intermediary between differing industry needs (STS Association Handbook, 1,5). The Key Management Centre acts as an escrow for the keys underlying the encryption of the algorithms used in the transfer of credit to EDs. It is still operated by Eskom, on behalf of the STS Association<sup>50</sup>.

In 2003 the STS standard was adopted by the International Electrotechnical Commission as a Publicly Available Specification, and is currently considered as the *de facto* industry standard for pre-paid metering<sup>51</sup>. This followed the formation of an IEC working group. The STS Association has also been busy with the development of STS2, with modifications aimed at increasing the type of functions possible on an STS-compatible meter. This would improve the ability of STS EDs to deal with complex tariff structures, while also facilitating prepaid metering for water and gas. The Association aims to complete the STS2 standard in time to allow for its inclusion in the expected release of an official IEC standard in 2006. Work is also under way for the development of an internationally oriented Key Management System, to be operational by 2006. The aim is to include multilingual, automated support services for clients all around the world on a 24/7 basis, distributed architecture of Key Management Services, the building up of processing capacity, and other measures aimed at making the standard more appealing to international users.

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<sup>49</sup> At present, the TRI continues to do the bulk of the testing and certification on behalf of the STS Association. TRI is now a for-profit consultancy, part of Eskom Enterprises, the non-regulated part of the Eskom group.

<sup>50</sup> Some industry participants currently see Eskom's continued control of the centre as a problem, in particular for exporters who face a credibility problem when selling to foreign utilities.

<sup>51</sup> IEC/PAS 62055-41 entitled 'Electricity metering – Payment metering systems – Part 41: Standard Transfer Specification'.

### **3.5 MNE entry in the industry**

The re-entry of Multinational Enterprises (MNEs) post-1994 coincided with the increasing international acceptance and export sales of the PPM technology. The main reasons for entering an alliance or seeking investment by MNEs were listed as: gaining export markets, access to distribution networks, and branding. This allowed two of the major manufacturers in the PPM industry being bought by MNEs: Spescom's metering division was bought by Siemens, while Conlog was acquired by Schneider Electric. The history of these takeovers illustrates both the benefits and problems with pursuing a MNE strategy to expansion.

Spescom, a former supplier of high-end electronics equipment to the military, was one of the leading participants in the PPM industry. A key innovation was its development of a keypad as a credit transfer mechanism, which is now a standard feature of EDs. In 1994 Spescom's metering division formed a joint venture with Siemens, and was renamed Energy Measurements. This move aimed to provide Energy Measurements with a support channel for its international expansion, through access to the marketing and distribution resources, as well as the brand name of a global player like Siemens. In 2001 Spescom sold its 50% stake in Energy Measurements to Siemens for R35-million, and exited the PPM industry entirely (R35-million)<sup>52</sup>. Siemens combined Energy Measurements, L&G, and its existing metering division into Siemens Metering<sup>53</sup>. While sales continued to grow, respondents reported that the expected benefits of the association of Energy Measurements with Siemens have not materialised: there was limited integration of Energy Measurements into the Siemens global production network, little additional access to resources. A similar situation was seen at Siemens's other metering divisions globally, with an overall lack of strategic focus, lack of access to marketing and distribution resources, and corporate culture clashes.

In 2002 Siemens sold its metering division to Kohlberg Kravis Roberts & Co, a global private equity fund. The resulting firm was rebranded under the globally recognised L&G brand, and the former Energy Measurements in South Africa consolidated its position as the principal producer and developer of prepaid metering. In 2003 L&G reported global sales of €388-million. In 2004, L&G (as a global firm including the SA division) was sold to Bayard Capital (KKR website).

By contrast Conlog, another leading PPM manufacturer acquired by an MNE, experienced a much tighter integration into its MNE parent company, and consequently achieved a greater performance. The core business of Conlog, an electronics company founded in 1965, was originally focused on automotive electronics. However, it became a core participant in the PPM industry. Its position in

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<sup>52</sup> As part of its strategic refocus to the ITC industry Spescom was divesting of non-core assets and Energy Measurements was seen as lying outside of its core focus area.

<sup>53</sup> Through an earlier purchase in 1997 Siemens Metering had obtained control of the Electro-Watt group in Europe, which also included the Swiss-based Landys & Gir (L&G), the oldest metering company in the world.

the PPM industry was strengthened when Eskom contracted it to develop the vending system specification as part of the STS standard development. It was also involved in the development of solar pre-payment systems for the off-grid electrification programme.

There are over 2 million Conlog pre-paid meters in SA and internationally. In 2000, Schneider Electric purchased Conlog's pre-paid metering division for R88-million. Schneider sought to establish it as the group's 'Centre of Excellence for Pre-Payment Solutions', and continued to use the Conlog brand name. Conlog focused on developing a more comprehensive service offering, such as entering water metering, establishing a training centre, and international help line. In 2002/3 Conlog secured 80% of Eskom's national contract for PPM supply, valued at R100-million, a €10-million contract in Sudan, and continued its expansion elsewhere in Africa.

## **4. Analysis of the framework and processes of the PPM technology's development**

A lot has changed in the structure of the South African SI since the beginning of the PPM industry in 1989, most significantly the end of the large military industry programmes, the opening up of the economy, the liberalisation of the energy market, the separation of Eskom in regulated and non-regulated entities, and less government support for R&D (to a large extent because there is no need for self-sufficiency). All of these conditions were key parts of the mechanisms that facilitated the development of the PPM industry. Does this mean that policy makers and innovators can draw no useful lessons from this case study? If one looks for one-to-one lessons, there would be none. But through this case study many mechanisms and strategies can be identified that could be of interest to both policy makers and market actors, which can be used, modified and applied in other contexts and sectors.

### **4.1 The institutional framework and firms' capabilities**

A precondition for the development and implementation of a complex technology development strategy is the availability of actors with the necessary capabilities in the SA system of innovation (SI). In terms of the manufacturers that would be involved in developing the technology, Eskom's technology specification called for secure and encrypted credit transmission between vendors and EDs. Hence some of the capabilities necessary for entry into the strategic alliance were advanced engineering and design capability, high-quality production facilities, hardware control software development skills, and knowledge of encryption technologies.

In the context of a developing economy and the sanctions in place at the time, it is remarkable that Eskom was able to access all of the required capabilities domestically. A number of historical and institutional factors specific to South Africa coincided, ensuring that both the technological capability and institutional setup existed, in the context of which an ambitious technology development programme could be put in place. The migration of capabilities from the military-industrial and communications SSIs to the energy SSI was an important element in the development of the PPM industry.

As one respondent noted, 'there was in South Africa a just-about-adequate technology base, thanks to a number of factors: Armscor, sanctions, and the requirements of the local primary industries... [in addition] as the solutions involved crypto, a then heavily controlled technology, and imported solution wasn't an option'). As illustrated in Table 4 below, at least two of the key manufacturers involved in the PPM industry's development had a strong history in the military communications industry, while other manufacturers often relied on the knowledge and experience of personnel that had formerly worked in the military industry. The civilian communications industry appears to have been an equally important source of capabilities, both for hardware

manufacturers (such as Tellumat, with capabilities developed both the military and communications industry), and software developers (such as Prism Technologies, with capabilities developed in the banking and communications industry). It is also significant that local actors developed the entire software and communications aspect of the PPM industry. The vending-systems software, different revenue management systems, encryption and communications protocols, and the on-board software carried by the EDs were all developed locally<sup>54</sup>. Hence the successful mobilization of organisations with the appropriate capabilities relied on the possibility of horizontal migration of technology and capabilities South Africa's innovation system from one Sectoral System of Innovation (SSI) – military and/or communications – to the Energy SSI.

**Table 4 – Sectoral membership of key PPM industry firms**

Company Name	Landys & Gir	Tellumat/Syntell	CBI	Conlog (Groupe Schneider)	Prism Technologies
Original Name(s)	Spesscom	Plessey	CBI	Conlog	MBO from Linkdata
Founded	1980s	1950s		1965	1994
Core PPM Product	Pre-paid meters, vending systems, CDUs	Meters, CDUs, vending systems (through JV Synapse)	Pre-paid meters	Pre-paid meters, vending systems, CDUs	Encryption units in CDUs
Pre-1990s Sector Involvement	Military electronics equipment	Military communications	Electrical industry	Automotive electronics	early electronic banking and payment networks
Details	A supplier of high-specification metering equipment to the military. The numeric keypad input mechanism that is currently standard on most EDs is derived from Spesscom's military applications	Developing communications, control and monitoring equipment for the military industry. Continues to be involved in the military industry (both in SA and internationally)	During Apartheid era had practical monopoly on circuit breaker manufacturing in SA. <i>But</i> key personnel working on PPM came from military industry		Development of secure transaction mechanisms for the banking industry.
Post-1990s non-PPM activities	Off-grid solar pre-paid metering systems. The parent company - L&G - is the global leader in metering.	Military & civilian communications applications; municipal services (including PPM); contract manufacturing	SA's leading circuit breaker manufacturer	Conlog is entirely focused on PPM systems. Groupe Schneider is a leading global provider of electrical equipment	Secure online payments in internet, wireless communications, banking, other areas.

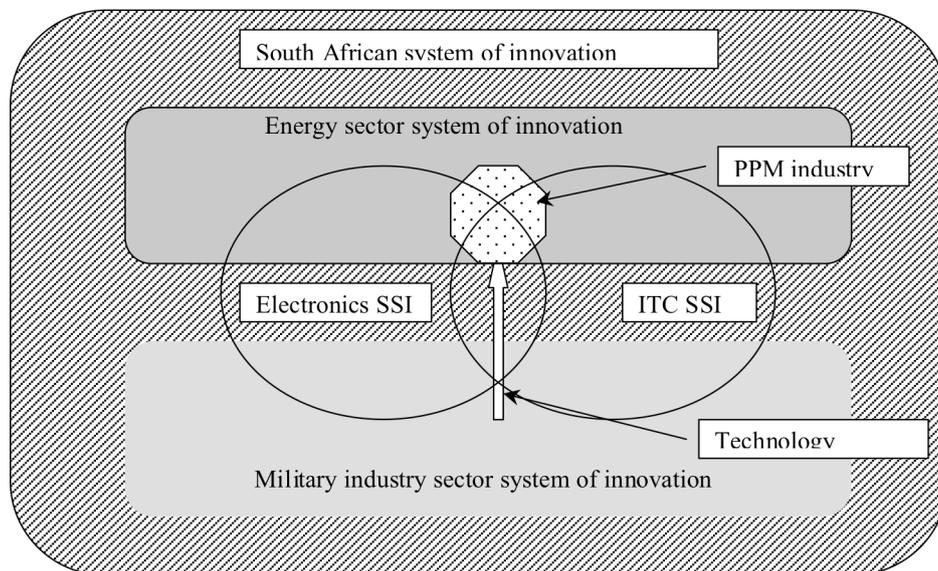
Two aspects of SA's system of innovation are of particular interest: the central role that the energy sector plays in the economy; and the state's role in building up an autonomous military industrial capacity (cf. Fine & Ragtime, 1996). Thus in the late 1980s both the Energy Sectoral System of Innovation (SSI) and the military-industrial SSI were important locations of innovation and technological development.

SSIs refer to persistent patterns of the organization of innovative activity within a particular industry. These arise from the dominant role that the technological

<sup>54</sup> Although with occasional foreign expert help for key high-level aspects of the technology, such as the use of a UK expert in developing the encryption keys.

paradigm within which production takes place plays in determining the dominant forms of organization of production. Thus the technological paradigm places limits on institutional diversity within the industry, which in turn explains similar organization of production within the same industry internationally. Thus auto manufacturers or pharmaceuticals globally are organized in remarkably similar ways, despite the variety of national institutional regimes within which they operate (Carlsson, 1995).

**Figure 3 – The PPM industry’s relationship to SA’s system of innovation**



Eskom’s dominant role in the energy SSI and previous experience in large-scale R&D projects & technology deployment provided it with the coordinating capacity to mobilise actors in its sector for the development of innovative projects. The horizontal migration of capabilities was facilitated by the cross-membership of many of the organisations in these SSIs: there were technology transfer channels available for capabilities to migrate from one sector to another. Decline in military expenditure in the late 1980s appears to have been a ‘push’ factor leading electronics and ITC firms to search for other markets where their capabilities could be applied. Spescom is one such example, as it quit the military industry entirely once it entered the PPM industry. Furthermore, decline in military expenditure is likely to have driven highly qualified personnel into the civilian sector. But at the same time, some larger companies (such as Tellumat) continue to work in both the military and civilian sectors.

After the initial formation of the strategic alliance around Eskom, cross-sectoral access to capabilities continued to be important. The availability of strong IT capabilities has allowed the continuous ‘smartering up’ of traditional products, such as metering and control equipment. It has also allowed a differentiation of the

strategies pursued by the different companies. Prism Technologies has used the strong capabilities in secure payments mechanisms it developed from the banking and PPM industry to push into other e-commerce and other markets (Prism website). Also, traditional industry distinctions have become less rigid, as hardware manufacturers have entered the software development.

For instance, Syntell Networks (the JV between Tellumat and Algorithm Software) was aimed at developing vending software for the prepaid meters. This software product has become an independent and significant source of revenue for Syntell. Conlog and L&G have equally strong in-house software development capability, again resulting in the strong performance of their vending systems products. Both Conlog and L&G market themselves as a one-stop-shop for municipal clients, where they can purchase the entire system, from hardware to vending software. For these companies the convergence between electronics engineering and software systems development has been key for gaining market leadership. Other firms (such as CBI) that have stronger base in electrical engineering manufacturing has used the ready availability of IT skills on the market to focus on design and manufacturing of meters, while relying on third party software developers for the vending systems. .

Another important factor has been the presence in SA's system of innovation of strong research institutions, and the PPM industry's development of strong linkages with these. Joint work was conducted with most of the major SA universities (the universities of the Witwatersrand, Stellenbosch, Cape Town and Pretoria), and the CSIR. Such interactions can be separated into several categories: high-level once-off projects (such as the development of the encryption technology underlying the STS standard, or enlisting the CSIR's help in developing a lightning protection system for the EDs); frequent low-level contract research projects (most of these involving manufacturers subcontracting academics to solve particular low-scale problems); and the development of routine organisational linkages (such as the working relationship between Eskom and the CSIR and electrical engineering departments at universities).

Eskom's relationship with universities and research institutes differs from that of other manufacturers in several aspects. Eskom has established long-term strategic relationships with universities and research institutes. It supports university electrical engineering departments at universities by financial, organisational and technical resources in exchange for a departmental focus of research and teaching activity to Eskom's priority areas.

## **4.2 The evolving role of a strategic alliance leader**

The key role of the energy sector in South Africa's industrialisation and resources sector, combined with the monopoly position of Eskom in the post-1950s allowed Eskom to develop a uniquely powerful position in the economy. This gave it the resources, credibility and market power to carry through large technology and industrial programmes. The scope and investments that went into the PPM industry are relatively minor compared to the resources that were committed to the Pebble-Based Modular Reactor (PBMR) programme, or the coal power station deployment in

the 1970s. Experience with such large programmes also gave Eskom the project management capability over a sufficiently large scale and time horizon. These skills and resources are crucial for the success of any organisation that seeks to play the role of a strategic alliance leader.

Dosi provides a useful distinction between technological *paradigms* and *trajectories*, where a technological paradigm is defined as a ‘pattern of solutions of *selected* technological problems based on *selected* principles derived from natural sciences and on *selected* material technologies’, while a technological trajectory is ‘the pattern of “normal” problem solving activity on the ground of a technological paradigm’ (Dosi, 1982:152). Thus a paradigmatic change constitutes a major systemic disruption that makes previous patterns of research and innovation in a particular area obsolete. The development of the PPM industry can be seen as paradigmatic change for both the electrical manufacturing industry (as it would displace traditional credit-based meters), and for utility providers due to the displacement of the whole credit-based metering and billing infrastructure. Within this paradigmatic change a number of trajectories could develop, based on patterns of design features which could accumulate into a dominant design.

In periods of radical technological change not even the participants in the industry have a clear understanding of the boundaries of their own industry, nor who the relevant players are. Under such conditions actors that have the capacity to interact with and shape the environment become key players, and are responsible for the framing of the environment that is taken as a given by later entrants to the industry. Clark and Tracey (2004, ch.5) argue that success in industries characterized by significant technological upheaval is premised on multiple-loop learning processes between groups of actors, and interacting with the environment aimed at both decreasing the level of uncertainty and impacting the environment in the interest of the actor. And of course, where the state plays a strategic role (for instance due to strategic interests in the military industry, social considerations in health care or environmental technologies), state-backed actors are in a position to impact heavily on an environment in flux.

Hence Eskom needed the role of a strategic alliance leader in order to be in a position to co-ordinate resource allocations to the different actors, push technology development in the preferred direction and close off some avenues of innovation. An important aspect of Eskom’s strategic alliance leader behaviour is that it was highly dynamic in nature, and changed quite radically through time. The changes were timed with the different phases in the development of the PPM technology, and in line with Eskom’s vision of what the long-term PPM industry should look like.

As the initial stages were characterised by high technological uncertainty and a large array of possible outcomes Eskom maintained a highly active role. Once the level of technological uncertainty declined As the early stages of development were characterised by a high-level of technological uncertainty and learning by all actors, Eskom wanted to stimulate the development of multiple trajectories of PPM hardware and systems design, while at the same time retaining ultimate control over which features are retained in a final dominant design. Once the level of technological

uncertainty subsided and Eskom developed a better understanding of the needs of a well-functioning PPM system, it was in a position to push for standardisation and commoditisation of key aspects of the PPM value chain. As discussed already, the key aim of this was to accelerate the maturing of the industry, avoid lock-in into individual manufacturer's technologies, increase competition, allow specialisation and the development of economies of scale. This would then allow Eskom to exit the strategic alliance leader, and focus on cost minimization of its electrification programme.

In short, as a respondent characterised it, Eskom's strategy boiled down to 'heavy involvement in the early stages, a push for standardisation, and thereafter reliance on the market mechanism'.

#### *4.2.1 Strategic alliance leader – active involvement in the early stages*

The manufacturers that entered into a strategic alliance with Eskom possessed the initial technological capabilities to begin product development, but this required a significant level of sunk costs for initial R&D and prototype development. Furthermore, while the innovation was taking place there would be a need for constant interaction between the different actors to enable knowledge to flow both horizontally and vertically, and to prevent innovation being diverted to areas outside the leader's strategic aims. Thus there was a need for both strong and credible incentives to justify the manufacturers' commitment to long-term investment, and dynamic interaction between the various members of the alliance.

Eskom relied on a combination of active and passive measures in developing and sustaining an innovative environment for the manufacturers in the early stages of the technology's development. There were three main elements to this strategy: (i) precommitment to purchase diverse solutions; (ii) dynamic interaction and knowledge dissemination; and (iii) threat of lockout if non-compliant with Eskom's requirements. Eskom's precommitment to the procurement of over one million EDs provided the long-term assurance that a market for PPM would exist. This precommitment was made credible by Eskom's dominant position in the electrical industry, as well as its past history of large and long-term industrial investment programmes in the energy industry. But there was also a need for short-term incentives that would reduce the risk for manufacturers whose investment horizons (or at least cash flow) were much shorter than Eskom's. This was satisfied by Eskom's pre-commitment to purchase initial product models at a high price, and with different design features.

Throughout the initial stages of development Eskom was actively involved, and played a role in 'correcting' trajectories of innovation when there was significant deviation from its strategic aims. So while the incentive structure promoted technological diversity, Eskom's active management process allowed it to choose early on between the different designs each manufacturer was working on. On occasions Eskom would be forceful in pushing a particular technology if it was convinced that this would improve the reliability of the technology as a whole – such was the case with Spescom's keypad solution, different types of magnetic card readers, or the development and adoption a new lightning protection standard. Eskom also used its

monopsonist power to block the entry of technology and design features that were not in line with the PPM strategy.

For instance, the company blocked the adoption of a flat-rate meter developed by CBI, because it did not fit in with Eskom's strategic aims for the electrification drive. The flat-rate meter was a potential rival to the PPM technology in its early stages of development, as it was cheaper and easier for the utility to operate than prepaid metering systems. CBI decided not to patent the technology, but to publicly disclose it, and promote its adoption internationally. However, both Eskom and the STS Association are reported to have blocked the adoption of the technology in SA because it conflicted with Eskom's PPM electrification strategy. Similarly, the company's push for low-cost devices prevented the introduction of a variety of enhanced features; for example, on-board customer messaging systems were excluded under Eskom's pressure. Thus there are elements of ambiguity in the role of monopsonists as leaders of strategic alliances: on the one hand they have the capacity to stimulate and co-ordinate radical innovation by multiple actors; but on the other they have the power to set up strong barriers to innovations that are not in line with their strategy.

#### *4.2.2 Strategic alliance leader: standardisation as the first step of disengagement*

As discussed, the generation of technological diversity in the initial stages of the technology's development was associated with the development of proprietary technological standards and systems by the different manufacturers, with up to five proprietary PPM systems in operation by 1992. Initially Eskom had committed to absorb the cost of running several systems, as it wanted the additional technology options it expected to get from the different manufacturers' independent innovative efforts. However, with the maturing of the technologies, less was being learnt from the continued operation of multiple standards, while the costs of running a multiple standard technology were increasing rapidly. The point at which the costs of running multiple standards are higher than the benefits of doing so is when standardisation becomes necessary.

As discussed earlier, standardisation would resolve a number of the costs of running multiple standards by eliminating duplication costs, opening up the industry's value chain for competition and further innovation, and allowing the consolidation of the market and the emergence of economies of scale. Standardisation allows the consolidation of the market size, which in turn allows producers to reap economies of scale, in turn leading to a decrease in the unit costs of production and prices. In addition, the emergence of economies of scale allows individual producers to focus on core capabilities.

As the technological requirements for the various components of the PPM system are harmonised, the different segments of the industry can specialise. Specialization allows the development of economies of scale and further incremental innovation, declining costs and improved quality of production. For instance, as the introduction of the STS standard standardised the communication between CDUs and EDs, CDUs could operate third-party vending software. In turn this facilitated the emergence of vending

software as an autonomous market segment, in which software development could take place independently from the ED manufacturers. For the firms that had developed in-house vending software (such as L&G) or collaboration with a software company (such as Syntell), standardisation allowed the development of vending software as a strong and independent line of business.

Another rationale for a push to standardisation is to avoid a lock-in of the industry into an inferior technology. In the context of the PPM industry, this is a somewhat complex issue. To begin with, Eskom's standardisation efforts were at least partly motivated by a desire to avoid such a lock-in. The decision to develop the standard in-house, with key work subcontracted to academic experts and industry participants can be seen in light of this desire to maintain control over the standard. So in this sense Eskom was successful in avoiding a lock-in to an *externally* developed standard. Furthermore, it does appear that the STS standard is performing comparatively well, both in terms of its growing adoption within SA and internationally and its support by the IEC. Conceptually of course the adoption of the STS standard prevents alternative standards from emerging. This is an issue that will always be relevant when technological standards are set, as the open-ended and evolutionary nature of technological change means that it is always possible that path-dependence effects lock-in industry into inferior technology (Arthur, 1989).

It is here that the setting up of the keeping of the STS standard open to industry, and the setting up of the STS Association as an independent custodian of the standard, charged with its continuous update and spread internationally. As discussed in the history section, the STS Association has been successful in promoting the adoption of the STS standard by the IEC. The STS Association provided a forum where interaction between users and producers could take place, and where changes to the standard that would affect multiple participants could be negotiated and formulated.

The STS Association's current development of STS2 illustrates this point: the aim is to include many new features that were underdeveloped or not even present in the original STS standard, such as multiple tariff support; simultaneous electricity, gas, and water metering; or internet connectivity. These are features that were identified by the changing client composition of the PPM industry, as well as brought by changing infrastructure and technology needs. So while some level of path-dependence and lock-in is inherent in any standardisation process, keeping access to the standard open and having an appropriate arrangement for the standard's maintenance and evolution helps minimise the lock-in costs to industry. It is likely that following disruptive innovation the presence of an independent standards organisation representing the interests of the various stakeholders in the industry could facilitate the responsiveness of the technological standard to changes in the industry and novel technological opportunities.

The importance of a co-ordinating actor in the implementation of standards is also illustrated by the adoption of the 'plug-in base' standard. In terms of technological intensity the plug-in base was not very innovative – it was designed by a single person at Eskom. However, this standardisation was an inexpensive way of removing a major physical barrier to ED inter-changeability, as now the installation base in a wall would

be the same for all EDs. Thus, at least in this case, the importance of an innovation was not so much its level of its technological complexity, but rather the ability of a coordinating actor to push through the adoption of this design as a standard.

Several of the respondents suggested that Eskom had expected from the beginning that the multiple-standards problem would arise, and that it would have to push for standardisation at some point. There is no way to ascertain to what extent the problems were expected, but it does make sense to see a coherent and dynamic innovation strategy, which involves the sequential switching of technology management techniques at crucial points. Importantly, due to the technological uncertainty implicit in innovation, it would have been impossible to know the type and timing of the standardisation consisting *a priori*. But what the strategic alliance leader benefited from was an awareness of the likelihood that the multi-standards problem would arise, which in turn would have guided the search activity of the technology managers.

As a speculative note, industry participants could have been aware of the two options facing Eskom: (i) choose a standard as close as possible to the existing standards to minimise the switching costs; and (ii) develop own standard, combining 'best of' industry. Prior knowledge or expectation of any of these two options would have set different incentives in place for the manufacturers. Prior knowledge or belief in the first strategy could incentivise firms to push for gaining early market share, instead of higher levels of innovation; that is, the larger the market share captured early on, the more likely that the manufacturers' standard would be adopted later on. Expectation of the second strategy would set 'better' incentives for innovation: since the bulk of the procurement would come *after* standardisation, then the early stage focus should be on developing better technological solutions and innovation, rather than early capture of market share.

In the case of Eskom, early commitment to the latter strategy would be credible, as its size (and possibly state backing) meant that it could 'take the pain' of losing a somewhat large base of meters. This dynamic could have interesting implications for other similar cases of technology and standards development, but where the strategic alliance leader chooses a more 'static efficient' strategy, or the large purchaser does not have the credibility to carry through a painful standardisation strategy. At the very least, a lesson for large organisations engaging in strategic technology development is to focus on setting the right expectations from the beginning of the technology development strategy, as a way of ensuring alliance participants focus their resources on innovation rather capturing early market share.

#### 4.2.3 *Strategic alliance leader: technology maturing and disengagement from the alliance*

The success of Eskom's standardisation means that it could reduce its level of engagement with manufacturers. The evaluation of their products was simplified, as benchmarking was easier, and there was no need to maintain close links to direct multiple technology development efforts. At this point Eskom could begin a push for a decrease in costs and consolidation of its supplier base. Manufacturers began a push for other markets (both exports and domestic municipalities). While this shift to a

diversification in the customer base was a likely response to Eskom's changing strategic role in the industry, it was also made possible by the presence of an internationally credible standard.

So the standardisation facilitated the development of an external market, which in turn weakened Eskom's power in the strategic alliance. But at this point Eskom was ready to rely on more 'passive' interaction with the manufacturers, through open-market tenders. Eskom's reduced support and increased cost pressures on the manufacturers reduced the incentives for staying in the alliance. Eskom has moved from what was described as a 'grandfatherly' role in the industry to a more classic monopsonist role characterised by increasing cost pressures on producers. Industry respondents indicated that owing to price pressure from Eskom the SA domestic market is no longer sufficient to sustain the local industry, making them dependent on exports for survival.

The entry of South African local authorities into the PPM industry in the mid-1990s allowed many of the manufacturers to diversify their client base, which appears to have weakened Eskom's negotiating power. The diversification of the market also stimulated further innovation, as municipal metering needs stimulated the development of the combined water and electricity meter, the development of STS2, as well as further innovation by vending software developers, aimed at accommodating different tariff schedules<sup>55</sup>. In the long run the most important diversification channel would be through exports. But while many of the manufacturers were successful in gaining export orders, some of the respondents were of the opinion that SA's PPM manufacturers were not sufficiently quick and aggressive on the foreign markets, and as a result there was a mismatch between the maturing of the industry domestically and the growth in the South African manufacturers' presence internationally.

Possibly in anticipation of this need to access export markets rapidly to avoid the cost pressures by Eskom, some PPM industry participants sought alliances and mergers with MNEs. But, as discussed earlier, this did not produce the significant positive effects expected. This could have contributed to the mismatch between the timing of Eskom's price pressures and the ability of the participants in the industry to fund further R&D through a growth in export earnings, thus compensating for the increasing pressures on domestic prices<sup>56</sup>. The domestic squeeze on the manufacturers' margins and the lack of a countervailing increase in resources from international expansion in turn appear to have led to a decline in manufacturers' investment in innovation, and a loss of key skilled personnel from the industry.

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<sup>55</sup> For instance, the first combined water and electricity meter was developed by Tellumat, which at that time had quit the Eskom market to concentrate on the local authorities market.

<sup>56</sup> One of the respondents felt that the SA industry had already missed its window of opportunity for developing a dominating presence in the international market, and expected Chinese and East Asian manufacturers to dominate the industry in the future.

### **4.3 The role of MNEs in the local industry**

The decade since 1994 has been characterised by a significant policy emphasis on Foreign Direct Investment (FDI) as a source of investment, employment and productivity growth for the SA economy. A significant part of the FDI that has entered South Africa has done so not through greenfield investments, but through mergers and acquisitions (M&As) of existing enterprises. Whereas there is broad agreement among economists on the positive effects of greenfield investment, there is still relatively little understanding of the effects FDI through cross-border M&As. There is a substantial literature on MNEs (which are the main actors in cross-border M&As), in which there are conflicting views on issues like international technology transfer in MNE networks, effects on innovation, employment, pricing structures, impact on domestic competition and market structure, crowding out of domestic R&D, and the possible severing of the links of domestic innovative SME from domestic system of innovation. This is not the place for an extensive discussion of this literature, but suffice it to say that current international evidence concerning the impact of M&As and MNE entry on domestic economies is ambiguous, and its costs and benefits are still being debated (Lall, 2000; Haller, 2004).

The PPM case study has raised important questions on many of these issues. As discussed earlier, many actors in the PPM industry saw entry into MNE networks as an important way of gaining access to international markets. The limited work done makes it difficult to generalise, but at the very least it is clear that the industry had very high expectations of the benefits of MNE entry, and that these expectations were not satisfied. While Schneider's takeover of Conlog was followed by improved export performance, Siemens's takeover of Spescom as an overall failure. The research conducted is insufficient to accurately determine the extent to which access to MNE resources helped these firms' performance, as the other manufacturers that remained independent have performed well despite the lack of MNE support. Firms such as CBI and Tellumat have remained strong participants in the PPM, and have experienced significant expansion on the international markets.

Overall, it appears that the industry has misunderstood MNE's motivations for entry, and the benefits and resources that could realistically be expected. What should be of interest is that MNE investment is translated into substantially different strategies for the acquired companies, and not necessarily dramatic improvement in performance. It is also important to highlight the late entry of MNEs into the industry at a point where the technology had already matured. While MNE entry may have resulted in inward technology transfer, the primary motive for MNE acquisition of PPM manufacturers was access to a globally unique set of capabilities which would complement those elsewhere in the MNE's production network.

## 5. Conclusion

Given the lack of prior research in this area, a major task of this project was to reconstruct the history of the development of the technology, and what was the role played by the different actors. Several phases of development were identified in the history of the PPM industry. The preliminary stage, in which Eskom formulated its overall technology needs in the context of the electrification programme, resulted in the identification of the requirements for the technologies to be used in the electrification of households. The recognition of the socioeconomic and infrastructural limitations that Eskom was facing led to the selection of PPM technology as a way of overcoming these problems and achieving lower electrification and running costs.

This was followed by the development of a strategic alliance between Eskom and various innovative firms that had the technological capabilities to develop a systemic innovation. The release of the NRS 009 specification in 1989 marked the beginning of the early stage of technology development, during which Eskom gave the manufacturers strong incentives to invest in new technologies and technological diversity. As the technology matured, Eskom was able to formulate its technological requirements in detail, which in turn allowed it to push for a standardisation of the technology. The implementation of the STS standard in 1993 (along with other lesser standardisation measures) allowed different manufacturers' products to be substituted for one another, and made the vending software applicable across hardware platforms. This was followed by a period of consolidation, with Eskom gradually decreasing the degree of its involvement in the industry, and relying more on the market mechanism.

At the same time, manufacturers were seeking to diversify, first turning to local authorities as an alternative market, and then to export markets. The manufacturers' growing focus on alternative markets put pressure on Eskom to allow independent management of the STS standard; this eventually led to the establishment of the STS Association in 1997. The next few years saw the continued decline in the amounts procured by Eskom, the use of the STS-compliant metering technology in gas and water applications, the growing role of MNEs, and an increasing focus on the export markets. By 2003 the International Electrotechnic Commission released the STS standard as a Publicly Available Specification, recognising South Africa's PPM technology as a *de facto* international standard. While PPM industry players face many challenges, the industry has matured to a level where it is largely autonomous of the initial strategic alliance leader, with the technology being diffused internationally.

Based on this, I was able to analyse the various processes that characterised the PPM history. The key finding would be that the PPM industry provides a powerful example of the possibility of developing a successful novel technology in developing economies. In particular, the combination of generic capabilities (such as software development skills, electronic and electrical engineering) with *specific* local conditions led to a novel recombination of knowledge sets, the generation of unique capabilities,

and ultimately the development of innovations. Antonelli (2003) notes that both knowledge complexity and fungeability are the cause of increasing returns in the generation of knowledge. Complexity matters when the production of new knowledge requires the combination of diverse and yet complementary bits of knowledge. Fungeability is found when some units of knowledge can apply in a variety of different contexts, different products and different processes. In the context of the PPM technology, the fungeable knowledge required for the development was general principles of electronic engineering, programming, cryptology and communications.

The elements of complexity specific to the South African situation were various aspects of the highly complex and exacting operational environment. The combination of these two aspects of knowledge allows the generation of globally unique innovations. From a policy perspective, this should be of interest, as it illustrates that the mobilization of scarce technology skills and resources toward the solution of locally specific problems that are deemed of strategic importance can result in the development of strong domestic technological capabilities and novel products that are marketable globally. This is not only so in the energy sector (increased efficiency, off-grid generation, renewables), but also in other important sectors such as healthcare.

Some of the key ‘lessons’ identified, which are likely to be of relevance in other contexts of policy analysis and innovation strategy are:

- *Institutional framework* – the system of innovation within which the actors operate explains their inherited capabilities, network linkages, access to resources, and constraints on their activities. Migration, or cross-membership of Sectoral Systems of Innovation (SSIs) was particularly important in allowing the recombination of capabilities developed in the military-industrial and Information Technology and Communications (ITC) sector to the civilian energy sector.
- *Strategic alliance leader* – in the context of radical or systemic innovations, the presence of an actor who could play the role of a strategic alliance leader facilitated the coordination of investments by innovative actors.
- *Role of procurement* – for innovators investing in radical or systemic innovation, a precommitment to long-term procurement plays an important role in decreasing uncertainty by ensuring the continued existence of a market. Such assurances allow the innovators to make a long-term commitment of resources to a priority area.
- *Technological diversity* – high levels of technological uncertainty characterise the early stages of technology development. The cost of this can be mitigated by the presence of a strong co-ordinating actor that can both provide the incentives for innovation and close non-desirable paths of innovation at an early stage.
- *Technology standardisation* – the development of diverse technological solutions may culminate in the development of multiple standards, which means running multiple networks. A strategic actor with strong market power can push for

standardisation at an early phase of the technology's development, which can result in the rapid maturing of the industry, development of economies of scale, specialisation, and access to other markets.

- *Evolution of the strategic alliance leader role* – the behaviour of the strategic alliance leader changes with the different phases in the development of the technology. In early stages the leader sets up incentive structures that are favourable to other alliance participants, with resource transfers and intensive interactions, and tolerance of high prices set by other members of the alliance. As the technology develops, the leader pushes for industry maturity. This may involve a push to standardisation, disengagement from the alliance, a consolidation of industry actors, and lower prices.

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