STRATEGY AND TACTICS FOR THE MINING INDUSTRY rev1

EXECUTIVE SUMMARY

The discussion document has been compiled by Professor RE Robinson (Robbie) and in Robbie's words 'It is my swansong to the SAIMM'.

The concept of the Mining Cluster has featured in many of Robbie's Journal Comments over the past few years. The discussion document contains his views on how the mining industry could be the instigator and trail blazer towards converting the impoverished bulk of the population into self-sustaining and economically independent communities that join a proud and prosperous South Africa. This is an impassioned plea from a man who is a past president of the Institute (1975 -1976), a recipient of the Institute's prestigious Brigadier Stokes Memorial Award (1985) and a former president of Mintek.

There are a number of elements to the Mining Cluster concept but the common thread that runs through them all is the need for the mining industry, the research organisations, the agricultural industry, government and labour organisations to come together and engage in developing a strategy that addresses the most urgent national priority, that of job creation. There is no doubt that if Robbie was 30 years younger he would be at the forefront of such an initiative.

The Mining Cluster concept requires a champion to take the initiative forward and it is envisaged that the mining industry will provide that champion. There is no 'quick fix' to the challenges of job creation in South Africa but the discussion document contains a number of options with foresight for innovation to generate incomes for impoverished members of a nation that will provide for a national survival strategy.

The opportunities are many and varied. The advances that Robbie has selected are to a large extent, the outcome of more than forty years of evolution of the ability to define mining and metallurgical operations and the research involved in terms of statistical probability models to reflect the economic parameters of success. Robbie's suggestions are intended to be selectively illustrative, not exhaustive, the latter being blatantly impossible, but it is believed that the selections come close to being possible in defining precisely the specific goods and services that are necessary to meet the immediate national target.

Do not be surprised at the emphasis on agriculture after Robbie's 65 years involvement with minerals beneficiation. He believes that it is the impact that the new Miners and Metallurgists can make on agriculture that is the key to generating millions of jobs that will prevent the country's rapid decline to anarchy.

DAVID TUDOR – EDITORIAL CONSULTANT

STRATEGY AND TACTICS FOR THE MINING INDUSTRY – COMBINED rev2

A DISCUSSION DOCUMENT by Prof RE Robinson

INTRODUCTION

It is my intention to illustrate the association of Research and Development with the achievement of strategic goals. When the most urgent national strategic priority is the creation of jobs to reduce poverty levels, it is vital that all in the national research community work together to expand existing operations or create new job opportunities for the production of goods and services. In the competitive global markets, it is invariably the case that research and development (R&D) have to be undertaken to make existing production more competitive, or to devise new products for marketing. Moreover, education to provide the youth and unemployed adults with the necessary skills is part of the development process.

Isolated or 'secret' work must give way to 'Portfolio' coordinated R&D which involves the interactive exploration of all promising options.

Portfolio Research, as its name implies is closely analogous to the risk venture capital policies. Investors have invariably preferred a portfolio of opportunities equivalent to a portfolio of equity investments. An even more appropriate analogy is its similarity to the most fundamental of scientific doctrines- that of Darwin. The availability of a number of capabilities to deal with random environmental changes is what ensures the survival of a species.

Thus the number of good options with foresight for innovation to provide incomes for impoverished members of a nation is what will provide for a national survival strategy.

This document aims to provide a window of portfolio options to achieve such an endpoint.

My contribution relates predominantly to the Mining and Metallurgical industry, but not entirely, because the common belief promoted by politicians and many strategists that the problems of poverty and job creation can be solved by beneficiation of our mineral resources is unduly optimistic. But I do not wish to spend time on this debate. Suffice to say that the prescribed target is 6 million jobs representing goods and services to a value of at least R600 billion/annum, which can be added to the GDP. (These are official figures) This might have been possible in the mining industry in the second half of the last century, but not now that mining activity has so markedly declined and our previously favourable power costs have increased to be globally non-competitive. The government is undertaking a large national development program (NDP) to build houses and provide the impoverished community with services, to improve transport systems and to encourage small business enterprises, but it is the creation of goods and services for sale that are needed to provide the income for the creation of sustainable new employment .

Looking at the R&D activities over the last two decades, I come to the conclusion that the best opportunities arise in the formation of cluster industries and to a significant extent these job creation options can be related to mining and agricultural activities. This creates clusters, which are an integrated mining coherent community in all senses of the word: social, cultural and loyalty to the national strategies and their employers. This will result in exploration of the many options to create new jobs, goods and services. The selections of the options are the key to ultimate success and this

must be a total R&D effort. Moreover this effort cannot be confined to the mining industry alone. It must involve to a large extent the necessary industrial and agricultural participation.

The opportunities are many and varied. I am only able to refer to a selection, all but one of which has appeared in the Journal of the Southern African Institute of Mining and Metallurgy, or at one of their conferences. Sadly most of our researchers prefer to submit their research work to overseas publications so as to obtain maximum citations. It is the local professional experts who are vital in the selection of the Risk Ventures that have the most probable success. I can best provide a list of keywords suggesting such options in the hope that an army of professional researchers and developers in many disciplines will come together to analyse and explore the pathways that I have signposted, plus the many others that exist.

The advances I have selected are represented in the following sections. They are, to a large extent, the outcome of more than forty years of evolution of the ability to define mining and metallurgical operations and the research involved in terms of statistical probability models to reflect the economic parameters of success. The culmination of this effort is well revealed in the Journal Comment of the December 2013 issue of the Journal. My suggestions are intended to be selectively illustrative, not exhaustive, the latter being blatantly impossible. But I do believe that my selection comes close to being possible in defining precisely the specific goods and services that are necessary to meet the immediate national target.

EDUCATION, SCHOOLS AND TRAINING

The schools education component of the general strategy is not only of the greatest importance but also of the greatest complexity in terms of the large number of activity options and the associated research. There can be no doubt that the development of skills at schools, training colleges and universities is the quickest path to sustainable employment. Equally there is no doubt that the success depends on the quality of the teachers, lecturers and mentors. Such a statement is in the nature of a cliché, but today the demand is for more than good disciplinarians achieving acceptable examination results. Now the call is for teachers who, in addition to their traditional roles, can inspire a culture of entrepreneurship and creative and innovative abilities. This in turn demands a revolution in teacher training, selection and interaction with career providers in a national society. Fortunately the time is ripe for such an advance, thanks to the revolution in IT technology.

My direct association at school level was with a school that was transformed into a multiracial and interdenominational school at the time of apartheid when I compiled many letters to industry to provide the school with computers and assistance in using them. This enabled the headmaster, Dr Jacques Kriel, to introduce a computer into every classroom at the school, leading to it becoming the top model C school writing IEB matric level exams with many distinctions and zero failures. It is the model on which I base my proposals for strategic planning.

These proposals are to take the best of many options to establish top level community interactive teacher and parent activities. The minimum requirement is that every pupil and every parent couple have a compact computer be it an I-pad or laptop. Crash courses for all adult employers will be offered. Private and, in fact, all schools are good business as indicated in previous Journal comments. There is a risk venture company on the JSE having great success in raising investment capital which has started 20 schools with a further 10 at the planning stage.

The maximum return in such an investment is to obtain the specially trained teachers in IT training technology and with experience in the different career opportunities. There must be interaction between the mining graduates, geologists and metallurgists and the teachers with interchange and advancement for teachers into industrial activities.

It is necessary to emphasize that the best way to achieve an effective interaction of multi-cultural communities is to encourage the joint participation of school children, parents, teachers and other villagers in mutually beneficial activities such as sport and other multi- participative activities. It is believed that the attraction of such educational opportunities will be a major motivation in attracting workers and preventing counterproductive antagonism. Moreover the association of school and training courses with careers with multiracial participation will result in the rapid disappearance of the necessity for Affirmative Action and Policies as well as BEE report card quotas.

The interactions between teachers and industrial employers are not without precedent. Interactive courses were used in the past (the Phoenix Courses developed by the National Institute for Metallurgy) and introduced scholars, teachers and professionals in industry to conceptual developments which involved economic evaluations based on the latest technology. They were a success in introducing the scholars and teachers to the nature and character of work that was taking place in industry. With more creative concepts added they could serve as patterns for application in the mining clusters which would generate examples of the excitement that entrepreneurial careers can engender into the future.

An equally important consideration in designing these interactions is the need to recognise the different learning and thought characteristics in young people. For example there are those that learn by memory processes and others by inductive logical thinking and many other approaches. This is a profound subject with many studies being conducted using computer techniques: a growing field of specialization which has led to the phenomenal success in producing so many mining graduates and diplomats. If that is the case then there is no reason why a similar success could not be achieved in persuading entrants to university and technical colleges to take up the many other engineering and science courses that are needed to create the employment in the cluster complexes. However the success will depend on the teachers in the schools and other intermediate training colleges, who must themselves benefit from the new approach.

Computer and IT technology has started and will continue to bring new dimensions and demands at schools and training colleges. To handle this development the teachers themselves must move rapidly into a professional status where computer and IT technology becomes an essential capability. Moreover this capability must be kept up to date by close interaction with the other professional workers making up the entrepreneur instigators of an advancing society.

The highly successful countries have demonstrated that for every trained university graduate, innovative success results from the availability of at least two practically competent, technically trained and computer literate co-workers.

Additionally if one includes tourism, for sustainability reasons, as an important activity of the clusters the career arena moves into art, history, physical education (sport), agriculture and marketing cultures. And curricula which include the interactive project work with working

professions. This interaction occurs in schools from the grades (as in language laboratories), to the matriculation levels in virtually all such disciplines.

The possible activities that would be relevant to the mining clusters are:

Hydroponic Fertigation

- Small scale facility for Hydroponic Fertigation (HPF) testing, e.g. best nutrient demand pattern, transpiration rates yields and temperature sensitivity
- Computer Surveys for new cultivars for HPF crops
- Facility for calibrating instrumentation for HPF use
- Laboratory for water analysis, make up of nutrients and programming of feed systems
- R&D projects aimed at improving drip systems, collection of products and seed selection and planting
- Recovery of nutrients from anaerobic digestion residues
- Methods of purification of polluted water with low cost and zero waste, with recovery of all valuable constituents

Curriculum projects

- Master Maths and Master Science' programs
- Language laboratory for global marketing languages and their conversion to indigenous culture and African languages
- Exchange visits, both internationally and locally
- Business and evaluation of potential new ventures in a SA context
- Geology: mineral collections as sources of standard reference

Tourist Attractions

With my participation in 1998, a R1million sponsored study was undertaken for the Premier of the Northwest Province to explore the potential tourism options for the area surrounding Rustenburg and the western limb of the platinum mines. The University of the Witwatersrand and the North West University including Potchefstroom University and a number of hoteliers and travel agents were involved. Even Disneyland expressed an interest.

The concept focussed on the fossil, archaeological, wild life reserves and the geological features of this area. The assignment was to include employment opportunities and funding income for bursaries for schools and tertiary education for low level income families.

One of the outcomes was the concept of the 'Cradle of Humankind' and the Origin Centre. This has evolved into a highly successful tourist attraction. For a number of reasons the bulk of the options analysed were left in abeyance and are still available as options in the form of exhibition centres, lodges for specialized studies and experimental work and outdoor trails in game and recreational areas.

Potential for development

Laboratories and academies for international visitors

- Palaeoanthropology

- Archaeology
- Genetic geochronology
- Origins of major geological complexes in southern Africa
- Mineralogy and precious mineral collections for tourists
- Semi precious stone polishing and ornament and jewellery production
- Origins of plant and animal life
- Game conservation and associated research projects
- History of ancient and modern man in Africa
- Rock-art, Bushman paintings
- Wild life origins, ancient and modern

Recreational and entertainment

- Game trails and lodges and bush camps
- Video and computer animation and photography
- African fashion displays - African leather cloth and beadwork
- Music history, African instruments, concerts dance and song
- Presentations of African mythology and animal fables
- DVD productions of the history of famous pioneers, prospectors and explorers. Studios for production and 3D displays

One example that caught my fancy in terms of innovation and creativity was the "Ox-Wagon Trail" in which elderly, disabled and young children were conveyed in covered wagons through predator game trails pulled by a mock-up 'ox' vehicle with guides cracking whips and generally looking after the visitors. This covered a weekend or longer and at each evening they were welcomed by villages with traditional meals, entertainment and traditional accommodation.

In conclusion, it can be seen that in all these activities, children, parents, employees of the mine and plants and particularly teachers with their skills in languages, cultures and training will hopefully find it easy to create a uniform and cooperative society with a wide diversity of income generating capabilities, employment and sustainability for long term growth, with many options for production of goods and services for sale. This is of course the long term essence of strategic planning.

The Mining Clusters are only one of the future industrial and agricultural clusters, but the general principles of supplementary job creation through sustainable education in properly staffed schools are universally applicable. This is the most promising strategy to convert the impoverished bulk of the population to join a proud and prosperous nation.

REJUVENATION AND SUSTAINABILITY OF GOLD AND PLATINUM MINING

For a variety of reasons, the employment opportunities in the gold mining and platinum mining sectors have been steadily declining with decreasing profits as a result of the rising cost of mining of the narrow reefs at increasing depths. Many closures of gold mines have become necessary over the last few decades.

Selective Blast Mining (SBM)

In an attempt to halt the decline, an R&D program referred to as "Selective Blast Mining" was reported in the Journal some 15 years ago which offered increased recoveries and much reduced

costs, but it was not taken up by the mines. An effective method for sequential cast-blast mining was demonstrated by JCC, a company set up by Immo Bock, in the early 1990's.

Reference:
"An economic model for gold and platinum mining using selective blast mining" by I. Bock, L. Jagger, and R.E.Robinson. The Journal of The South African Institute of Mining and Metallurgy. March/ April 1998 pages 75-84

This comprised an electric pulse system, operating at 7 millisecond intervals, initiating 1 second delay detonators. The latter were required to avoid the first blast in a sequence obliterating the electric wiring to initiate the succeeding detonators. With a 7 millisecond detonation sequence, an excellent cast blast pattern was obtained. This electrical method was abandoned as it did not deliver an absolute zero defect system, an essential demand in mining blasting protocols. The reliability of the imported delay detonators was a consideration. It also required a significant measure of fragmentation as the result of gas evolution in the high value narrow reef section of the stope face. This was recognised as a disadvantage since the valuable gold (and/or platinum) were in a micro-sized particulate form which could be dispersed by the high velocity gases which caused the fragmentation.

A novel concept became evident as a result of papers published recently in the Journal, by E. Sellers of AEL, who showed, by some dramatic graphic diagrams, that the fragmentation effects could be separated from the shock wave fracture which did not involve gas evolution. After discussions with Sellers' employers, AEL, and the closely associated company, Det Net, familiar with more modern methods of detonation, it was believed that there would be no problem in designing a system, where the fragmentation and cast blasting could be confined to the waste rock portions of the stope face and the narrow reef portions could be subjected to shock-wave fracture cracking without gas evolution or casting. Patents were taken out by Det Net several years ago. However, no experimental work of any kind has been forthcoming, nor any design specifications of delay detonators or shock tube systems have been proposed.

In the light of the strategic demands, it is now imperative that all the expertise available be marshalled to rapidly establish the best of several options for cost evaluation and demonstration on gold and platinum mines.

A group of researchers has been established under the leadership of Rod Pickering as chairperson of the Centre for Mechanized Mining Systems Steering Committee to investigate automation for the narrow reef mines and includes the selective blast mining concept. Pickering's message is crystal clear: South Africa's narrow-reef mining has to move to the next level, or the country will end up with a decimated gold mining industry in the near future. Similar sentiments apply to the platinum mining industry. Should the main directions of the proposed overall strategy be accepted, Pickering's team would be the champions of such an investigation.

Selective Blast Mining provides a number of options to decrease the magnitude of underground blasting, reducing the quantity of rock to be transported to the surface with increased gold recovery and reduced dangers of rock-burst accidents. The technique leads to several options for automation of blasting and avoiding manual rock transfer. It will lead to added value skills on the part of the

underground miners and in broad terms, lead to a rejuvenation of gold mines and more cost effective platinum mining.

A recent research paper in the Journal has resulted in a suite of statistically derived 'Cost Curves' for virtually all the gold and platinum mines and some rapid examination of these can provide a good estimate of the potential if it is given the high priority that is suggested. It is important to establish, as early as possible, some statistical estimate of the mines that might be resuscitated in both the gold and platinum sectors. A negative indication in terms of job creation could well torpedo the overall concept of the 'mine clusters' concept. Fortunately early indications are possible using the algorithms developed by the team at the Wits Mining Department (Refer to 'Cuthbert Musingwini'). These were for rapidly calculating the 'cost curves' for a comprehensive suite of gold and platinum mines both dormant and operating. One can calculate which of these might be viable for a prescribed period, should selective blast mining be applied. The calculation should, in the first instance, be based on the assumption that only a fraction of the material blasted from the stope face has to be hoisted to the surface, crushed, ground and subjected to gold and/or platinum extraction.

Mine Call Factors (MCF) and the statistical evaluation of precious metal recoveries

When I was first assigned the task of resolving the "non- assayable gold' controversy at Daggafontein Mine in 1955, the Mine Call Factor had to be reported as a legal requirement to the Police. This was part of the campaign to detect theft of gold, and as an acknowledgement of the statistical nature of sampling and fire assay. Some 60 years later, the MCF still bedevils the gold (and platinum group metals) mines' valuation procedures.

The work on SBM that was reported in the 1998 paper suggested from the MCF calculations that significant gold losses were occurring as a result of the blasting of the narrow gold reefs and was of the order of 20% or more in gold and platinum mines.

However a recent paper in the January 2014 issue of the Journal indicated that this could have been the result of faulty sampling routines used for the underground resources. The magnitude of the bias errors is such that it is critically important to introduce proper sampling methods for mine valuation calculations if only for strategic research planning. Clearly this source of uncertainty must be rapidly resolved before meaningful experimental work is conducted. Fortunately a group of specialists from AMIRA/SAIMM are available and an advanced Mine Evaluation course is to be run in September 2014, by which time appropriate codes of practice may have been established.

The Impact of Rock Cutting using a High Velocity Water Jet Containing an Abrasive Powder

This possibility was reported by a group of geologists at the University of the Free State. It was claimed that narrow slots could be cut, about 3 mm width minimum, and up to a depth of 1 metre in hard rock using high velocity water jets incorporating broken glass powder as the abrasive medium. The cutting system had been developed in Germany. Although this suggestion has not reached a mature stage, its application is of great possible significance. If such a slot could be cut just above the narrow reef positioned close to the hanging wall (roof) of the stope, it would act as an insulator against any damage to the roof by the blasting activities below the reef. The shock wave for fracturing the reef would not be transmitted to the hanging wall above the slot.

If this could be done on an economical basis, not only would considerable costs be avoided in ensuring that rock falls from the hanging wall material did not endanger workers or machinery, but the transmission of shock waves through the supernatant rock mass would be avoided and the seismic effects would be minimized. Another factor which would considerably reduce seismic effect would be the nature of the millisecond blast impact. This would be represented as a series of blast waves with a frequency of approximately 140Hz rather than one single big blast with a much greater impact on seismicity. There are several options as regards the abrasive material. Other options such as diamond wire and diamond toothed reciprocating saw blades could also be examined. Although not of the same urgency in establishing the operation of dormant mines, it is well worthwhile exploring a portfolio research project with as much international cooperation as possible. Since such technology might have many applications in automated deep level mining, it is suggested that a team of engineering students be commissioned to do a survey of commercial technology suppliers for a multidiscipline Portfolio R&D exercise, and that the work at the Free State University be continued with international participation if deemed appropriate.

There is an alternative possibility under investigation and ultimately it might be necessary and economical to adopt the fully remote automated 'Raise Boring' system being investigated by Anglo Gold Ashanti for ultra deep level mining. This could extend even further the concept of mine cluster advantages, in the sense that most of the workers would have an opportunity to learn skills relevant to the automated operations.

There is a high probability that many mines in the Witwatersrand complex and Welkom in the Free State, can be the basis of meaningful mine clusters which are the strategic scenario I am proposing.

THE MINING CLUSTER CONCEPT

The main thrust here is encapsulated in a recent "President's Corner" by Gordon Smith. In the August 2013 Journal issue in an 'Adapt or Die' comment, Gordon wrote:

"The technology transfer challenge facing the underground narrow tabular mining industry is less about technology and more about people and a social compact to allow transformation of the industry. The questions I keep asking myself are: Do we fully understand the problem, and do we have the right approach and skills to achieve that understanding?"

In any rejuvenated mining cluster there is no question that the old contract migrant system of employment must be abandoned. Those underground or plant workers who were employed on this old system must be taken on with the same privileges as all the other mine employees. Of fundamental importance is for them to have their families, not only living in the mining cluster, but also enjoying the social acceptance as full members of the society. As discussed later, their children must attend the same schools and the parents, teachers and children must achieve the same norms of behavior. If additional sources of income can be found without cost to the mine, this will represent a most important factor in achieving the full participation. Not surprisingly there are several options for generating additional incomes. But the one selected for further discussion is one that will have very important implications and great applicability in the national priority of creating additional goods and services in the national development plan. It has been chosen because it has been specifically mentioned by key members of government.

Small lot farming close to mines

This might appear to be a startling line of thinking! But in the previous 'golden' century, the predominant employer of labour was the agricultural industry, and the migrant contract workers left behind their families to eke out a living on farms.

In the recent budget the Minister of Finance gave high priority to tackling the high level of unemployment in the rural areas and referred to the rampant poverty in the tribal villages as a result of the problems of available land and water for agriculture.

Remarkably and fortunately there is a profound revolution in agriculture taking place the world over. It has been quietly ignored but it becomes highly relevant.

It would be more than appropriate for the mining clusters to introduce the new elements of this agricultural change, particularly as they fit in perfectly with the modern style mining activities that form part of this strategic concept. It is far removed from peasant farming. It is based on high technology, computerized control methods which are similar but simpler than what is now commonplace in the mining industry. The required skills can be easily absorbed by pastoral farmer families backed by the technology that is readily available in agricultural circles and among mining graduates.

The agricultural system is known as Hydroponic Fertigation (HPF) and is well used in several countries where water supply and land quality is a problem. It was established in Mexico and developed for peasants in collaboration with the originators in Israel. It is based on sub-surface drip irrigation directly onto the roots of the plant. The quantity of the solution of nutrients can be carefully controlled (by programmed computer algorithms) so as to provide the exact amount needed by the plant at the various stages of plant growth.

HPF was described in basic form at an international conference attended essentially by the South African coal mining industry in 2004. It was presented in this instance as a means of obtaining carbon credits to offset the carbon dioxide emissions which, in South Africa, were among the highest relative to GDP because of its almost total dependence on coal for power generation and the coal to liquid plants of Sasol. HPF was the favoured system for producing bio-fuels which is even more significant today because ethanol, the common biofuel, is top of my list for use as an energy source for underground automation in mining.

HPF, when coupled with communities skilled in computer automation methods, is in the nature of a miracle for countries with water shortages, a small proportion of agricultural land and an impoverished rural community. This means most of Africa. It has many other highly significant advantages, one of which can be well appreciated by mining engineers, in that it uses the main constituent needed for plant growth at a high efficiency. This is the water taken up by the plant from the soil (the transpiration efficiency) of ca 85% as compared with the 15% of the best irrigated commercial surface methods, since water and fertilizer costs are paramount in crop production. The leakage of nutrients from the land into the nearby water courses and aquifers is negligible. This provides highly competitive farming, with year round regular delivery of products to consumers. It operates best on flat horizontal waste land such as mine non-toxic slimes dams and even desert or semi-desert land. It can be modified to operate on terraces, which is of interest for re-establishment

of open pit mining areas such as abound in the South African coal mining industry. Apart from this land advantage, HPF technology solves the agricultural water problem which is generally cited as the main factor limiting rural agriculture. Indeed there are several options available for providing adequate irrigation water. Perhaps the most significant is the use of domestic effluent and the effluent from Acid Mine Drainage and from hydrometallurgical processing such as uranium and base metal recovery plants.

By using some innovative concepts such as a continuous planting and harvesting unit, unskilled labour productivity can be upgraded (including computer familiarity), and can be made highly productive. The first assessment indicates that one farmer family could achieve an income of the order of R50 000 per annum working on a number of continuous units, each requiring a fraction of a hectare which, in no frost areas, can provide for harvesting throughout the year. Even in winter frost conditions, maize can be harvested for 300 days per year. High planting densities can be used so that one hectare can provide an annual yield of 100 tons of maize and approximately 200 tons of biomass. If the 100 ton of maize is converted to ethanol using sacharification and yeast fermentation a yield of approximately 40 Kilolitres of alcohol can be produced. The high protein residues after fermentation, known as dried distillers grain and solubles (ddgs) can be combined with the digestible portion of the biomass to provide approximately 100 tons of a most highly valued animal and poultry feed. The remaining 'refractory biomass' can be converted to a syn gas (H2+C0) which is a source of liquid fuels using Sasol GTL technology. It can also be a source of hydrogen for platinum fuel cells or even ammonia production for fertilizer.

The same range of products can apply to other grain crops such as grain sorghum. Even sugarcane can be grown to provide ethanol and similar by-products.

The low cost of production compared to that of commercial farming gives rise to worthwhile income to the farmer families and the producers of the other products.

Indeed this agricultural method opens up the total Zero waste approach in all mining clusters and probably all other industrial and civic clusters. But I present these agricultural options as one of the few options of the high success probabilities for a rapid solution to the poverty and job creation problem. There is a 'sitting duck' market for biofuels and biomass power production but also many other agricultural products far exceeding the markets for beneficiated mineral products. The local production of the biofuels (replacing the 120 million barrels of imported oil) from bio ethanol and biodiesel, with all the added value food and industrial products, is getting on to the target of many millions of jobs. Indeed the conversion of the country to a large percentage of bio fuels consumption has significant other manufacturing job creation potential. The concept of the local production of a hybrid ethanol/electric car could be a model for Africa and for underground mechanization for the mining industries of Africa. There are possibilities of cultivating Guayule crops for isoprene rubber and long life tyres for mining applications and heavy vehicle transport. Leather, cotton and indigenous wool garments are also possible - even inland fish farming is an option.

HPF economics

The recently developed agricultural irrigation technology known as hydroponic fertigation (HPF) plays a cardinal role in establishing small lot farming activities in the proposed Mining Clusters. Demonstration of the HPF system at Cradock and on several mining sites, such as West Driefontein,

using abandoned slimes dams, showed that astonishing results could be achieved by sub-surface drip irrigation, the essence of HPF. Accordingly a survey was undertaken on this technology in Mexico, Israel and to a limited extent in Australia. There are a very large number of options for crops that are, and can be grown, ranging from grain crops, vineyards and long –stemmed roses. These options are such that there is a high probability of success of initiating HPF in mining clusters to create income earning activities for small groups of farming families.

To illustrate the potential of HPF and to catalyse an urgently required experimental programme, some features and calculations for maize farming are shown below.

- Commercially available, low cost recyclable drip tubes buried at ca 100 mm sub-surface, using perforated plastic tubes fed from solution feed tanks with ca 1meter gravity head and simple on/off solenoid valves for distribution and volume control.
- An average Plant Transpiration Efficiency (PTE) of 85% is achievable as compared with the best overhead irrigation PTE of 15%. This equates to a water consumption and corresponding fertilizer (or nutrients) consumption for HPF of .less than 1/5 of the best commercial practice, provided that roots are kept permanently moist but not water-logged.
- Agricultural soil is not needed. Sandy soil to a limited depth provides for a fine root structure that does not need to 'search' for water and nutrients which allows for easy, manual, whole plant harvesting.
- Planting densities of 25 plants per sq. meter are possible. The limiting factors are sun shine availability, energy and the diffusion of carbon dioxide to plant foliage.
- Nutrient composition can be adjusted to give the optimum conditions for the different phases of plant growth to provide maximum plant growth in minimum time of ca 120 days at typical Highveld temperatures.
- A unique, and in Africa, important feature is that sterilized domestic effluent (clarified sewage) is approved internationally for use as irrigation water.

There are countless ways of providing a matrix of drip tubes to provide a reasonably uniform subsurface distribution. The simplest is a manifold feeding an array of perforated narrow tubes just above the rows of seeds. With tubes of 5 meters spaced 20 cm apart and connected to a central manifold to give an array of 10meters by five meters. Such an option is for unskilled villagers to put in place by one farmer family in one week. The idea is to start planting one such unit a week to form a continuous line until the first plant unit is fully grown. Thereafter this unit is harvested by the simple manual removal of the whole plant. A new growing unit is planted to replace each harvested unit in turn to provide a continuous weekly production throughout the year. This provides a continuous feed to ensure processing efficiency. The family is paid on delivery providing a regular weekly income.

The calculations to illustrate this simple model are shown below. This should be confirmed by experimental work in due course.

Assumptions:

- An optimum planting density of 25 plants/m2
- Average individual plant content of:
  - 250g maize -starch
  - 500g animal feed as digestible biomass plus protein
  - 250g refractory biomass.

The above values are calculated from American data for the latest cultivars.

On a weekly harvesting programme, for each unit of 50m2, the maize starch produced would be 25x50 x250g =0.3125 tons/week.

Total yield in a year depends on temperatures and winter frosts; say between 40 weeks and 50 weeks growing time and between 12.5 and 15 tons per annum per family unit, allowing for normal plant variances.

At recent maize prices of R3500/t, this gives an annual income of R40 000 to R50 000 including the protein rich animal feed.

One must not forget the value of the refractory biomass equal say to 15t per annum. In terms of converting this biomass to syn gas, as described in the Beautifuel process, each ton of biomass is equivalent to 1bbl of crude oil and at R1000/bbl, this gives an extra income of R15000, thus making a total of ca R60 000/annum per family.

If the maize –starch were to be converted to ethanol at a conversion ratio of say 0.4kl/ton then each unit could produce around 5.5 Kl/a, of ethanol (at R12/l) with a final sales value as motor fuel of ca R66 000 and an oil barrel replacement value of ca R35000/a.

In the fermentation process the protein food value is much enhanced by the inclusion of yeast protein and growth factors. This was the basis of the Rumevite feed blocks that were developed by Sentrachem. When added to the digestible biomass it realises a high feed value of at least R1000/t, an additional value of R15, 000 giving a total income value of ca R65 000/a to the farmer family including the syngas value.

The cost of maize growing cannot easily be calculated other than to say that apart from labour (income to families) the costs in terms of fertilizer, land, transport, storage etc., will be of the order of 1/5th of the best commercial practice costs. The figures are admittedly theoretical and speculative but it is well within the bounds of probability that small lot farming can provide an attractive additional income to members of mine clusters.

It is these costs and incomes that must be the subject of intense discussion and cooperation with all the concerned parties at a national level.

R&D Concepts for Multiplication Factors and Added Value

There is in this revolutionary agricultural process a host of innovative concepts to produce additional jobs and to add value to new and existing products. They are listed below with only brief notes to initiate future discussions and planning.

The calculations above are for one family of what used to be termed ‘a migrant contract worker’. For illustrative purposes I look at the hypothetical situation of say Welkom, which when revitalized will have say 5000 labourers employed in the clusters with their families to create small lot HPF farms.

The clusters can produce vegetables and accommodate abattoirs, food processing plants, cotton leather and woollen garment production and plastics such as rayon and polyethylene.

There is the realisation that 5000 families could now become fulltime community members of resuscitated mines in the Welkom area.

It is obvious that ethanol should be produced (2500kl), high quality animal feeds and syngas to make diesel fuel or hydrogen for fuel cells using platinum. Apart from the conventional meat, wool, leather, cotton, poultry and vegetables there are other products of importance such as feedstocks for diesel and aviation fuel. There could be high productivity in the production of soya beans and castor beans. The HPF options for multi crops to produce bio-fuels can be researched with multiple benefits in high school research projects with inexpensive equipment and graduate supervisors.

The total additional contribution to GDP in the Welkom area would be well above R1billion. An ethanol plant is being planned at Bothaville to produce 150 000kilolitres/annum of ethanol and this could almost certainly be expanded to accommodate the maize from small lot farming activities in the Welkom area. The animal feeds could be returned to Welkom for use by farmers producing meat, milk and other products that present employment opportunities. To calculate accurate and credible figures would require close consultation with the commercial agricultural community.

At Welkom there would have to be a water treatment plant, with suitable expertise and laboratories and a computer centre to organise the programming of the HPS farming activities. Obviously arrangements must be included to restore social services and for transportation and supply of seeds and replacement equipment. This would be no problem in the mining cluster community assuming that there was a dedicated development activity..

In the Rustenburg/Bafokeng/Marikana platinum belt environment the numbers are much higher, probably 5 to 6 times that of Welkom. This easily justifies an ethanol plant in its own right, let us say 150 000 tons per annum with a correspondingly increased contribution to GDP. Interestingly this would justify this area being converted to 100% ethanol fuel pumps rather than merely a 2% addition to gasoline as approved for the Bothaville plant. This is undoubtedly the ideal fuel for underground automation. The deal offered to AMCU/NUM workers would be long term family membership of a Mining Cluster, with opportunities for the family to earn a 50% increase on their current salary and a first class schooling for their children.

The land required is of the order of 0.1 hectare per farmer family excluding housing and community facilities such as schools and clinics etc. In other words for Welkom 500 hectares and for the platinum belt 2500 hectare. Clearly the availability of land is not a problem.

The water requirement for the HPF system is of the order of 2m3 per day per farmer. This can almost certainly be met by treatment of domestic sewage in and around Welkom and Rustenburg. The sterilization process is extremely simple comprising the anaerobic digestion of the sludge to produce methane and using this methane for heating the clear overflow water in a heat/energy exchange system using submerged combustion. These are common-place operations, but will require the civil engineering contractors to provide these facilities. The water can also be supplied by the conventional HPF ‘Pond’ system provided the rainfall is of the order of 700mm/annum.

The fertilizer system that is needed for the HPF installation demands no more than 4 tanks for all phases of plant growth. The tanks would contain pure/clean water, ammonium nitrate, ammonium mono/phosphate, potassium nitrate with trace elements, all of which are standard products.

It is of interest to note that if HPF small lot farming were to be introduced to replace all imported oil barrels say 140million barrels, 4 million small lot farmers could be involved in a short time period. The use of the HPF system is of such importance to the country and it will do more towards solving the poverty and job creation issues that it demands the best consultation in this technology, such as Peggy Bradley the director of the Hydroponic Research Institute in Mexico, to advise the Departments of Agriculture and the Department of Industry to establish other industrial and agricultural clusters across the country from Namaqualand to the Eastern Cape and surrounding Coega.

ADDITIONAL OPTIONS FOR INDUSTRIAL R&D ACTIVITY

Acid Mine Drainage

Treatment of solutions from acid mine drainage (AMD) and solutions from uranium and base metal leaching. Such solutions contain sulphuric acid and a number of toxic metals such as cobalt, nickel, uranium and large amounts of ferrous and ferric ions.

The current method for treating AMD is to add a large amount of low-grade lime and to settle out the sludge of hydrate precipitates allowing an overflow to drain into water courses which causes a disastrous increase in the total dissolved solids in water resources. The toxic sludge represents a long duration environmental hazard when it is discarded on slimes dams, as in the HDS process currently being built at huge cost.

This R&D Portfolio Program, with many options available, is based on some features of a process which have been published, in “Science in Africa” a website Journal reaching a wider scientific community in SA.

The uses of ion exchange (IX) resin to ensure no additional impurities are added to the effluent being treated and that no impurity constituents are ‘dumped’ but are converted to saleable by-products. This is done by the use of regenerants for the IX resins such as ammonia and nitric acid becoming valuable by-products, saleable as fertilizers at a value which is at least equivalent to the cost of these reagents. All of the options are zero waste and low-cost processes.

Such a process was submitted as a tender by an established contractor to the Grootvlei Mine, for approval by the Water Research Commission. This IX process was rejected in favour of the ‘Bio-Sure’ technology coupled to the HDS sludge process.

The IX process would have provided several thousand jobs to impoverished rural families and is one of the simplest of the options to implement. The main features are summarized below without going into too much detail to indicate the nature of the IX concept.

The first step is to neutralize the sulphuric acid with weak free base anion exchange resin to a pH value of 3.5. This will, with the injection of air, precipitate all the ferrous and ferric ions as a high grade ferric oxide which is readily saleable as a high quality pigment. The anion resin is eluted with ammonia gas to give an aqueous effluent that can be used as a fertilizer.

The second step is to absorb all the cations on a cation resin in the acid form. The effluent can be neutralized with ammonia gas to produce a fertilizer solution or it is absorbed onto a weak base

resin to produce potable water. The cation resin is eluted with nitric acid and from this eluate all the toxic metals can be precipitated as saleable products and produce a filtrate of ammonium nitrate, another fertilizer. The suite of toxic metals in the form of hydrates can be separated into individual saleable materials.

There would be no dumping of waste materials. The cost of the resin regenerants would be recovered by the sale of fertilizer solutions and making full use of the effluent water.

There are many alternative options to cater for the presence of sodium impurities, for example, and for making saleable building materials using low grade waste coal fines. Special types of equipment have been developed to handle the resin processes varying from simple batch tank reactors to counter current multistage resin-in-pulp contactors, most of which are commercially available but some in pilot plant or conceptual form. These lead to a versatility to cater for virtually all forms of AMD and most of the base metal and uranium process effluents.

Many portfolio projects are possible, some of which are appropriate to high school experimentation which is a feature of the overall strategic proposals. Another option is the production of d-i-y building blocks from high sulphate solutions. One particular option, the Bipolar Cell, is mentioned below as it has an additional impact on some new uses of platinum.

The Bipolar Cell

The bipolar cell is similar to a chlorine/caustic soda electrolytic production cell which is today used widely for the production of these chemicals. The bipolar cell is one in which an anionic selective membrane is inserted between the feed solution compartment and the anode compartment, to prevent any hydrogen ions moving from the anode compartment to the cathode. This enables a salt such as sodium nitrate or sulphate to be converted electrolytically to caustic soda and nitric or sulphuric acid respectively.

Bipolar cells are available commercially. They are not often used because it has been found that the usual anionic membrane is degraded rapidly and high maintenance costs are incurred. Several patents have been lodged to produce special membranes but the costs of these are excessively high. It is believed that there are ways of overcoming the cost disadvantages so the bipolar cell can be more widely used industrially, particularly if coupled to a platinum/hydrogen fuel cell. The bipolar cell produces hydrogen and oxygen gases at the cathode and anode respectively at a high level of purity which is ideally suitable as feed material for the platinum fuel cell thus providing direct current of approximately the correct voltage, very efficiently and at low cost.

Innovative options exist for a cost effective bipolar cell to be developed, which will have a major impact on effluent treatment particularly where sodium and other alkalis are the main impurities. For example, in the case of acid mine drainage from coal mines, and in gold mines, the sodium concentrations are increasing. In the case of gold, it is probably as a result of the use of sodium cyanide replacing calcium cyanide.

Low cost production of caustic soda or the acids would be invaluable for regeneration of resins, or recycle for primary leaching.

This applies particularly to the platinum processing and by-product recovery.

Patent protection for these uses would be essential to protect the benefits to research portfolio investors, since the applications could well be globally applicable.

The Kell Process

The Kell process, using hydrometallurgical techniques, has been well documented and it is being taken up by a joint effort between the Industrial Development Corporation and the Pallinghurst Group. The most costly component is the roasting process of the residue from pressure leaching to improve the PGM's recovery to get close to 100%.

Letowsky, in the 1990's, showed convincingly that the UG2 PGM's could be recovered by a chlorination hydrometallurgical process if the redox potentials could be increased with temperatures to 108C, and at high ferric chloride concentrations of 10N which appeared to be necessary. But this work was ignored by investigators, presumably for practicality reasons.

However new options have been suggested to reach the necessary conditions in a pressure leach operation and it is not impossible that this would be at a lower cost than roasting. These are novel concepts which, if not already attempted, should be investigated so as to be considered in the current design strategies.

Guayule Plant Project. Suitable for the Karoo, Eastern Cape and Coega

This plant produces poly-isoprene latex for high quality tyres for heavy and underground rough rock operations. All isoprene is imported into South Africa.

The Guayule plant is a small bush plant and would possibly is ideal for terraced style HPF growing in worked out open pit coal mines. This could be particularly applicable to the Anglo American financed project for the production of a fungus to resuscitate ground left after coal mining. This is not completely new as preliminary experiments were carried out in the Karoo in the 1970's.

'LiReCol' Vehicle Production in SA

This is my invented name for Lithium, cobalt, Rare earth, Ethanol hybrid electric motor and utility vehicle. This will be in two forms. A spark ignition high compression engine for ethanol and a diesel version with dimethyl ether (DME) with the same formula (C_2H_6O). Interestingly cobalt, a key element, is abundantly produced in SA as a by-product from the platinum base metal refineries and there is a good prospect of finding spodumene and petalite and other lithium and rare earth resources in Southern Africa thus challenging the research geologist and chemists.

Detailed R&D options such as full flow electrophoresis separation methods are available on request.

Maybe automobile assemblers in SA would be interested in joining Toyota to ensure an ethanol hybrid car in every cluster family in Africa.

CONCLUSIONS

To develop the Mining Cluster concept an immediate commitment must be made to bring the possibilities that emanate from the concept to the attention of all those who are concerned and involved with provincial and national government.

Although not enough data has been collected for the coal and other mining operations, there is no doubt that the Mining Cluster concept coupled with HPF establishes a centre of economic activity which in all its ramifications offers a sustainable centre that can provide valued income and job generation. It also offers a possible solution to the present deadlock between unions and industry.

The association of mining (and industrial) clusters with agriculture and education is the only hope for a sufficiently rapid transformation to generate 6million jobs. This is recognized as a highly controversial strategic consideration. Unless the concept can be initiated by the Mining Industry on a catalytic basis, it is unlikely to overcome the obvious antagonism of the commercial farming community.

It is the mining industry that can be the instigator and trail blazer of the Mining Cluster concept to rapidly develop the country into a normal, first-world, non-racially biased nation with 50+ million, reasonably affluent people.

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