No.20

ACB BRIEFING PAPER No. 20, 2010

Synthetic Biology in Africa: recent developments

By Gareth Jones and Mariam Mayet

PO Box 29170, Melville 2109, South Africa
www.biosafetyafrica.net

The African Centre for Biosafety (ACB) is a non-profit organisation, based in Johannesburg, South Africa. It provides authoritative, credible, relevant and current information, research and policy analysis on genetic engineering, biosafety, biopiracy, agrofuels and the Green Revolution push in Africa.

www.biosafetyafrica.org.za
PO Box 29170, Melville 2109 South Africa
Tel: +27 (0)11 486 1156

Design and layout: Adam Rumball, Sharkbouys Designs, Johannesburg

Contents

"With the tools of synthetic biology, we don't have to just accept what Nature has given us."[1]

Professor Jay Keasling, CEO of the Joint BioEnergy Institute of the US Department of Energy

Acronyms

ACT	Artemisinin-based Combination Therapies
ABE	Advanced Bio-Extracts Ltd
BMGF	Bill and Melinda Gates Foundation
COP 10	Convention's Conference of the Parties
CSIR	Council for Scientific and Industrial Research
DST	Department of Science and Technology
EU	European Union
EXCo	Executive Committee of the Department of Science and Technology
GM	Genetically Modified
GE	Genetically Engineered
HLEG	High Level Expert Group
HPLC	High Performance Liquid Chromatography
IDC	Industrial Development Corporation
iOWH	Institute for OneWorld Health
JSPS	Japan Society for the Promotion of Science
MoU	Memorandum of Understanding
MTSF	Medium Term Strategic Framework
MRC	Medical Research Council
NRF	National Research Foundation
SANERI	South African National Energy Research Institute
SBI	SunOpta Bioprocess Inc
SBMT	Stellenbosch Biomass Technology
SBSSTA	Subsidiary Body on Scientific, Technical and Technological Advice
TLC	Thin Layer Chromatography
UCB	University of California, Berkeley
USDOE	United States Department of Energy
WHO	World Health Organisation

Introduction

The focus of this paper is the emerging field of synthetic biology, in particular its implications for the African continent. Synthetic biology combines a number of scientific disciplines and is generally understood to involve the deliberate design of biological systems, using standardised components that have been created in a laboratory. It has been hailed as the key to a new post-oil global economy of abundance for all. In public, this rhetoric has been backed up by high profile research into the creation of synthetic artemisinin, a vital anti-malarial drug. However, behind the headlines the oil and military defence industries see synthetic biology as the perfect vehicle for the continuation of their power and accumulation under the guise of fighting climate change.

The potential for the technology in the global fight against Malaria is considerable, as are the potential impacts of synthetic artemisinin on the cultivation of Artemisia (the plant that contains the vital natural ingredient) in East Africa, where a fledgling industry supporting thousands of small holder farmers is developing. South Africa was initially heavily involved in synthetic artemisinin and there are currently plans for the development of a national synthetic biology strategy in the country. This is considered in the context of the country's drive towards a 'green economy', with particular credence given to the disastrous implementation of its national biofuels strategy. Finally, we turn our attention towards the newly established Stellenbosch Biomass Technology Company, which has teamed up with the Canadian firm Mascoma with a view to producing second generation agro-fuels in South Africa using both techniques of synthetic biology and genetic engineering.

Our conclusion leaves more questions than answers because of the emerging and secretive nature of the field, but highlights the very significant implications of this new technology and the need for a precautionary and vigilant approach towards it.

What is Synthetic Biology?

'[synthetic biology] is broadly understood as the deliberate design of novel biological systems and organisms that draws on principles elucidated by biologists, chemists, physicists and engineers...in essence it is about redesigning life'. (UK Royal Society).[2]

The emerging field of synthetic biology has been making waves in the global scientific community recently. Earlier this year, Craig Venter, the doyen of the genomics world, claimed that his company had created the world's first self-reproducing organism. Scientists have proclaimed that the discipline is on the cusp of opening doors to almost limitless supplies of agro-fuels and pharmaceutical compounds. The ethical implications of this new technology are considerable, as not only will it ultimately offer the potential to create biological systems and organisms that do not occur in nature, but scientists have already been able to synthesise several lethal human pathogens and viruses.[3] Presently, according to an EU High Level Expert Group (HLEG) on synthetic biology, 'it seems likely that we do not as yet possess a conceptual ethical framework that can provide a common context for such debates'.[4]

As definitions of synthetic biology depend upon the scientific approach taken or the final application of a given project, a standard classification has remained elusive. However, it is

generally accepted that the discipline utilises principles drawn from multi-disciplinary fields, including nano-technology, biology, physics, chemistry and genetic engineering, to design and engineer biological components that can be used interchangeably to construct a variety of biological systems. These systems could be constructed for a variety of uses, ranging from the production of pharmaceuticals, chemicals, hydrocarbons and food.[5]

Funding of Synthetic Biology

Research carried out by the Synthetic Biology Project[6] has revealed that there are currently over 180 organisations in the United States and a further 50 in Europe that are involved in synthetic biology research, development and commercialization. The current annual research market for synthetic biology is worth an estimated $600 million, a figure that could potentially exceed $3.5 billion over the next decade. Other projections from the industry go even further, with one postulating that the as much as 20% of the $1.8 trillion global chemical industry could be dependent on synthetic biology by 2015.[7]

Since 2005, research related to synthetic biology has received approximately $430 million from the US government, while the European Union (EU) and the governments of the Germany, the Netherlands and the United Kingdom have spent in the region of $160 million. The United States Department of Energy (DOE) is by far the biggest individual source of research funds, with conservative estimates putting its largesse at $350 million over the period (which could be as high as $700 million). The United States Department of Defence is also reported to have committed $20 million of its gargantuan budget for 2010/11 towards synthetic biology research, though further information is unavailable to the public. Synthetic biology was earmarked as a priority research area in the EU, back in 2003 and $53 million in funding has been approved since then. The UK government is estimated to have spent between $30 million and $53 million since 2005. In 2008, three Dutch universities (Delft University of Technology, University of Gronigen and the Eindhoven University of Technology) announced an investment plan of $90 million over the next five to ten years.[8]

Just 4% of US research spending since 2005 has been devoted to the ethical, legal and social implications of synthetic biology. In Europe the figure is even lower, a paltry 2%. Most disturbingly, not a single research grant dedicated to the risk assessment of synthetic biology can be identified.[9] Private funding for synthetic biology research is directed overwhelmingly towards agro-fuel applications, with big-oil leading the way. In 2009, Exxon Mobil, in its first major investment in agro-fuels, entered into a $600 million partnership with Synthetic Genomics to develop transportation fuels from algae.[10] In 2007, BP announced a $500 million research agreement with the University of California, Berkeley (UCB), to develop synthetic agro-fuels.[11] Amyris biotechnologies, the company established in 2003 by Professor Jay Keasling, the principle investigator on the UCB's artemisinin project, recruited the former head of U.S. fuels at BP to be its first CEO. Its largest stockholder is the French oil and gas giant Total.

This flood of capital into the field has, in the view of at least one professor of biomedical engineering, detracted skills and focus from areas where the discipline could potentially benefit the wider public.[12] The parallels with the genetic engineering of food crops could not be more striking. For the last decade highly lucrative GM commodities such as maize and soy (that are predominantly used to feed the animals, which in turn feed the global minority who can afford

meat) have been bringing in record profits for the global agro-seed-and chemical complex. Over the same period the deluge of 'benefits' that were set to emancipate the wretched of the earth from hunger and poverty have seemingly failed to materialise.

Malaria, Artemisinin and Synthetic Biology – Another "African Saviour"

Ten years ago, when genetic engineering was still in its commercial infancy, its proponents held up the example of 'Golden Rice', genetically engineered for higher Vitamin A content, to dismiss any concerns or calls for precaution regarding the technology. At present, with Golden Rice still not commercially available, a whole new batch of 'climate ready' crops have been promised that will safeguard our future food supplies in the face of increasing climatic instability. Undoubtedly, Synthetic Biology's own poster project has been the joint research carried out at UCB to create synthetic artemisinin, a key anti-malarial drug.

The research began in 2004 and is a joint effort of UCB, the Institute for OneWorld Health (iOWH) and Amyris Inc, a private genomics company established by lead investigator Professor Jay Keasling. Initial funding of $42.6 million was provided by the Bill and Melinda Gates Foundation (BMGF). It was announced in July this year that the project was ready to move beyond its development phase into full commercialization, in partnership with French pharmaceutical giant Safoni Aventis and with the aid of a further $10.7 million grant from the BMGF.[13] It was previously hoped that this would be available by 2009 or 2010.[14]

Malaria, Artemisinin and ACTs

The World Health Organisation (WHO) estimates that half of the world's population is at risk of malaria. Of the almost 250 million cases reported each year, an estimated 860,000 are fatal. Children are particularly vulnerable, accounting for 85% of all fatalities.[15] While exact figures are impossible to come by, it is clear that Africa takes the brunt of Malaria's massive burden, with estimates putting its share of global fatalities anywhere between 70%[16] and 90%.[17] The WHO recommends that Artemisinin-based Combination Therapies (ACT) are 'at present the only remaining effective treatment for uncomplicated malaria' and claims that the appropriate use of ACTs works in more than 90% of cases.[18] By 2009, ACT has been adopted by 80 countries globally as a first-line treatment of uncomplicated *P.falciparum* malaria.[19] Procurement of ACT doses by the WHO has risen rapidly in the last decade, from 500,000 in 2001 to 160 million in 2009.[20]

The use of drugs in combination is common practice in the treatment of many diseases, including TB, HIV/AIDS and cancer, as it reduces the likelihood of resistance developing to any one particular drug. While it is acknowledged that artemisinin-based monotherapy can cure malaria, in 2006 the WHO called for an immediate halt to the provision of single-drug artemisinin malaria pills, owing to fears of resistance development. Presently, the cost of ACTs fluctuates between $1 and $3.50 dollar a course, putting it out of reach of the estimated one billion people who live on less than a dollar a day.[21]

The only known wild source of artemisinin is the *A. annua* plant, which is endemic to China. Its sister species, *Artimisia Afra*, grows in the wild in South Africa, but does not produce artemisinin itself. Since the discovery of artemisinin as an anti-malarial compound in the 1970s, *A. annua* has been cultivated in China and Vietnam. In the 1990s cultivation spread to Africa.[22] The plant takes 6 – 8 months to mature between planting and harvest and the total production cycle can exceed 14 months. Once manufactured most ACTs have a shelf life of 24 months or less, which presents significant logistical constraints, especially in countries where demand forecasting and storage facilities are limited.

The supply of anti-malarial medicines is highly fragmented, with a huge private sector and with national regulatory authorities having limited control over products circulating on the market. Globally, a significant portion of the supply of artemisinin based anti-malarial medicines comes from countries with new, fast-growing pharmaceutical industries, notably China, India, Pakistan and Vietnam, but also many African countries including Ghana, Kenya, Nigeria, Togo, Uganda and Tanzania. A study by the Dutch Royal Tropical Institute concluded that it is possible to cultivate sufficient artemisinin to cure all the malaria patients in the world and that an ACT could be made available at an affordable price within 2-3 years (writing in 2006). However, achieving this would require significant investment, as well as a complete overhaul of the supply and distribution chain.[23]

In addition, the authors of the aforementioned study were of the opinion that the 'slow and cumbersome implementation of the WHO's 'pre-drug qualified policy' has resulted in a monopoly like situation. Only six companies[24] own a pre-qualified ACT, meaning the retail price is prohibitive for the majority of those who are exposed to threat of malaria on a daily basis. This is a problem throughout the global pharmaceutical sector and is not just restricted to the case of Malaria. In 2009, the pharmaceutical industry accounted for 9 of the world's top 50 most *profitable* companies, with only the financial sector and oil and gas having a larger representation. In 2009, the profits of these 9 corporations (in the middle of the greatest contraction in the world economy since the great-depression) were an eye-watering $83 billion.[25]

The fact that ACTs are still not widely available in malaria endemic areas could support the belief of governments in developing countries that the local production of Artemisia may be preferable. It may also strengthen their bargaining position when negotiating the price of synthetic artemisinin, should it become available in the future. The cultivation and certain extraction (with ethanol for example) and processing methods of *A annua* can be done with relative ease in developing countries. Their artemisinin content can also be analysed though a recently developed Thin Layer Chromatography (TLC) method, which is within 1% accuracy of the High Performance Liquid Chromatography (HPLC) method, considered the international 'gold standard'.[26]

Artemisinin Cultivation in Africa

After China and Vietnam, East Africa is now the third most important artemisinin growing region in the world.[27] The high altitude, high light intensity (due to its proximity to the Equator) and cool night temperatures are all conducive to the successful cultivation of *A. annua*, though poor logistics and lack of market integration have been cited as potential hindrances.[28] That said, a fledgling commercial sector has emerged in Kenya, Tanzania and Uganda. It has been

dominated by the activities of one holding company, Advanced Bio-Extracts Ltd (ABE) and two main subsidiaries: East African Botanicals (EAB), Ltd. in Kenya and African Artemisia Ltd. (AA) in Tanzania. In 2005, Novartis made a bridging loan of $14 million to ABE largely for expanding processing capacity and pledged to purchase a significant proportion of production.[29]

In Kenya, where commercial cultivation started in 2002, with just 3 to 4 farmers on 40ha, by 2010 over 7,500 farmers made their livelihoods from it.[30] One of the advantages, cited by farmers of growing artemisia, is that they are less reliant on expensive chemical inputs such as fertilizers and pesticides when compared to more traditional food crops such as maize or wheat.[31] In Uganda, a joint venture between a local company and Indian pharmaceutical giant Cipla is set to take off, with the WHO recently prequalifying the processing plant set up to extract artemisinin from locally cultivated *A. annua*. Cipla has already opened a letter of credit covering a full year's purchase of artemisinin, which will be exported to India to be used in the manufacture of ACTs.[32]

Like any new technology, it is the unforeseen consequences as much as the promised benefits that require a considered scrutiny. Following the increase of production to a commercial scale, Sanofi-aventis will now produce synthetic artemisinin in 100,000 litre vats. [33] Details as to where this will take place are scarce, but given that the infrastructure is already in place in California, home to Amyris and the UCB, or indeed Paris where Sanofi-aventis is headquartered, it seems unlikely that Africa would be chosen as a site for capital investment. If synthetic artemisinin is to be produced in huge vats in the industrialised north, will these supplies be used to smooth out fluctuations in supply and demand (and therefore price), or will they completely undermine a fledgling industry that is developing in African countries? Issues around intellectual property are also likely to come more to the fore. The resources that Amyris and other northern players have at their disposal will make this area a virtual non-contest unless sufficient public attention can be drawn to the topic, such as with civil society pressure on the pharmaceutical industry to provide cheap HIV/AIDS drugs for patients in South Africa.

Recent advances in plant breeding have also created hybrid *Artemisia* strains that can yield up to 3 times as much artemisinin as their wild counterparts. These plants are now being grown and harvested commercially in Madagascar, and trialled in South Africa, Uganda and Zimbabwe.[34] What will the fate of this research be, if synthetic artemisinin can be ordered directly from the laboratory? As has been the case in genetic engineering, will the concentrations of expertise and capital divert valuable research funding and ideas into a few high profile 'silver bullets' rather than supporting local enterprise and traditional knowledge?

South Africa's Synthetic Artemisinin Project

In 2004, The South African and Japanese Governments signed a bilateral agreement to enhance collaboration within the field of science and technology. To enhance the exchange of researchers and expertise between academic and research institutions in the two countries, South Africa's National Research Foundation (NRF) and the Japan Society for the Promotion of Science (JSPS) concluded a Memorandum of Understanding (MoU) in March 2005. One of the projects jointly funded by these two organisations is the ´Add value to indigenous plants in South Africa to aid in combating malaria´ project.

The objective of the research project, which was originally scheduled to run from 2006 to 2009, was to engineer the production of artemisinin in a South African indigenous scrub called *Artemisia Afra*, which is a sister species of the Asian plant, *Artemisia annua*. As mentioned, the low concentrations of artemisinin found naturally in *Artemisia annua* make it an expensive anti-malarial treatment. The research focused on finding molecular differences between the two Artemisia species and determining the feasibility of developing plant biotechnology protocols for transforming the *Artemisia afra* plant into an artemisinin-producing variant.

Four organisations were involved: The Riken Plant Science Centre and Yokohama City University from Japan, and the Council for Scientific and Industrial Research (CSIR) and the University of Pretoria from South Africa. The University of Pretoria received a total grant of R330,000 for the 'Add value to indigenous plants in South Africa to aid in combating infectious diseases' project'. Part of this grant was used to conduct research on active compounds within *Artemisia Afra*. Although funding had initially been sought for follow-up research, in early 2009 the World Health Organisation (WHO) announced the emergence of parasites resistant to artemisinin at the Thai-Cambodian border, which had the potential to curtail the previous advances made in global malaria control methods. As such, it was decided at the CSIR not to continue down this path. In response to this, and perhaps trying to protect their much bigger previous outlay, the Bill and Melinda Gates Foundation pledged a further $22.5 million.

SA's Bioeconomy, Bioenergy and Synthetic Biology

The South African government has fully embraced the grand rhetoric of the need to construct 'knowledge' and 'green' economies. The Medium Term Strategic Framework (MTSF) for 2009 – 2014 seeks to 'progressively and actively set the country on a new growth and development path'. As coal provides more than 90% of the country's electricity, South Africa has pledged to reduce its carbon emissions by 42% below a 'business as usual scenario' by 2025, energy efficiency and diversification feature prominently.[35]

The South African government is extremely keen on job creation in the clean energy production market. In this regard, the South African Green Economy summit highlighted that globally: 300,000 people are employed in the wind power sector; 600,000 in the solar thermal sector, and in Brazil, the USA, Germany and China, it is estimated that almost 1.2 million people are employed in the generation of biomass-derived energy (mostly in agrofuels). South Africa has thus set its sights on a domestic biofuels industry that could potentially employ up to 700,000 people where 15% of South Africa's electricity came from renewable sources by 2020. [36]

The disastrous planning and implementation of the National Industrial Biofuels Strategy (see below) does not appear to have dampened the expectation that agrofuels will eventually form a significant part of the country's energy mix. Several prominent members of the research and policy community, including those from the Industrial Development Corporation (IDC)[37] and the South African National Energy Research Institute (SANERI)[38] contend that the use of synthetic

biology for second generation agrofuels in South Africa could be commercially feasible within the next five years. Both organisations are currently involved with projects in this field. The IDC have been in contact with Amyris for about a year regarding their work on synthetically engineered yeast that ferments sucrose to a C15 hydrocarbon. This can be processed into a green diesel that can be used as a 'drop in' fuel, rather than having to be blended as ethanol does. Although nothing concrete has materialised to date, a possible long-term consideration for the IDC will be to apply to Amyris for a commercial license to use the technology in South Africa.[39]

The National Strategy on Synthetic Biology

"South Africa intends to achieve international recognition in synthetic biology within the next five years."[40] CSIR annual report 2007/08.

The Department of Science and Technology (DST) has been involved in the field of synthetic biology since at least 2005, when Biopad, a biotechnology investment trust it funds, joined the private South African genomics company Inqaba Biotech as a shareholder and strategic partner. As part of an infrastructure investment by Biopad in 2007, Inqaba purchased genome sequencing equipment from pharmaceutical giant Roche, with the intention of offering sequencing services to customers in Africa.[41] The Council for Scientific and Industrial Research (CSIR) 'joined the ranks of pioneers' by establishing a synthetic biology research capacity, a move that would hopefully position South Africa as a 'world leader' in the field. The main focus areas at the CSIR are energy transduction, molecular biomaterials and gene expression and biophysics.[42]

Despite these early developments, by around 2007, it was still generally accepted by the key role-players that whatever research was taking place involving synthetic biology was still being done in isolation, with little cross collaboration in the field.[43] Under its emerging research areas sub programme, the DST had finalised a strategic plan for the fledgling discipline in October 2007.[44] This was to be consolidated into a national strategy that was expected to be up and running by early 2010. It would include: the finalization of a national strategy by August 2009; the establishment of research centres to be completed by November of the same year; a minimum of three fundamental research projects started; and human capital development programmes put in place, with a minimum of 10 students receiving training by 2010.[45] The core team that have been involved in the development of the strategy included personnel from the DST, the CSIR the Medical Research Council (MRC), and the University of the North West.[46]

However, after the draft strategy was presented to the DST Executive Committee (EXCo) last year, it was decided that a more multidisciplinary approach was required, including engagement with experts from fields such as structural, systems and synthetic biology, and functional genomics. Discussions at the DST's EXCo meetings have been ongoing, and preliminary findings are expected to be presented towards the end of 2010.[47] Attempts have been made to access the EXCo meeting minutes, though unfortunately at the time of writing, our request was still being processed. Sadly, this lack of transparency and public participation has been a common feature in public policy in South Africa, particularly with regard to biotechnology.

First Generation Agrofuels and South Africa's National Biofuels Strategy

A useful point of reference for a nuanced reading of the push for a 'bioeconomy' in South Africa would be the controversial National Biofuels Strategy, published in December 2007. The pressing need to 'decarbonise' the global economy and avert catastrophic climate change has presented the world's biggest polluters with an excellent opportunity to re-market themselves as the harbingers of this brave new world. South Africa, eager to cement its place at the international table post 1994, took its first steps into the controversial field of agrofuels in 2005, when it commissioned an interdepartmental Biofuels task team to develop a 'draft industrial biofuels strategy'. The initial strategy proposed that biofuels could account for 3.4% of South Africa's liquid fuel needs by 2013, and that maize and sugarcane would make a substantial contribution to this.[48]

The United States meanwhile, in moves designed to reduce its insatiable appetite for oil and dependence on politically sensitive regions, had taken up its own agrofuels policy with a vengeance, with devastating consequences for maize consumers in Mexico, leading to the so called 'tortilla riots' in early 2007. Further calls from civil society and several prominent policymakers, including SA reserve bank governor at the time, Tito Mboweni, as to the inherent risks to food security of growing food for fuel caused a turnaround in the South African agrofuels strategy. To the dismay of the agribusiness lobby who had been anticipating a windfall, the final biofuels industrial strategy published in December 2007 prohibited the use of maize (and jatropha) as an agrofuel feedstock.

The main goal of the final strategy is to bring land labelled as 'under-utilised', mainly in the former homeland areas, into mainstream agricultural production. The large monoculture plantations required to feed the huge proposed processing plants are an anathema to the current land use practices of 'under-utilised' land, which in fact support a complex social and economic structure that is not recorded in formal economic statistics. The current strategy is up for re-appraisal in 2013. It remains to be seen whether second generation agrofuels, and indeed synthetic biology, will play a more significant role in the future. In the short term this may well depend on public sector support, something that the government in South Africa is keen, in theory at least, to lend.

Second Generation Biofuels and Stellenbosch Biomass Technologies

On 5 July 2010, a new company, Stellenbosch Biomass Technologies (SBMT), made its appearance on the South African bio-energy scene. At its launch, SBMT announced that it had acquired exclusive rights to adapt and commercialise the latest cellulose conversion technology developed by US company, Mascoma Corporation, for the production of biofuels.[49]

SBMT aims to establish a commercial bioethanol production plant by 2014, producing 40-million litres of ethanol from cellulosic material in South Africa. Stellenbosch University and the South African National Energy Research Institute are SBMT's local partners.

Cellulosic ethanol is a forerunner in the production of second-generation biofuels from non-food lignocellulosic plant sources, including grasses, wood and agricultural residue such as sugar cane bagasse.

The South African biofuels breakthrough is being touted as a vehicle to reduce greenhouse-gas emissions and move Southern Africa towards a greener economy, and promote socio economic development, rural agriculture, economic diversification and job creation.[50]

The company aims to apply Mascoma's consolidated bioprocessing technology to provide low cost, high efficiency technology that can ensure substantial savings in capital and operational expenses in the production of cellulosic ethanol. The technology has already been piloted in Rome and is now ready to be introduced to South Africa. SBMT's work in South Africa is currently at the lab scale yeast development stage, such as enzyme production and hardening, as well as improving the Mascoma technology integration with local feedstocks, such as paper sludge, sugar cane, sorghum and triticale.

SBMT is currently seeking public and private investment partners. The feedstock selection will largely depend on who the investment partners are likely to be. Once the necessary investment is secured, the company hopes to set up its first demonstration scale plant within the next two years, to show off the commercial viability of the venture. Adapting the technology to local feedstock will need substantial funding: R&D funding of about R20m –R30 m over a period of three to four years and demonstrating the technology at pilot scale will require an estimated R70m-90m. Commercialisation, with a production capacity of about 400ML per year, will require an estimated R70m-R90m.

SMBT is relying on good government incentives and policy to promote the bioenergy industry when South Africa's Industrial Biofuel Policy is reviewed in 2013.

Big Dreams for Africa

Professor Emile Van Zyl, a highly regarded and respected academic who was awarded the Senior Chair of Energy Research at the University of Stellenbosch in 2007, is the founder of SBMT.

According to Professor Van Zyl, Africa could replace its transportation fossil fuel demands with renewable biofuel and still be a net exporter of biofuels. Van Zyl paints a rosy picture: "If Africa were to join the renewable energy race and realize its potential, it could not only reduce the continent's dependency on oil-bringing foreign exchange savings and much-needed political stability - but also improve food and energy security, support the industrial sector, reduce green house gases and promote land restoration. It would also alleviate poverty by improving access to energy in rural areas, booking local agriculture production, giving farmers access to additional markets and revenues and generating jobs." [51]

Mascoma Corporation

Mascoma Corporation is rated as one of the top 10 most innovative companies in the bioenergy sector. Mascoma's investors include General Motors and Marathan Oil. Mascoma is part of an industry wide race to make ethanol from non-food sources, such as wood chips and grasses, at a commercial scale.

Its consolidated bioprocessing method converts non-food biomass feedstocks to cellulosic ethanol using a proprietory process that eliminates the need for costly enzymes and additives.[52] Mascoma's website described consolidated bioprocessing as using yeast and bacteria that are engineered to produce large quantities of the enzymes necessary to break down the cellulose and ferment the resulting sugars into ethanol.[53] Mascoma is focussed on streamlining a multi-step cellulose conversion process by genetically engineering a microorganism that can metabolize cellulose and produce ethanol in a single step.[54]

According to General Motor's director of Global Energy Systems, Andreas Lippert, who also sits on Mascoma's board of directors, industrial scale cellulosic ethanol will begin flowing around 2011 and advanced agrofuels are set to replace corn ethanol by 2015.

On 1st September 2010, Mascoma announced that it had acquired SunOpta BioProcess Inc (SBI) biofuel division. SunOpta is headquartered in Ontario, Canada. The acquisition brings together the fibre preparation and pre-treatment technologies of SBI and the consolidated bioprocessing technology of Mascoma, for converting non-food cellulose (wood chips, energy crops and organic solid waste) into ethanol and high value co-products.[55] According to SBMT's Professor Van Zyl, this merger could inevitably strengthen the partnerships SMBT can rely on when rolling out the technology in Southern Africa.[56]

According to the Mascoma's press release,[57] the acquisition has brought about a company well positioned to achieve the industry's objective of low-cost, sustainable production of transportation fuels from non-food biomass. By integrating SBI's state-of-the-art fibre preparation and pre-treatment technology (known as the upstream component of cellulosic ethanol production) with Mascoma's consolidated bioprocessing technology (known as the downstream component of cellulosic ethanol production), the new company brings together the two core technical components essential for the effective conversion of non-food cellulose into ethanol and high value co-products. In addition, the combined entity will have the leading intellectual property position in the cellulosic biofuels sector, extensively covering both pre-treatment and consolidated bioprocessing technologies.

The GE and Synbio Components

We have been able to surmise the following with regard to the technology being used from personal communication exchanged with Professor Van Zyl and from our own research: Mascoma is using both genetic engineering and synthetic biology. Mascoma's work has concentrated on genetically engineering yeast with several genes to break down cellulose. Such genes are either used in their original form, as they are found in nature, or they are re-designed synthetically to work better in a yeast. By rewriting the code in synthetic DNA they are able to choose codons that

work better for the host cell (e.g. that are more readily recognised by yeast,) while still producing the same amino acid as the original sequence. It appears that Mascoma has engineered a number of sequences from different sources (and altered versions) together into a longer sequence and then this has been inserted into the yeast as a metabolic pathway. In other words, they have built a long piece of synthetic DNA that encodes the genes needed and genetically engineered it into yeast.

Concerns

We have posed a number of further questions about the proposed project to Professor Van Zyl but have not been able to ascertain the answers to them yet. These include the following:

Whether Mascoma's strains are housed in South Africa, and if so, under what containment conditions? In this regard, we are concerned that a microbe that can efficiently digest cellulose as a sugar source might have a significant environmental advantage if it escapes into the wild.

What the plans are to set up biorefinery facilities? Where such facilities may be established, within what time frames and using what biosafety controls?

What feedstock SBMT may be looking at for African production of cellulosic ethanol (grasses? African hardwoods? agricultural residue?) and what sourcing plans have already been made, if any, in this regard?

These questions have been posed in the light of the concerns already highlighted by groups working closely on the issue for some years. Spearheaded by the ETC group, in 2007, 38 civil society organizations sent an open letter to the synthetic biology community, expressing concern over the absence of societal debate concerning the socio-economic, health and environmental implications and the absence of regulatory oversight.[58] Indeed, the ETC Group has in several of its own publications raised a number of questions and concerns. They point to the enormous complexities involved in the creation of novel life forms and ask pertinent questions: how can accidental release of synthetic life forms into the environment be prevented or the effects of their intentional release be evaluated? How will research be regulated? Should we engineer life in this way when the environmental and human safety questions are so vast?[59] Who should decide? Will all plant material eventually become feedstock for fuel?[60]

The ETC group points out that advocates of synthetic biology assume that unlimited supplies of cellulose biomass will be available. They ask the questions, can massive quantities of biomass be harvested sustainably without eroding/degrading soils, destroying biodiversity, increasing food insecurity and displacing marginalised peoples? Can synthetic microbes work predictably? Can they safely be contained and controlled?[61]

Implications for Africa

As far as we know, there are no national, regional nor international biosafety rules in place to regulate synthetic biology in the world today, despite its ability to have far reaching implications for humanity and the natural world. Nevertheless, the issue has been discussed at international environmental fora, including the Convention on Biological Diversity. At the 14th meeting of the Subsidiary Body on Scientific, Technical and Technological Advice (SBSSTA 14), synthetic biology was specifically debated, in particular, the need for a global moratorium. The Report of the Fourteenth Meeting of the Subsidiary Body on Scientific, Technical and Technological Advice[62] contains several references to synthetic biology, in square brackets, including a de facto moratorium on the release of synthetic life forms.[63] However, square brackets means that it has not achieved unanimous agreement and will be further discussed at the 10th Ministerial meeting of the UN Convention's Conference of the Parties (COP 10) that will take place in Nagoya Japan, 18-29 October 2010. Although the issue is on the international agenda, it is doubtful whether the proposed moratorium will survive in the face of the huge financial and strategic interests at stake. At the very least, those concerned with the implications of this technology on society and the environment may be able to obtain some form of rules and procedures to govern the use of the technology. Even this route will be highly contested and bitterly fought by those set to benefit the most.

The impact of synthetic biology on the African continent would require extensive public debate in an open and transparent manner. Valuable lessons must be heeded from prior experiences where exogenous technology has been imposed on the continent, without there being enough public engagement and most certainly, adequate local capacity to regulate it. For the most appropriate example in this instance one need look no further than what has been happening with biotechnology using genetic engineeting techniques in Africa.

Currently, only three countries on the African continent commercially produce genetically modified crops: Burkina Faso, Egypt and South Africa.[64] This has not stopped a deluge of 'capacity building' initiatives, funded in the main by the biotech industry and their PR shock troops at organisations such as USAID and the Gates Foundation, throughout the continent. While ostensibly the modus operandi of these initiatives is to help Africa to feed itself, in the absence of domestic biotechnology expertise it also conveniently provides the opportunity for the shaping of the biosafety discourse to suit the technology's developers and others that stand to benefit from the use of the technology.[65] Further, the gains made at the multilateral level for the safe governance of biotechnology, through the Cartagena Protocol on Biosafety, are being undermined by efforts to 'harmonise' biosafety legislation across Africa through its regional economic communities (RECs). For example, from a recent draft GMO policy document from the Common Market for Eastern and Southern Africa (COMESA), it was patently clear that the architects of the policy had close ties to an industry that would benefit enormously should such policies come to fruition.[66]

Conclusion

Synthetic biology offers yet more currency to the hubris that man truly is 'master' of his environment. Yet this mastery comes with a heavy responsibility. The potential to produce almost limitless amounts of cheap medicine and clean fuels must be tempered by the fact that

the technology is still in its infancy, and that its real consequences cannot yet be predicted with any great certainty. As is the case with food, abundance alone does not guarantee availability. Will the provision of anti-malarial drugs be more effective in a centralised system, where a few companies exert exclusive control, or in a more nuanced fashion, where locally sourced material can be quickly and efficiently distributed to those in most need?

To date the real money in synthetic biology appears to be following its energy potential, with the world's largest oil companies having already sunk hundreds of millions of dollars into the field. South Africa appears to be banking on the technology as a means to cement its place inside this global event. This unbridled enthusiasm, however, has taken place largely beyond public scrutiny or awareness of what is really and truly at stake.

References

1 **Synthetic biology can help extend anti-malarial drug effectiveness**. Science Daily. 11th March 2009. http://www.sciencedaily.com/releases/2009/03/090306172619.htm (accessed 13/09/2010)
2 European Commission (2010). **The Ethics of synthetic biology**. Luxembourg: Publications office of the European Union.
3 Ibid.
4 **Synthetics: the ethics of Synthetic biology**. IDEA League Summerschool, August 2007, The Netherlands. http://www.ethicsandtechnology.eu/images/uploads/Ethics_of_synthetic_biology.pdf (accessed 14/09/2010)
5 European Commission (2010). **The Ethics of synthetic biology**. Luxembourg: Publications office of the European Union.
6 The Synthetic biology project was established as an initiative of the Woodrow Wilson International Centre for Scholars to 'foster informed public and policy discourse concerning the advancement of synthetic biology' http://www.synbioproject.org/about/ (accessed 23/08/2010)
7 Synthetic Biology Project (2010). **Trends in synthetic biology research funding in the United States and Europe**. Woodrow Wilson International Centre for Scholars. http://www.synbioproject.org/process/assets/files/6420/final_synbio_funding_web2.pdf (accessed 2/08/2010)
8 Ibid.
9 http://www.synbioproject.org/process/assets/files/6420/final_synbio_funding_web2.pdf (accessed 2/08/2010)
10 http://www.genengnews.com/analysis-and-insight/synthetic-biology-the-devil-is-in-the-financial-details/77899331/ (accessed 22/08/2010)
11 http://berkeley.edu/news/media/releases/2007/02/01_ebi.shtml (accessed 23/08/2010)
12 http://www.genengnews.com/analysis-and-insight/synthetic-biology-the-devil-is-in-the-financial-details/77899331/
13 http://www.physorg.com/news198146090.html (accessed 17/08/2010)
14 **Extreme genetic engineering**. (2007) ETC Group.
15 WHO Global malaria Programme (2010). **Good Procurement practices for artemisinin-based antimalarial medicines**. World Health Organisation. http://whqlibdoc.who.int/publications/2010/9789241598927_eng.pdf (accessed 17/08/2010)
16 Dalrymple, D. (2006) **Artemisia, agriculture and malaria in Africa: The interplay of tradition, science and public policy**. http://www.rollbackmalaria.org/docs/mmss/ArtemisiaAgricultureMalaria.pdf (accessed 15/09/2010)
17 Rezelman, D. & Goris, H. (2008) **The role of herbal products containing Artemisia annua in malaria treatment. A proposal for further research**. http://tinyurl.com/3yabx6f (accessed 14/09/2010)
18 **Drug resistance could set back malaria control success**. WHO Media Centre. 25th February 2009. http://www.who.int/mediacentre/news/releases/2009/malaria_drug_resistance_20090225/en/index.html
19 Heemskerk, Schallig & de Steenhuisjen Piters (2006). **The World of Artemisia in 44 questions**. Royal Tropical Institute. http://www.kit.nl/smartsite.shtml?id=5564 (accessed 18/08/2010)
20 **World Malaria Day 2010: Africa update**. Roll Back Malaria. http://www.rbm.who.int/ProgressImpactSeries/docs/wmd2010report-en.pdf (accessed 15/09/2010)
21 Ibid.
22 Ibid.
23 Ibid.
24 http://www.who.int/malaria/medicines.pdf (accessed 27/09/2010)
25 http://money.cnn.com/magazines/fortune/global500/2010/performers/companies/profits/ (accessed 19/08/2010)
26 Rezelman, D. & Goris, H. (2008) **The role of herbal products containing Artemisia annua in malaria treatment. A proposal for further research**. http://tinyurl.com/3yabx6f (accessed 14/09/2010)
27 **Small farmers cash in on Artemisinin production**. All Africa. 21st January 2009. http://allaf rica.com/stories/200901210671.html (accessed 14/09/2010)
28 Heemskerk, Schallig & de Steenhuisjen Piters (2006).
29 Dalrymple, D. (2006) **Artemisia, agriculture and malaria in Africa: The interplay of tradition, science and public policy**. http://www.rollbackmalaria.org/docs/mmss/ArtemisiaAgricultureMalaria.pdf (accessed 15/09/2010)
30 **Investing in the bottom of the pyramid**. Steenkamp, D & Thomas, W. Leader. 1st July 2010. http://www.leader.co.za/article.aspx?s=1&f=1&a=2079 (accessed 14/09/2010)
31 **Small farmers cash in on Artemisinin production**. All Africa. 21st January 2009. http://allaf rica.com/stories/200901210671.html (accessed 14/09/2010)
32 **Uganda in double blow against Malaria – with local drugs**. Wakabi, M. The East African. April 5th 2010. http://www.theeastafrican.co.ke/news/Uganda%20in%20double%20blow%20against%20malaria%20with%20local%20drugs/-/2558/892496/-/143mf9t/-/index.html (accessed 15/09/2010)
33 **Demand for malaria drug soars**. Nature news. Richard Van Noorden. 3rd August 2010. http://www.nature.com/news/2010/100803/full/466672a.html (accessed 16/09/2010)
34 Ibid.
35 Green Economy Summit 18 – 20 May 2010. **Towards a resource efficient, low carbon and pro-employment growth path**. Departments of: Economic Development; Environmental Affairs; Science and Technology; Trade and Industry. http://www.green-economics.info/wp-content/uploads/2010/05/SummitDiscussionDocument.pdf (accessed 14/09/2010)
36 Ibid.
37 Asogan Moodaly, Industry specialist, alternative energy, IDC. Personal correspondence, 15/09/2010.
38 Thembakazi Mali, Senior manager, Clean Energy Solutions, SANERI. Personal correspondence. 13/09/2010
39 Asogan Moodaly, Industry specialist, alternative energy, IDC. Personal correspondence, 15/09/2010.
40 **CSIR Annual Report 2008/09**. Council for Scientific and Industrial Research. http://www.csir.co.za/publications/pdfs/12345.pdf (accessed 13/09/2010)
41 http://www.inqababiotec.co.za/index.php/about-us (accessed 24/08/2010)
42 Refilwe Ngoato, manager, office of technology transfer, University of Pretoria. (formerly Deputy director: Emerging research areas at the DST). Personal correspondence. 13/09/2010

43 Sparrow, R. **Synthetic Biology: Harnessing biological molecular machinery**. SA – CZ workshop presentation 16th January, 2007. Council for Scientific and Industrial Research. http://www.esastap.org.za/esastap/pdfs/present_czwks_sparrow_jan2007.pdf (accessed 10/09/2010)
44 http://www.info.gov.za/view/DownloadFileAction?id=90162 (accessed 24/08/2010)
45 **Corporate Strategy 2009/10**. Department of Science and Technology. http://www.dst.gov.za/publications-policies/strategies-reports/DST%20CORPORATE%20STRATEGY%202009-10.pdf/view (accessed 23/08/2010)
46 Refilwe Ngoato, manager, office of technology transfer, University of Pretoria. (formerly Deputy director: Emerging research areas at the DST) Personal correspondence. 13/09/2010
47 Dr. S Bareetseng, biotechnology unit, Department of Science and Technology. Personal Communication. 01/09/2010.
48 Agrofuels paper.
49 See for example, New Biofuel project launched 8 July 2010 http://www.bioenergypro.com/africa/new-biofuel-project-launched-1072010/
50 New Biofuels entity targets commercial production by 2010, 16 July 2010 http://www.engineeringnews.co.za/article/biofuels-to-flourish-by-2014-2010-07-16. (accessed 4 September 2010)
51 E, Van Zyl. Maximising Africa's bioenergy potential 1 September 2010 http://www.scidev.net/en/opinions/maximising-africa-s-bioenergy-potential.html (accessed 2 September 2010)
52 New Biofuel Company Brings US Tech to South Africa. 5 July 2010 http://ae-africa.com/read_article.php?NID=2167 accessed 4 September 2010
53 http://www.mascoma.com/pages/sub_cellethanol04.php
54 Inside Mascoma's ethanol-making lab (accessed 8 September 2010) http://news.cnet.com/8301-11128_3-10047209-54.html (accessed 4 September 2010)
55 Mascoma Acquires SunOpta BioProcess Inc 1 September 2010. http://www.mascoma.com/download/Mascoma%20SBI%20September%201%202010.pdf (accessed 4 September 2010)
56 Personal communication, Professor Emile Van Zyl, 6 September 2010.
57 Mascoma Acquires SunOpta BioProcess Inc 1 September 2010. http://www.mascoma.com/download/Mascoma%20SBI%20September%201%202010.pdf (accessed 4 September 2010)
58 See, http://www.etcgroup.org/en/node/11 (accessed 13 September 2010)
59 See in this regard, Second generation Biofuels: An unproven Future technology with unknown risks Helena Paul and Almuth Ernsting http://www.biofuelwatch.org.uk/inf_paper_2g-bfs.pdf accessed 4 September 2010
60 See for example, ETC Group Communique Peak Soil+Peak Oil=Peak Spoils http://www.etcgroup.org/upload/publication/pdf_file/ETCComm_peakspoils_Dec07_5.pdf (accessed 7 September 2010). See also, ETG Group. 2007. Extreme Genetic Engineering An Introduction to Synthetic Biology http://www.etcgroup.org/upload/publication/602/01/synbioreportweb.pdf (accessed 7 September 2010)
61 Commodifying Nature's Last Straw? Extreme Genetic Engineering and the Post-Petroleum Sugar Economy ETC Group October 2008 http://www.etcgroup.org/en/node/703 (accessed 4 September 2010)
62 **UNEP/CBD/COP/10/3)** http://www.cbd.int/doc/?meeting=sbstta-14 (**accessed 12 September 2010**)
63 The precision language on synthetic biology in the biofuels reads as follows1: [14. Decides to convene an ad-hoc technical expert group on synthetic biotechnologies and other new technologies that are used or projected to be used in the next generation of biofuels to assess their impact on biodiversity and related livelihoods.]
[16. Urges Parties and other governments, in accordance with the precautionary approach, to ensure that living organisms produced by synthetic biology are not released into the environment until there is an adequate scientific basis on which to justify such activities and due consideration of the associated risks for the environment and biodiversity, and the associated socio-economic risks, are considered]
(2) This paragraph is in square brackets due to (i) financial implications, and (ii) a lack of consensus from the meeting on the need for the ad-hoc technical expert group and its mandate.
In the paper on new and emerging issues (L.14), the decision2:
Invites parties, other governments and relevant organizations to submit information on synthetic biotechnology and geoengineering in accordance with the procedure of decision 9-29, for consideration of SBSTTA, while applying the precautionary approach on field releases of synthetic life, cells or genomes into the environment.
64 James, C (2009). **Global Status of Commercialised Biotech/GM Crops: 2009**. ISAAA Brief No. 41. ISAAA: Ithaca, NY.
65 GRAIN Briefing (2004). **USAID: Making the World Hungry for GM Crops**.
66 African Centre for Biosafety (2010). **Comments on COMESA's draft policy on GMOs**. ACB Briefing Paper No. 17. http://www.biosafetyafrica.net/index.html/images/stories/dmdocuments/COMESA%20Comments-2010.pdf (accessed 27/09/2010)