5 JOINT RESEARCH PROJECTS
CLEAN TECHNOLOGY

Arabidopsis plants

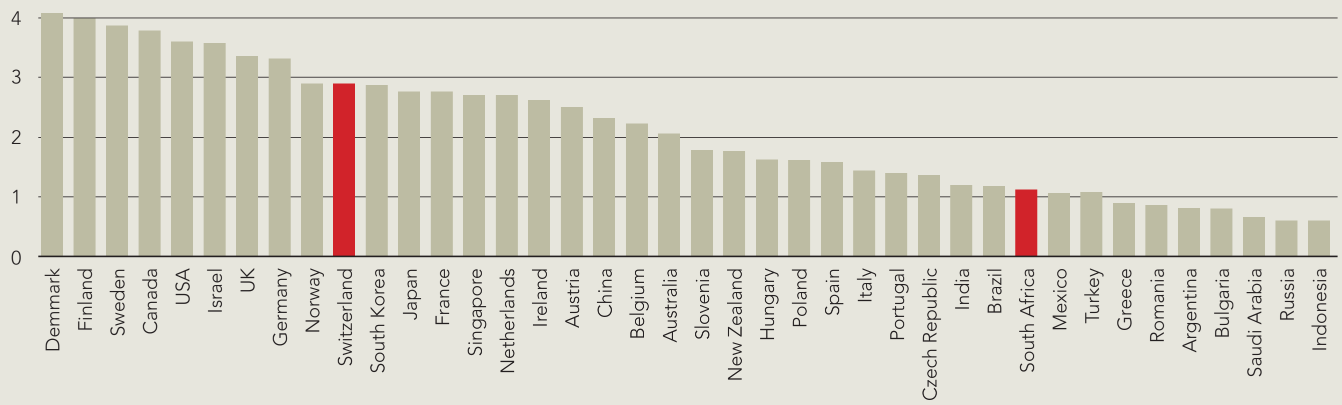
Technological progress is often associated with human action, which leads to pollution and therefore destruction. Fortunately this is not always the case, since clean and green technologies are specifically aimed at maintaining and preserving natural ecosystems by reducing the detrimental effects of human activity on the environment.

The topic of clean and green technologies was introduced into the SSAJRP Phase II call of the joint research projects that was launched in 2013, acknowledging that international collaboration is key in finding answers to global stressors on the environment. These stressors manifest through climate change, increasing environmental pollution, or the depletion of natural resources. Globally, there is an upward trend in the scientific discovery of green technologies that aim to prevent, reduce and/or reverse the negative impacts of human activity on the environment (Panwani, 2018).

Clean technology has the added benefit of economic growth and job creation to maintain and/or improve living standards. For example, the Swiss cleantech sector employs 5,5% of the total workforce and there has been a 25% increase in cleantech jobs over the last five years, adding 4,2% to the Swiss GDP. The Swiss 2017 Cleantech report put Swiss research and development in clean technologies at over $500 million in 2014, with the bulk of the funding from the private sector. The Federal Council issued the Swiss Cleantech Masterplan to encourage innovation in clean technologies in the private sector.

South Africa has made great strides towards a green economy with a focus on clean technology, spurred by its geographical advantage of enormous untapped renewable energy supplies. Notable is the Global Cleantech Innovation Programme (GCIP) for SMEs to promote clean technology innovation. The GCIP is implemented with the support of the Global Environmental

Cleantech Countries Innovation Index, (GCII, 2017)



Facility (GEF), the United Nations Industrial Development Organisation (UNIDO), and the TIA. An inventory of the South African Green Economy was undertaken in 2017, which stated that the robust vision of South Africa for a greener economy is underpinned by a total of 32 sub-frameworks, strategies, policies or Acts to achieve environmental sustainability (Dept of Environmental Affairs, 2017).

The Global Cleantech Innovation Index (GCII) 2017 was established to identify country-based success factors and barriers for entrepreneurial companies in developing sustainable solutions.

The GCII 2017 reiterated the 2014 findings that there are three pillars that facilitate cleantech innovations and uptake: addressing growing demand for renewable energy and other technologies; connecting startups with multiple channels to increase their succes rates; and international engagement across the cleantech ecosystem. Switzerland came in at number 10 and South Africa at number 31 out of 40 countries (see table above). The score of each country is established by looking at the average between inputs to innovation and outputs to innovation as being the country's ability to commercialise innovation (Global Cleantech Innovation Index, 2017).

OUTCOME OF THE CLEAN TECHNOLOGY DOMAIN: ECONOMIC VALUE

Many of the projects in this domain revealed robust innovation potential, which bodes well for the highly relevant Cleantech environment.

INNOVATIONS	TOTALS	%
Impact innovation achieved	4	20
Projects have innovation potential	7	35
Innovation potential beyond projects	5	25

INDUSTRY LINKAGES	TOTALS	%
Research support from industry	3	15
Industry Funding	2	10
Industry partner SA	2	10
Industry partner CH	3	15
Industry Interested	2	10
SA Industry funds received	0	0
Swiss Industry funds received	0	0

INTELLECTUAL PROPERTY	TOTALS	%
Joint IP	1	5
Swiss IP	0	0
SA IP	2	10
Swiss IP Protected	2	10
SA IP Protected	0	0
Joint IP Projected	0	0

Joint Research Projects

Outcomes of the Clean Technology Domain (10 projects)

RESEARCH DOMAIN: CLEAN TECHNOLOGY

TOTAL FUNDS, INCLUDING THIRD-PARTY FUNDING:
CHF 3 276 834 ZAR 49 504 062

UNIVERSITY PARTNERS

Swiss Federal Institute of Technology Zurich
Swiss Federal Institute of Technology in Lausanne
University of Lausanne
University of Zurich
University of Bern
Global Indian International School
Swiss Federal Laboratory for Materials Testing and Research
Swiss Federal Institute for Forest, Snow and Landscape Research

Stellenbosch University
University of Pretoria
University of the Witwatersrand
University of Cape Town
University of the Free State
iThemba Labs / UNISA

PHASE		
PHASE I	2008 – 2012	No projects
SEED FUNDING PHASE	2012 – 2013	1 project
PHASE II	2013 – 2016	7 projects
PHASE III	2017 – 2020	2 projects

Phase III projects have not as yet reached full-scale scientific outputs.

BENEFICIATION

ECONOMIC
- **10%** Mineral beneficiation
- **50%** Technology development
- **30%** Economic platform
- **40%** Africa economy
- **10%** Knowledge economy

GLOBAL CHALLENGES
- **80%** Climate change
- **30%** Energy storage
- **40%** Mitigation

NATIONAL OBJECTIVES
- **20%** Policy beneficiation
- **50%** National strategies in South Africa
- **70%** HCD of historically disadvantaged
- **60%** Gender balance redress in SER

PUBLICATIONS

14 24
26
64 TOTAL

BOOK CONTRIBUTIONS

1
4
5 TOTAL

POSTGRADUATES

6	MSc	21
13	PhD	22
10	Postdoc	10

82 TOTAL

HDI

5	MSc	4
5	PhD	5
1	Postdoc	2

22 TOTAL

EXCHANGES

24 TO SWITZERLAND
47
23 TO SOUTH AFRICA

CONFERENCES & PRESENTATIONS

13 14
46
73

WORKSHOPS

9 9

CHALLENGES

IN THE FIELD
- **10%** Difficult to reach study environment
- **20%** Exchange of materials and research samples

INNOVATION
- **10%** Joint IP
- **10%** Establishment of a NDA

GENERAL
- **20%** Immigration rules in CH
- **20%** Different university procedures

FUNDING
- **10%** Decrease in ZAR Value = decrease in project funds
- **20%** Inadequate funding for equipment
- **10%** Lack of follow-up funding
- **20%** High flight costs to Europe
- **20%** Support for HCD and scholarships
- **30%** Experienced limited challenges

APPRECIATION

- COLLABORATION: **40%** Alignment of PIs objectives **90%** Joint knowledge **50%** Joint publication **70%** Joint exchanges **20%** Workshops
- HUMAN CAPITAL DEVELOPMENT: **50%** Appreciate Swiss contribution **90%** HCD in general **10%** Could demonstrate South Africa research excellence
- RESEARCH FACILITIES: **30%** Opportunity for applied research **20%** World-class infrastructure in CH **10%** Access to unique research environment globally
- GENERAL APPRECIATION: **10%** Leverage funds from other grants **20%** Appreciation of project funding

RESEARCH LINKAGES AND BENEFICIATION

INTERNATIONAL

30%	NORTH AMERICA
30%	BRICS COUNTRIES
50%	EU COUNTRIES
40%	AFRICAN COUNTRIES

UNIVERSITIES AND NETWORKS

20%	SOUTH AFRICAN UNIVERSITIES
10%	SWISS UNIVERSITIES
30%	CONTACTS AND NETWORKS ESTABLISHED

BENEFITS OF LINKAGES

60%	NEW RESEARCH TOPIC
10%	EXTENT COLLABORATION WITH SWISS AND SOUTH AFRICAN PARTNERS
40%	GOVERNMENT INTEREST IN PROJECT

SWITZERLAND GLOBAL JOINT
SOUTH AFRICA TOTALS

ABB – A Swiss Private Company in the 4th Industrial Revolution

ABB Ability™ consolidates and expands all of its technologies to connect customers to the Industrial Internet of Things.

With the commercial launch of more than 210 solutions and services, ABB is unlocking value for customers in the Fourth Industrial Revolution. By combining ABB's deep domain expertise with network connectivity and the latest digital technologies and innovations, ABB Ability™ creates powerful solutions and services that solve real business problems and produce tangible business opportunities.

ABB Ability helps customers in utilities, industry, transport and infrastructure develop new processes and advance existing ones by providing insights and optimising planning and controls for real-time operations. The results can then be fed into control systems to improve key metrics such as factory uptime, speed and yield.

The offering builds on ABB's pioneering technology and more than four decades of industrial digital leadership and will enhance customers' ability to innovate and compete in the emerging digital-industrial marketplace.
The list of innovative and versatile solutions associated with ABB Ability™ includes such offerings as ABB Ability™ AssetInsight, ABB Ability™ Ellipse® Enterprise Asset Management software, and the ABB Ability Data Center Automation infrastructure management software. It will leverage the power of the digital revolution by enabling reduced maintenance costs, longer asset life, more efficient operations, reduced environmental impacts and improved worker safety.

ABB Ability's next-generation digital solutions and services are being developed and built on Microsoft's leading Azure cloud platform, based on a strategic partnership with the software company.

ABB Ability™ enables users to seize the opportunities presented by the Internet of Things. With the help of new ABB digital services and technologies, users can upgrade their existing systems to boost productivity through reduced downtime, greater efficiency and higher yields. The company's solutions and services tap into the benefits derived from rapidly expanding information and data flows.

The Internet of Things, Services and People expresses ABB's belief that human expertise will remain at the core of this new, more connected and digital world. Connected devices will enable new service models. Despite extensive automation, we will continue to rely on human collaboration and expertise. ABB's capacity to connect all that information and analysis directly to the control room, using it to make instantaneous operational decisions, is what makes ABB Ability™ truly powerful and unique.

ABB Ability™ is going to keep evolving and expanding to serve needs and solve new problems that our customers face. The fact that it can be constantly adapted for new applications is exactly why it is so important – both to ABB and to our customers around the world.

In South Africa, ABB signed a research, development and innovation partnership agreement with the University of Witwatersrand (Wits) with the view to support and tap into digital innovation to augment its own research, development and engineering work. This partnership with the Wits digital innovation hub, Tshimologong Precint, led by Professor Barry Dwolatzky, aims to support students, entrepreneurs and innovators with the view to leveraging global supply chains.

ABB (ABBN: SIX Swiss Ex) is a pioneering technology leader with a comprehensive offering for digital industries. With a history of innovation spanning more than 130 years, ABB is today a leader in digital industries with four customer-focused, globally leading businesses: Electrification, Industrial Automation, Motion, and Robotics & Discrete Automation, supported by its common ABB Ability™ digital platform. ABB's market leading Power Grids business will be divested to Hitachi in 2020. ABB operates in more than 100 countries with about 147 000 employees.

www.abb.com

Demonstrating the applications of Vanadium dioxide smart nano-scale material in the terahertz photonics spectral regime

UNIVERSITY PARTNERS
University of Bern
Professor Thomas Feurer
iThembaLABS, National Research Foundation and University of South Africa (UNISA)
Professor Malik Maaza

This project rests on the properties of Vanadium dioxide that is part of the smart-material family. Vanadium dioxide is gaining exponential interest in the research and development community as a promising technological application; it is considered as a promising material for oxide electronics. Complex oxide materials offer many characteristics that cannot be achieved with current electronics based on silicon.

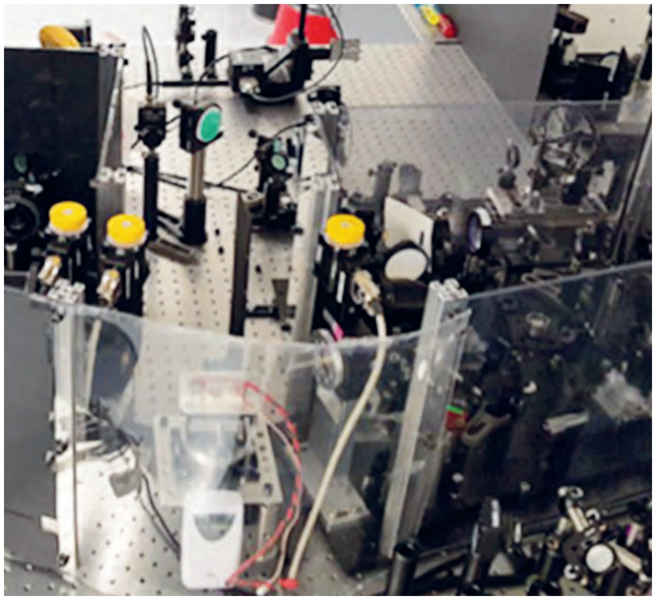
The Swiss-South African research proposal aimed to map for the first time the thermal variation of the carrier's density and its dynamics in nano-scaled V02 1-D type nano-rods by time domain terahertz spectroscopy (TDTS) that probes inter-molecular interactions within solid materials. It also intended to demonstrate the feasibility of a femtosecond photo-induced optoelectronic nano-gating. THz-TDS, is a spectroscopic technique for determining the properties of a sample probed by short pulses of terahertz radiation.

The joint research proposal was initially between iThemba LABS-UNISA and the University of Bern and, subsequently, collaboration with Empa through a Swiss Scholarship grant (ESKAS). During a visit to Switzerland, the project partners in collaboration with Empa, discovered additional technological application potential beyond the joint research project with a focus in the nanotechnology economy: upscaling of green biosynthesised oxides.

Although the objective to demonstrate the application of Vanadium dioxide smart nano-scaled material in the terahertz photonics spectral regime was reached to a certain extent, the device aspect is still to be finalised.

If the validation of the targeted devices/technology were finalised, there would be potential for mineral beneficiation in terms of Vanadium mineral usage as South Africa has the second largest Vanadium deposits globally.

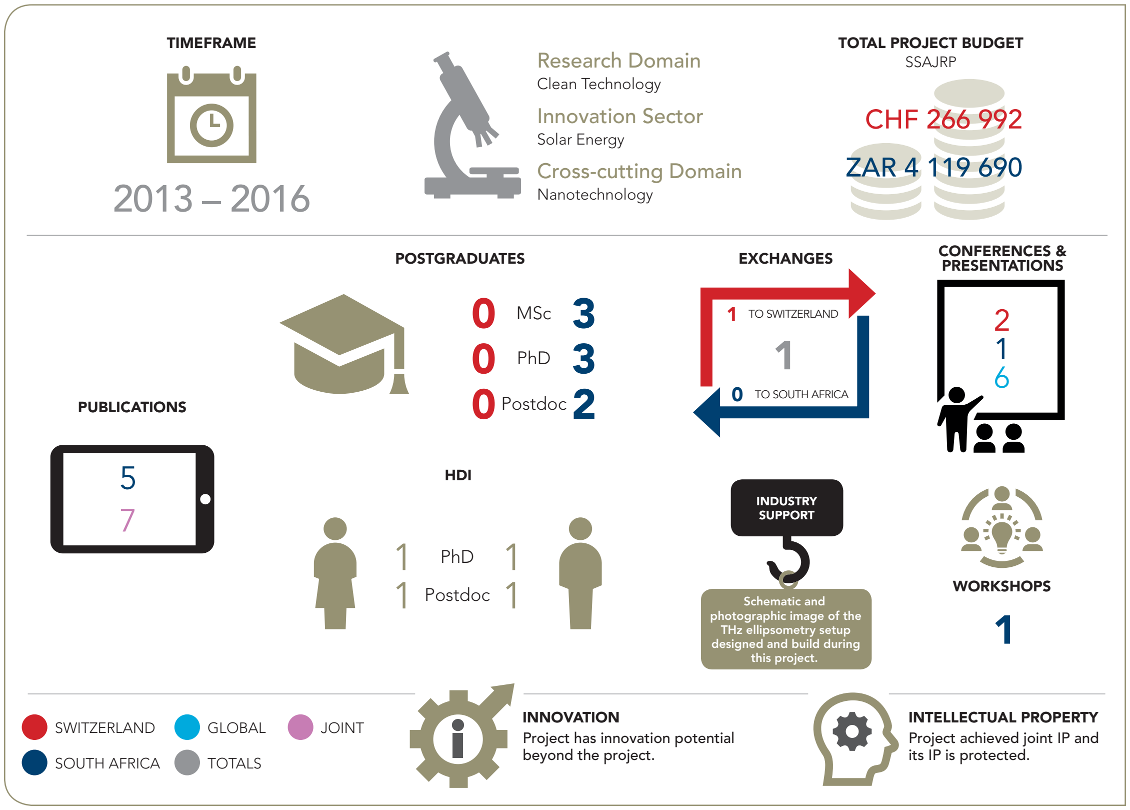
The South African senior and junior team members have gained insight into the Swiss R&D translation approach. They had an opportunity to access unique world-class infrastructure not available in South Africa and limited to very few international laboratories, such as the Ellipsometry Unit at the University of Bern.



Schematic and photographic image of the THz ellipsometry setup designed and built during this project.

Professor Malik Maaza

Photograph courtesy of Malik Maaza



The adoption of clean energy technologies in South Africa: the costs to adopting technology restrictions

UNIVERSITY PARTNERS
Graduate Institute Geneva
Professor Tim Swanson
University of Cape Town
Professor Mare Sarr

The overarching objective of the project was to identify the nature and extent of the costs of shifting toward new technologies, and the nature of the interventions that will be important to mitigating these. The project will deepen understanding of the cost and trade-offs required for a green economy.

This joint research project forms part of the "Innovation, Diffusion and Green Growth" project, located at the Graduate Institute in Geneva (GIIS). Collaborative partners are at the EPFL in Lausanne, ETH Zurich in Zurich and the London School of Economics. Fundamentally, the collaboration will contribute to a GIIS project by providing the perspective of a developing country and simultaneously provide insight into the reach of the South African green economy objectives and an opportunity to deepen international collaboration in these research areas.

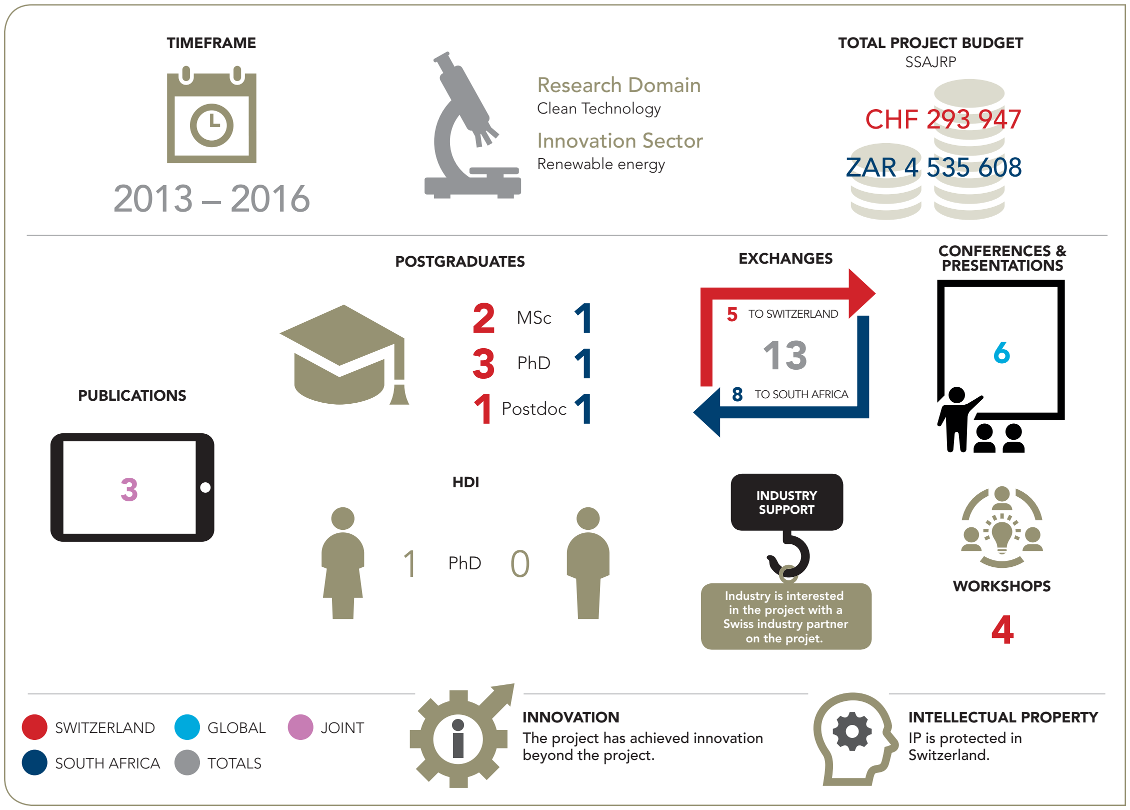
This project also examined whether governments are able to steer production towards a green economy, using only temporary policy interventions as is now commonly prescribed in the economic literature of directed technical change. The research shows that this might not be the case in an open economy that possesses abundant fossil fuel endowments and that is heavily invested in carbon-intensive production (such as South Africa). Indeed, if major trading parties to this resource-rich country care about potentially irreversible consequences of climate change, reductions in global emissions below catastrophic levels may require a resource buy-back policy over time to ensure the resource-rich nation will stop or at least seriously curtail production in the dirty sector.

Part of the project looked at the impact of policy shocks on the South African coal mining industry, using a field experiment in the Mpumalanga coal fields. The researchers explored how substantial changes might impact on mineworkers in the industry, based on their individual contractual status, unionisation and ethnicity. This allowed exploration of the determinants of cooperation or conflict among mine workers when faced with a shock to their industry.

The study aimed to uncover the effect of relative concerns (i.e. social comparisons between individuals) on public good provision, either by aggravating or alleviating the free-riding problem. Moreover, by changing the reference group at which individuals target their relative concerns – from national (local public good) to international (climate change mitigation) peers – they tested whether concerns within countries are different or similar to concerns between countries. The experiment was conducted in five of the top emitting countries: the United States, European Union, China, India and South Africa.

Key findings of the project were that the transfer of resource-conserving technologies for developing countries to reduce pollution could only be successful if accompanied by incentives. Temporary policy interventions towards a green economy prove challenging in an open resource-rich economy that relies heavily on carbon-intensive production. A possible solution is a resource buy-back policy.

Professor Mare Sarr



Solar light-driven homogenous catalysis for greener industrial processes with H_2 as energy source and CO_2 as C1 building block

UNIVERSITY PARTNERS

University of Zurich
Professor Roger Alberto
University of the Free State
Professor Andreas Roodt

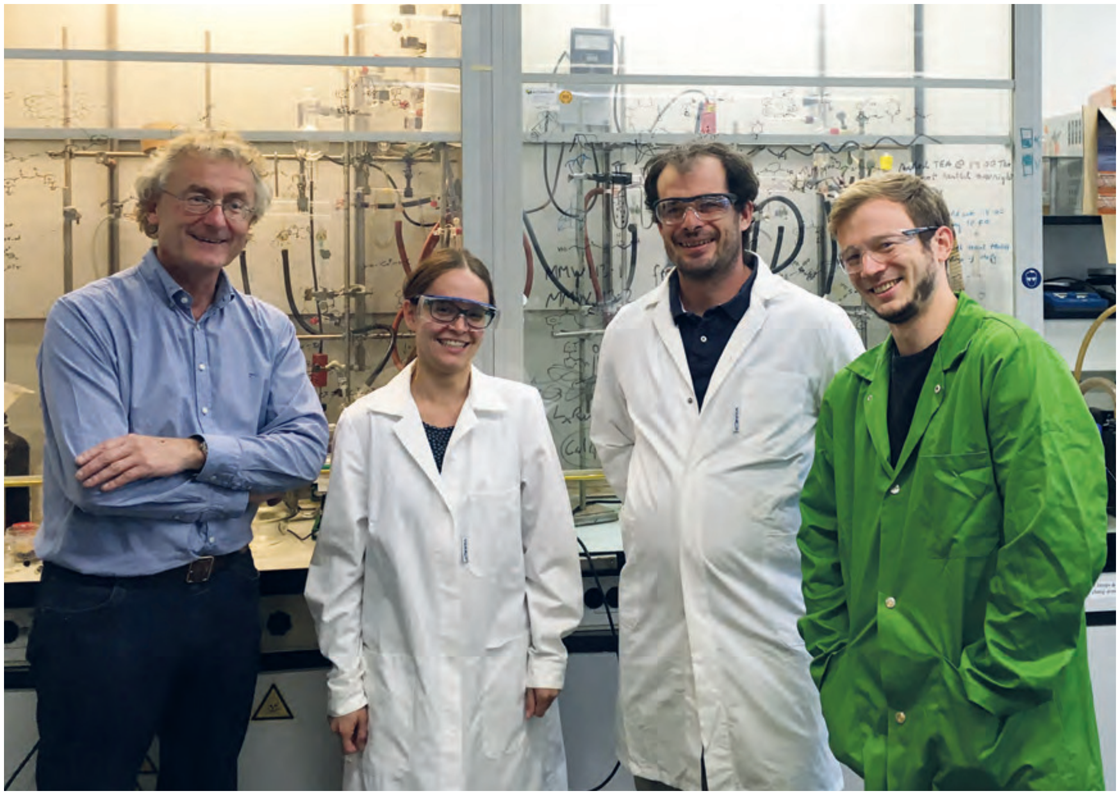
Photograph courtesy of Andreas Roodt

South African researchers at the UFS in Bloemfontein. From left: Drs Truidie Venter and Marietjie Schutte-Smith, Professor Andreas Roodt, Lindy Gantsho, Drs Dumisani Kama and Johan Venter, Nina Seitelo and Drs Alice Brink and Pennie Mokolokolo.

The overarching aim of this project is solar light-driven homogenous catalysis for a greener environment and industrial processes. The researchers are exploring two sub-projects: using hydrogen as energy source, and fixing or converting carbon monoxide as C1 building block for the synthesis of other useful chemicals.

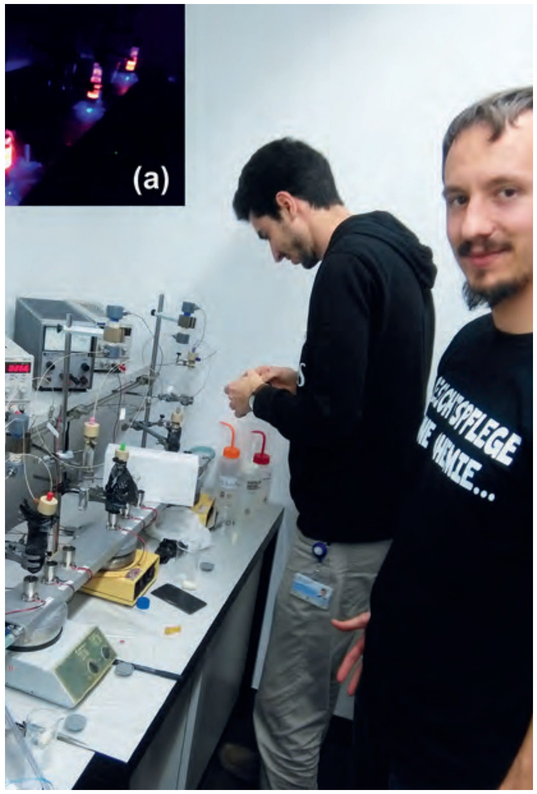
Currently, over 80% of Europe's energy use is based on oil, gas and coal. In South Africa, the value is estimated at over 90%. The South African National Development Plan and the Department of Trade and Industry underwrite the need for cleaner energy. Sasol, an important player in the petrochemical industry in South Africa, considered the research proposed within this broad project so important that they are providing additional support for research associated herewith.

The South African students involved in this overarching project are critical for the development of capacity on the overarching thrust of green chemistry,



Photograph courtesy of University of Zurich, Dept of Chemistry, Secretariat

Swiss researchers at the University of Zurich. From left: Professor Roger Alberto (Swiss PI), Franzsika Rahn (PhD student), Dr Benjamin Probst and Nicola Weder (PhD student).



Photograph courtesy of University of Free State, Prof Dr Andreas Roodt

Swiss PhD students Daniel Hernandez and Peter Müller set up photochemical experiments; Insert (a): Photochemical splitting of water to produce hydrogen gas.

cleaner environment and reduction of greenhouse gases, not only from a superficial, but specifically from a fundamental chemistry point of view.

The work initiated by the research teams is fundamental in nature, but they aim to apply the anticipated findings. It has consolidated the research cooperation between the Swiss and South African groups significantly, as well as beyond the actual project.

Following the plan as outlined in the proposal, the main research in the first 12 months was on the conjugation of water reduction catalyst or their ligands to the bis-arene scaffold to achieve key structures.

The results of this period of the project are promising enough to ensure that the team can enter a truly original track in the development of combined supramolecular frameworks for photocatalytic water reduction and carbon dioxide activation/ conversion. With these results in mind and ensuring further results, the submission of a proposal to a corresponding EU programme is foreseen. The ongoing cooperation in the project's field has led to parallel cooperation on other topics as well.

Top-notch results emerging from this project because of mutual cooperation are basic for future applications while inducing other cooperations at the same time.

TIMEFRAME

2017 – 2020

Research Domain
Clean Technology

Innovation Sector
Renewable energy

TOTAL PROJECT BUDGET
SSAJRP

CHF 602 735

ZAR 9 300 196

PUBLICATIONS

1 9 1

POSTGRADUATES

1	MSc	7
2	PhD	6
0	Postdoc	1

HDI

2	MSc	2
1	PhD	2
0	Postdoc	0

CONFERENCES & PRESENTATIONS

1 5

SWITZERLAND · GLOBAL · JOINT · SOUTH AFRICA · TOTALS

INNOVATION
The project has innovation potential beyond the project.

Understanding the impacts of climate change on Arctic, Antarctic and Alpine permafrost microbiomes (cryolink)

UNIVERSITY PARTNERS
Swiss Federal Institute for Forest, Snow and Landscape
Dr Beat Frey
University of Pretoria
Professor Don Cowan

Photograph courtesy of Don Cowan

Professor Don Cowan and NZ colleague Ian Hogg in the Antarctic Dry Valleys.

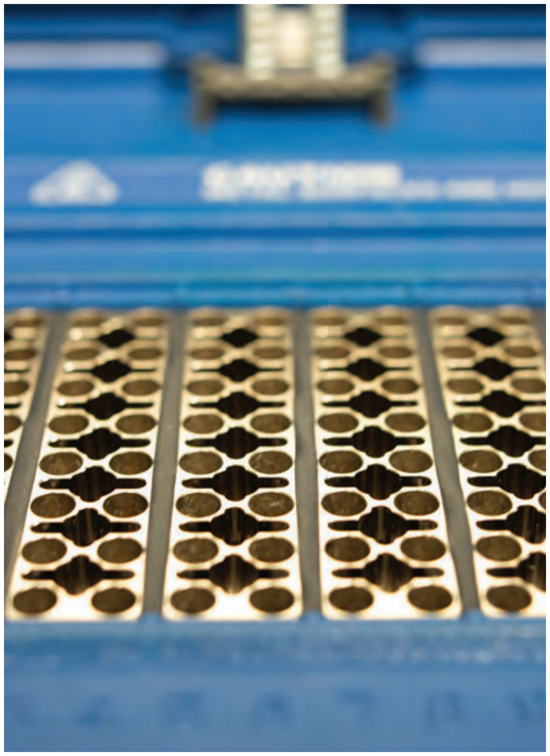
Swiss collaborators in the greenhouse (from left): Carla Perez Mon, (PhD student), Dr Aline Frossard scientific collaborator and Dr Beat Frey, principal investigator.

Various stones from glacial forefields to study bacterial biofilms on weathered mineral surfaces.

The research team proposed an extensive study to elucidate the ecology of microbial communities associated with permafrost systems and investigate comprehensively the diversity and functions of microorganisms in three bio-geographical areas: the Arctic, the Antarctic and the Alpine regions.

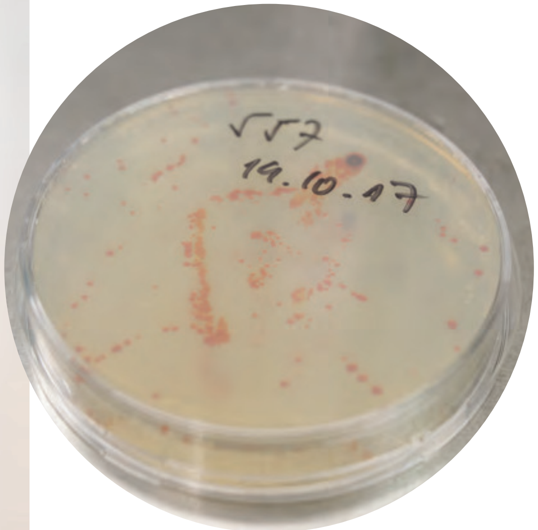
Cold habitats represent the majority of the Earth's biomes and permafrost, defined as the part of the soil frozen for at least two consecutive years, and are widely spread on land surfaces. Permafrost areas are considered "extreme environments" and harbour microorganisms with an ability to adapt, not only to sub-zero temperatures, but also to low water, carbon and nutrient availability. However, these habitats constitute a unique niche for cold-adapted microorganisms. Little information is available on the ecology of microorganisms in permafrost, despite their high importance in view of their high susceptibility to global change.

Nowhere is climate change more visible than in the Polar Regions. As a consequence, there is an increasing need to estimate the impact that global warming will have on the Arctic, Antarctic and worldwide. Polar Regions play a key role in



Laboratory device to amplify low DNA amounts extracted from mineral surfaces.

Photographs documenting glacier retreat in the last five years in the Swiss Alps.



Orange-colored bacterial strains isolated from 13 000-year-old permafrost soils to screen for interesting metabolites.

the Earth's climate system. There is considerable socio-economic interest in predicting how permafrost thaw and how the carbon balance of these ecosystems will respond to ongoing climate warming. Global warming unlocks an unknown microbial diversity in Arctic, Antarctic and Alpine permafrost soils with direct feedback on greenhouse gas emissions.

The research collaboration will provide value by developing the complementary skill sets of the two partner institutions. It will contribute to the capacity building of students and skills development through doctoral student training programmes. Furthermore, the collaboration will provide access for both institutions to Polar and Alpine sampling sites. Accessibility of sample sites is an ongoing challenge; for example, access to Antarctic permafrost sites is only available in the austral summer season. Since permitting for sample transfers is increasingly stringent, sample and material exchanges are a challenge.

In South Africa, this project undertaken under the auspices of a long-standing collaborative relationship with researchers from the University of Waikato (New Zealand), through who access to Antarctic McMurdo Dry Valley soils is available.

TIMEFRAME

2017 – 2020

Research Domain
Clean Technology

Cross-cutting Domain
Climate Change

TOTAL PROJECT BUDGET
SSAJRP

CHF 559 519

ZAR 7 575 895

POSTGRADUATES

Switzerland		South Africa
0	MSc	1
2	PhD	2
1	Post Doc	2

HDI

1 PhD 0

INDUSTRY SUPPORT

South Africa Principal Investigator has an industry partner.

CONFERENCES & PRESENTATIONS

2

6

SWITZERLAND GLOBAL JOINT
SOUTH AFRICA TOTALS

INNOVATION
Project has innovation potential beyond the project.

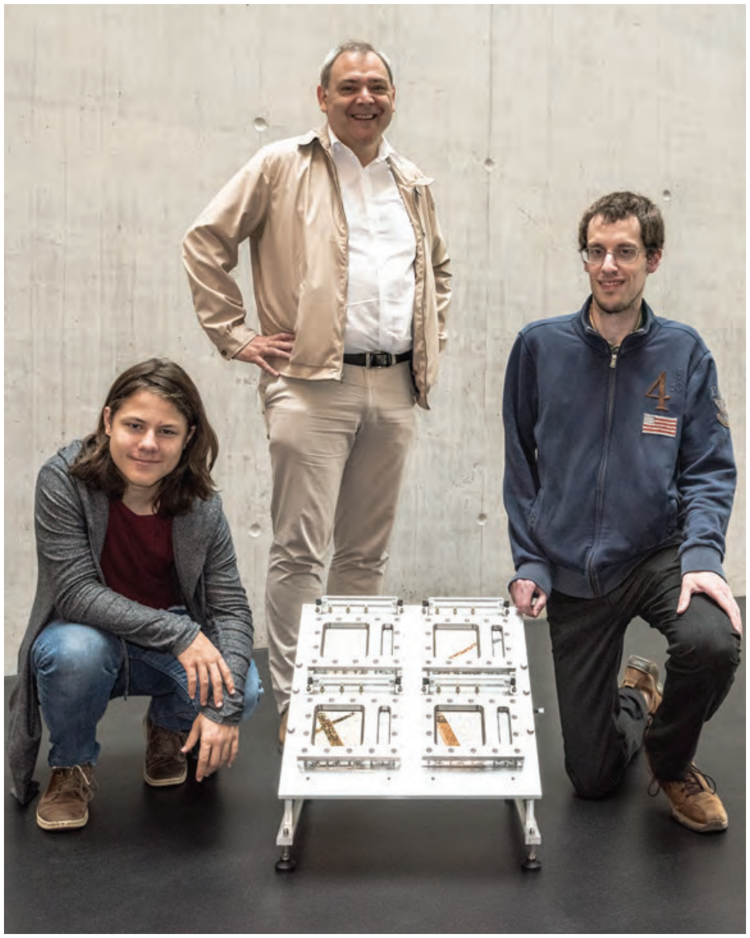
Production of liquid solar fuels from CO_2 and water using renewable energy resources

UNIVERSITY PARTNERS

Swiss Federal Laboratories for Materials Science and Technology
Dr Artur Braun
University of Pretoria
Professor Egmont Rohwer

Photographs courtesy of Artur Braun

Jospeh Simfukwe (left} won the poster prize at the Materials Research Society Fall meeting 2017 in Boston Massachusetts for his computational work on iron oxide photoelectrodes for solar fuel production.



Dr Artur Braun and students with biomimetic PEC for solar hydrogen production with daylight.

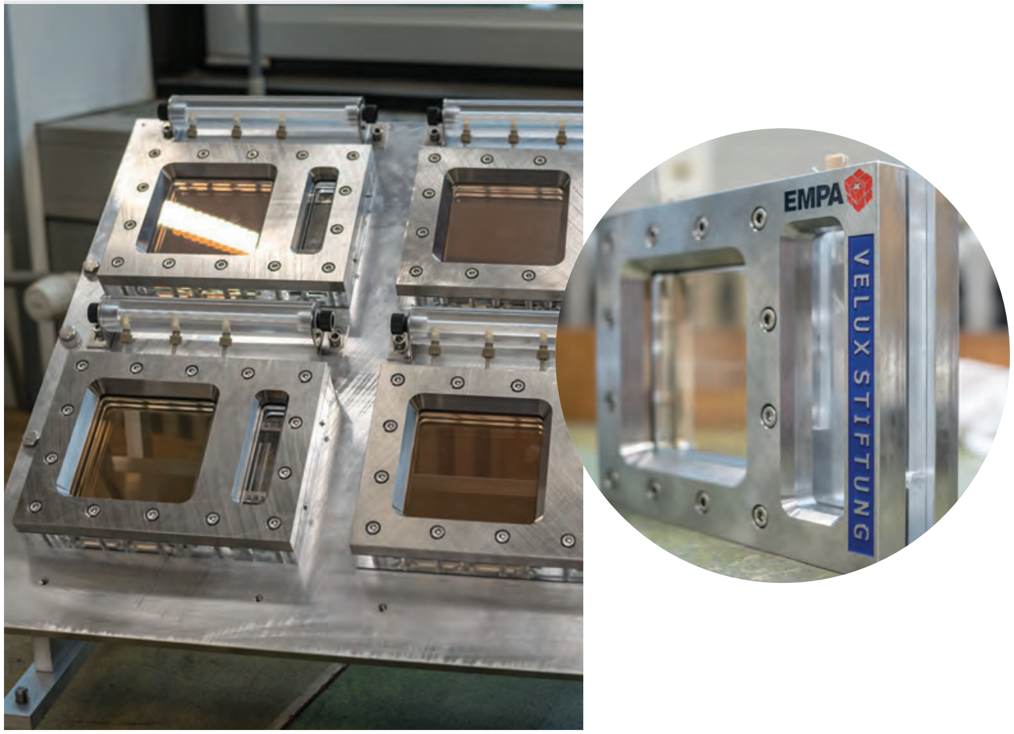
The objective of the project is to provide liquid fuels of the future without producing greenhouse gases during combustion as liquid fuels will continue to be an essential feature of, for example, air transport. The project therefore aimed at converting carbon dioxide to liquid solar fuels, addressing the broader challenge of sustainable energy production.

Batteries simply do not provide enough energy density (energy per mass) to replace aviation fuel for long-distance flights. Hydrogen produced from renewable energy sources has been proposed to fill this gap but the technical difficulties in storing and transporting hydrogen as a high-pressure gas or a liquid at ultra-low temperatures, are appreciable. Hydrocarbon liquids produced from renewable energy sources and CO_2 in the atmosphere, on the other hand, could produce direct substitutes for fossil-derived petrol, diesel and aviation fuel to serve the full transport sector in future. Only the same amount of CO_2 would be released from their combustion as that originally taken up from the air during production of the fuel. CO_2 and water would thus simply provide the building blocks for the synthetic liquid energy carriers, only to be released again after fuel combustion.

The successful production of such renewable liquid fuels could have immense consequences on, among others, the ability to store and transport large amounts of wind and solar energy with existing (fossil fuel) infrastructure. Such technology

Professor Egmont Rohwer

Photograph courtesy of Prof E Rohwer

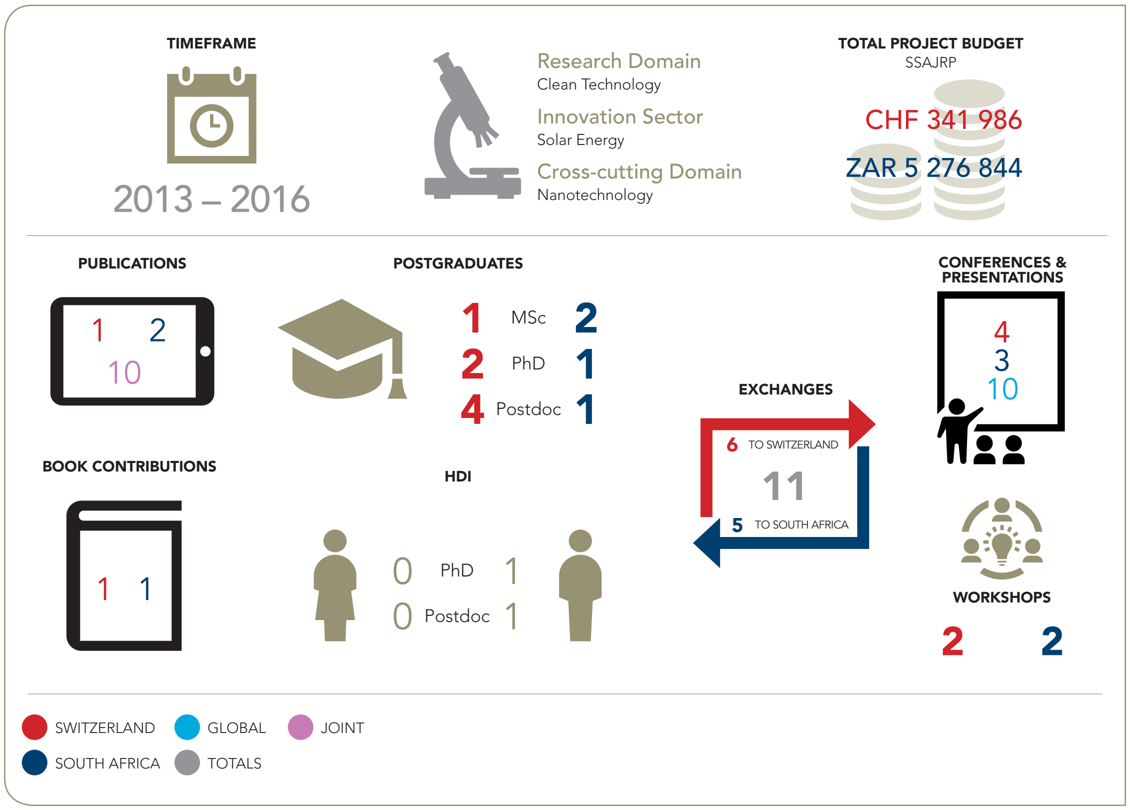


could totally eliminate the combustion of fossil fuels and their associated contribution to global warming. A world-wide trade in renewable fuels could result, providing revenue to countries like South Africa that have immense potential in cost-effective production of solar and wind energy.

The researchers took two approaches towards the project's goal. One was aimed at a full artificial photosynthesis where the solar light harvesting and the chemical conversion happen in the same cell. Hematite was used as a novel light-harvesting system. The second approach used electrical energy, assuming it to be from conventional photovoltaic cells, and conversion was by co-electrolysis of water and CO_2 using a novel cathode catalyst.

The project was highly competitive and of interest at an international level. The project established the field of semiconductor photoelectrochemistry for solar fuel production in South Africa. The observation of the formation of methanol from formic acid is promising and of industrial interest, but has not yet reached the necessary level, and needs to be achieved with CO_2 instead of formic acid.

The team has presented the results in Africa, Europe, China, and in the United States.



Agricultural residue from sugarcane harvesting for the production of bio-energy and chemicals in biorefinery (enerchems)

UNIVERSITY PARTNERS
Swiss Federal Institute of Technology in Lausanne
Professor Edgard Gnansounou
Stellenbosch University
Professor Johann Görgens

The project team aimed to develop biorefinery scenarios that utilise fibrous sugarcane material as feedstock for the co-production of bio-ethanol and valuable chemicals. These biorefineries could be developed in a manner that provides both economic and environmental benefits to stimulate interest in the policy and commercial spheres in their commercial implementation.

Key questions in the development of such biorefineries are the mix of products to be included and their optimal sizing and locations in the context of South Africa. The project was built on the assumption that such biorefineries will be integrated into existing sugar mills and first-generation bioethanol plants, which benefits conversion efficiencies and reduces costs. Both sugarcane harvesting residues and surplus bagasse from sugar mills or first-generation bioethanol plants will serve as feedstock to these lignocellulose biorefineries.

The project team rigorously investigated a number of biorefinery scenarios applicable to the South African sugarcane industry. Experimental work provided technical information that they subsequently used for simulation of these biorefinery scenarios. The outcomes of such simulation work demonstrated the potential environmental benefits of biorefineries, while also providing perspectives on commercial viability. The researchers communicated these outputs to policymakers as well as industrial partners in South Africa, providing further support for development of the bioeconomy of South Africa.

The simulations work completed in the project is also relevant to other sugarcane-producing areas, such as Brazil, India and China. The co-production of lactic acid or furfural with ethanol is highly novel in these contexts, and the project has certainly advanced understanding of these opportunities.

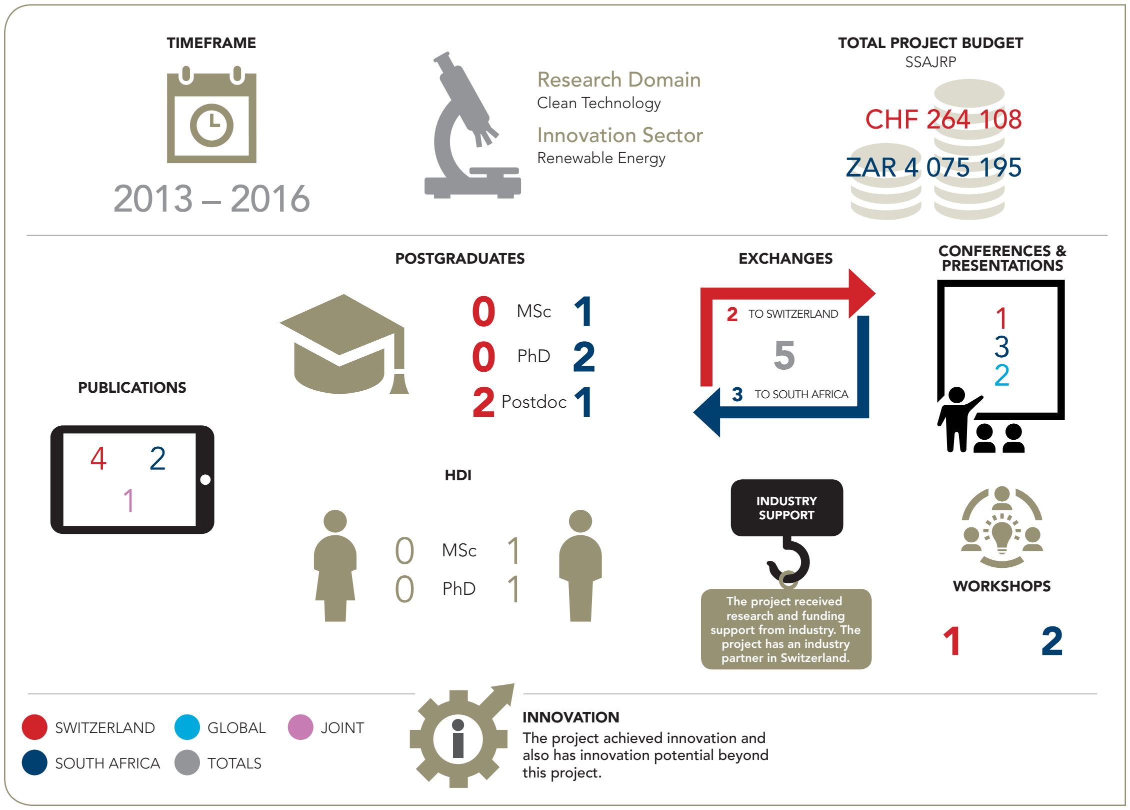
Research links were established with the South African Sugarcane Research Institute (SASRI) as well as the South African Sugar Milling Research Institute. These institutes provided some technical inputs required for the simulation of the scenarios and further techno-economic and life cycle assessments.

Photograph courtesy of Edgard Gnansounou

From left: Dr Jegannathan Kenthorai Raman, Postdoc Research fellow, Dr Pavel Vaskan, Postdoc Research fellow, Dr Elia Ruiz Pachon, Postdoc Research fellow, Juliette Brunet, MS student, Professor Dr Edgard Gnansounou, Director of the Research Group, Michael Agiovlasitis, MS student, Dr Daniel Tuazon, Postdoc Research fellow and Sabrina Martone, Administrative assistant.

Members of the research team at Stellenbosch University (from left): Professor Johann Görgens, Thapelo Mokomele (PhD student) and Dr Kathleen Haigh (postdoctoral researcher).

Control systems for pilot-scale bioreactor for ethanol production.



The project work has directly added to the strategic development of biorefinery plans in the industry. The anticipated project outcomes provide a basis for developing sustainable biorefinery systems, which allow highly efficient and cost-effective processing of biological feedstocks to a range of bio-based products.

The sugar industry is interested in the project and provided the feedstock (sugarcane trash and bagasse) for the study. The sugar industry needs to add more value to fibrous residues such as these as a means to revitalise the industry, which is presently in decline. The industry has major socio-economic impacts in a widespread part of South Africa.

The award of further funds by the South African Sugar Milling Research Institute to expand on the research and investigate potential biorefinery scenarios, demonstrated further interest in the potential to broaden the product range of sugar mills.

Factors regulating carbohydrate storage in plants: implications for biotechnological improvement of crops for food and for clean, green technologies

UNIVERSITY PARTNERS
Swiss Federal Institute of Technology Zurich
Professor Samuel Zeeman
Stellenbosch University
Professor Jens Kossman

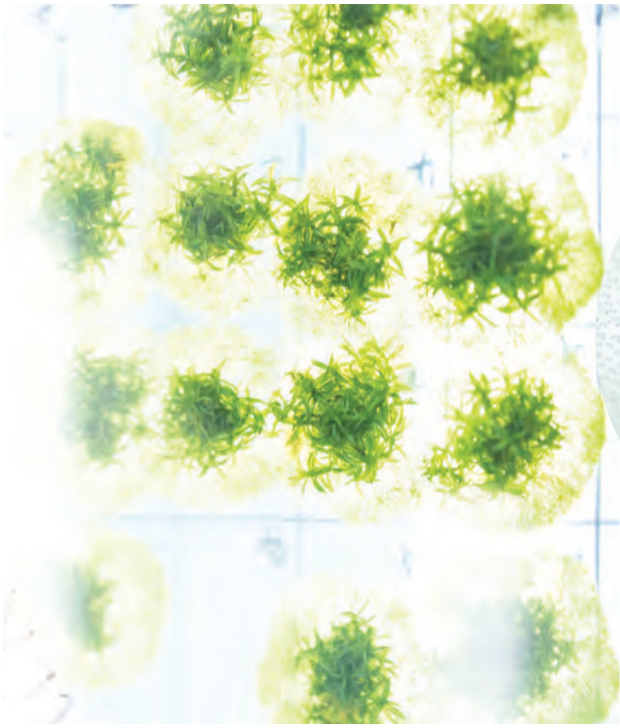
Arabidopsis plants.

Jonathan Jewell, Professor James Lloyd, Dr Paul Hills, and Professor Jens Kossmann.

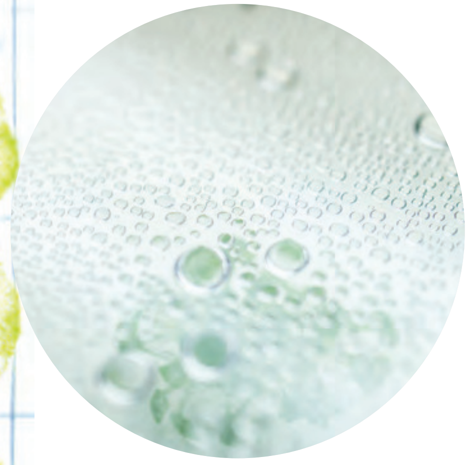
The project work fundamentally addressed questions relating to building a bio-based economy as the researcher involved tried to manufacture crops that are more efficient and are a better resource for renewable materials. The Swiss group has written patents to protect their IP in terms of the new genes they have identified that are involved in starch metabolism and it is hoped that they will be used to improve industrial starches. The South African group has produced plants with improved industrial starches and hope that this will be used industrially in future.

The key objective of this project was to make new discoveries about how plants make the important storage carbohydrate, starch. Starch crops represent the cornerstone of human nutrition, and much of our arable land is devoted to their production. In this project, the research team used new information derived from the analysis of starch granule proteome – the proteins adhering to starch granules. This allowed them to identify previously uncharacterised proteins involved in starch biosynthesis. They used molecular-genetic and biochemical approaches to analyse the functions of

Petri dish with water droplets.



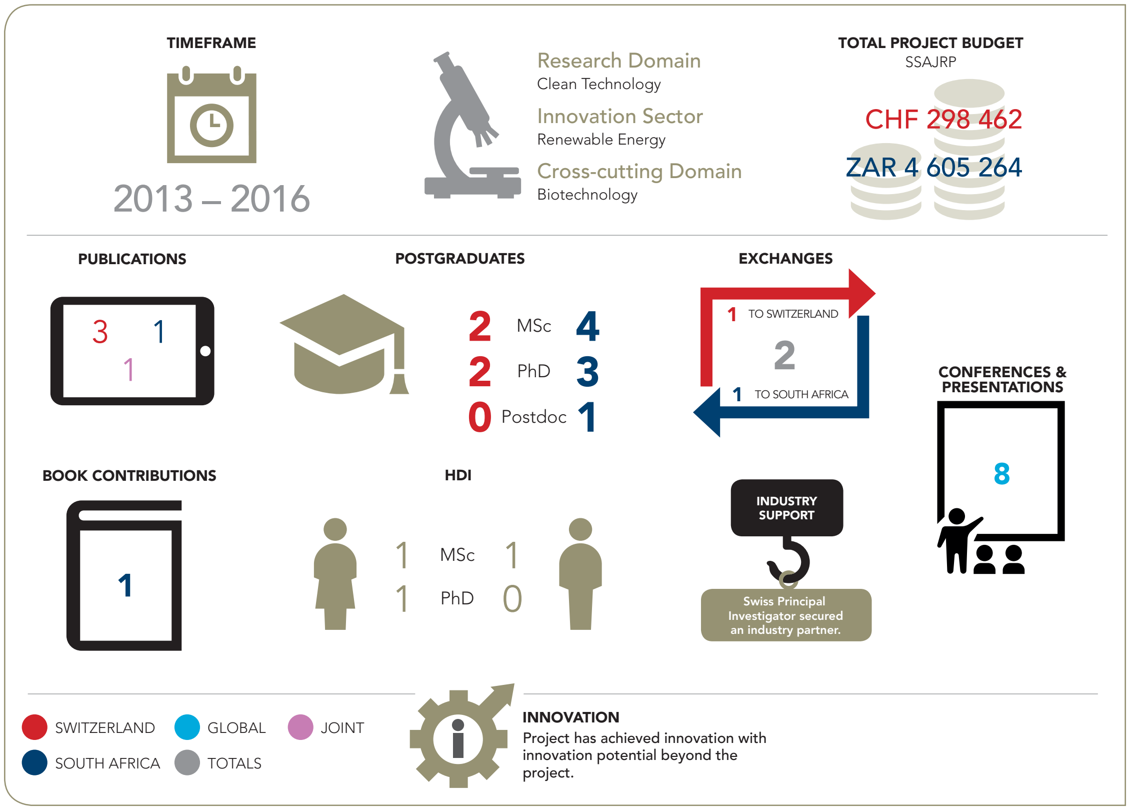
Physcomitrella patens plants.



the newly identified proteins both *in vivo*, primarily using the *Arabidopsis thaliana* model system, and *in vitro*. In addition, they altered starch metabolism in potato as this makes large amounts of starch in storage organs, and improved the industrial properties of that starch.

This project has been highly competitive on a global scale. It has led to the discovery of new genes involved in starch metabolism and the work describing this has been published in three papers within extremely high-impact journals. In addition, it has led to the discovery of a new mechanism to increase starch phosphate contents in plant storage organs. Work from the previous Swiss-South African grant was finalised, and led to a publication in a well-regarded scientific journal, with two more publications being prepared. The project also led to a publication in a high-impact review journal, *Current Opinions* in *Biotechnology*.

The ETH Zurich and Stellenbosch University signed an MoU for joint future projects on food security. They also hope to submit a successful grant application to a European Union call related to generating multipurpose crops using genome-editing technologies. The South African group has started collaborating with a group in France at Lille University due to contacts gained as a direct result of the project.



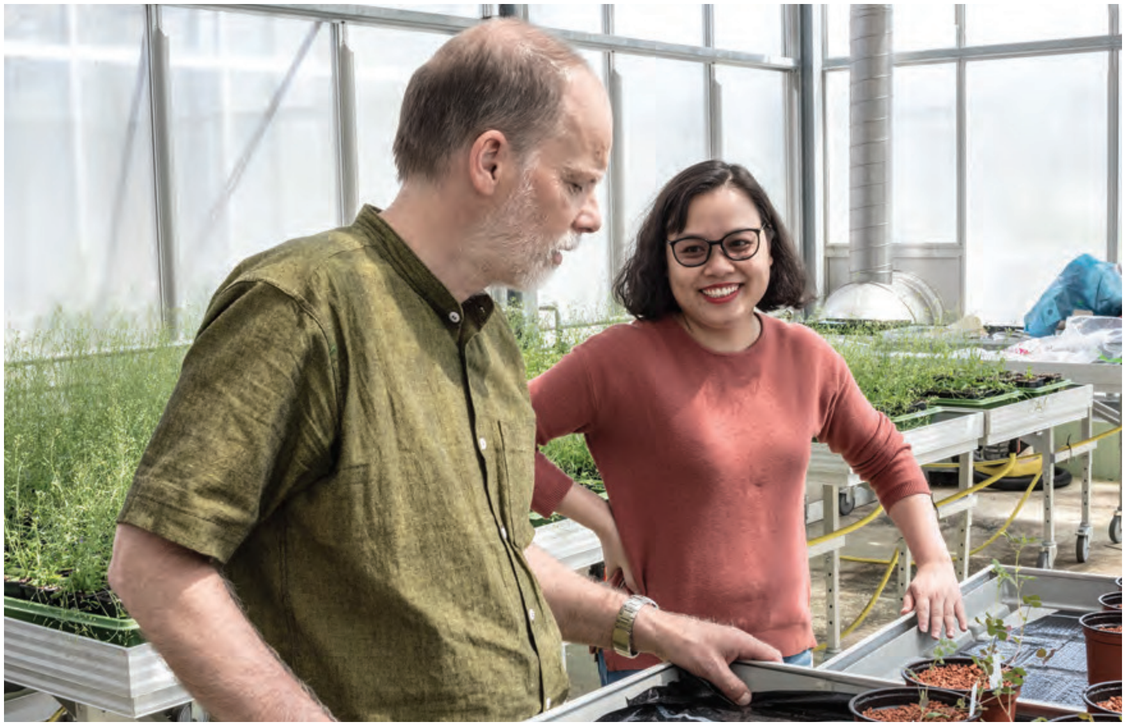
Development of crop plants with reduced requirement of phosphate fertilisers via the cisgenic regulation of PHO1 and GULP1 activity

UNIVERSITY PARTNERS
University of Lausanne
Professor Yves Poirier
Stellenbosch University
Professor Alex Valentine

The primary aim of the research was to study and modulate the expression pattern of the PHO1 and the GULP genes in *Medicago truncatula* (a small annual plant in the legume family) and understand its implication in phosphate homeostasis and the adaptation of plants to phosphate deficiency leguminous plants, in particular under conditions of nodulation.

This project enabled the discovery of a novel role for the *Medicago* PHO1 gene in nodulation and nitrogen fixation, and also uncovered novel aspects of the adaptation of legumes to phosphorus deficiency. The success of this project was dependent on the complementary expertise of the South African and Swiss partners, as well as intense exchange of ideas and skills between them. Such interaction would have been impossible without this funding scheme.

The project has contributed immensely to capacity development in the South African group, since they gained new students from designated groups to work either fulltime or part-time on this project. This collaborative project also enabled both the South African and Swiss partners to gain knowledge



Professor Yves Poirier (left) and Dr Thi Ngoc Nga Nguyen from the University of Lausanne.

Growing Medicago *plants in the greenhouse under various nutrient regimes.*

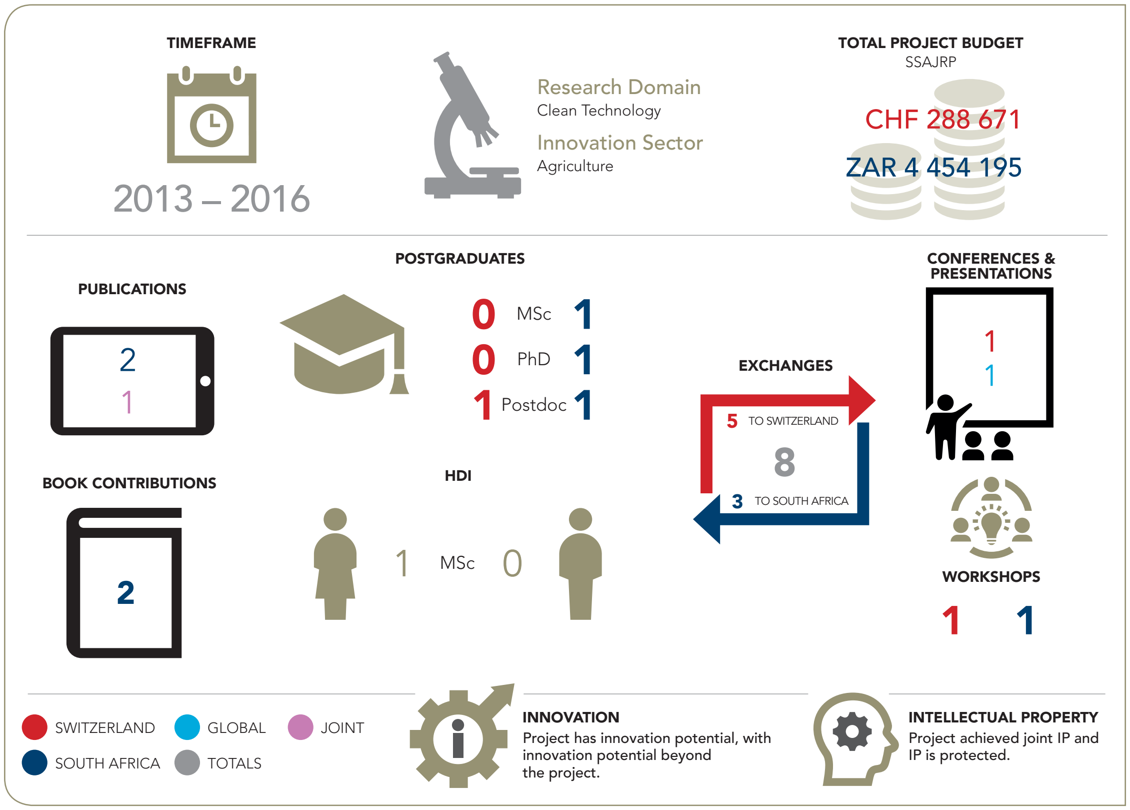
Growing Medicago *plants under* in vitro *conditions.*

and expand their expertise in novel areas of plant molecular biology, and particularly on legume and nitrogen fixation that will be key to a future research programme and ability to apply for new funding from national and international agencies.

This project received input from a collaboration with Dr Micheal Udvardi from the Noble Foundation in the USA whose group has unique expertise and resources related to *Medicago* genomics.

Reciprocal research visits took place to the South African and Swiss laboratories, where researchers were able to learn techniques and exchange valuable ideas for publications and future continuing work, as well as exchanges of research material (including from the USA lab). During the funding period, this project contributed immensely to technology transfer, capacity development, and international collaboration.

The research partners also used the expertise gained in this project to interact with the local community in two ways: they initiated an urban community vegetable garden project at a local school, where their knowledge on low-nutrient adaptations could be applied to crop production; and they engaged in a project with a poor farming community in the rural areas of the Cederberg, where knowledge from this project could be applied to rooibos tea production.



Development and transfer of a cassava transformation technology platform for industrial application

UNIVERSITY PARTNERS

Swiss Federal Institute of Technology in Zurich
Dr Hervè Vanderschuren
University of the Witwatersrand
Professor Christine Rey

Photograph courtesy of Rey laboratory

Transgenic cassava lines in tissue culture, developed for resistance to African cassava mosaic virus.

This research proposal was aimed at implementing a cassava genetic transformation platform and exploring RNAi-mediated biotechnologies to generate cassava that is resistant or tolerant to cassava mosaic disease (CMD). The project also had as a goal to consolidate the collaboration between Switzerland (ETH Zurich) and South Africa (University of the Witwatersrand), whose interests in cassava aligned, and to share knowledge and transfer cassava transformation capacity from ETH Zurich to establish a high-throughput transformation biotechnology platform in South Africa.

Cassava *(Manihot esculenta Crantz)* is a major staple food of the poorest communities in sub-Saharan Africa and is also an important food security and subsistence crop. The attractive industrial use of cassava for starch and biofuel production is rapidly increasing the global demand for cassava. Cassava cultivation is also increasing in southern Africa. South Africa could become the leader in cassava starch technologies in Africa. In sub-Saharan Africa the major limiting factors to increased cassava production are CMD, caused by cassava mosaic geminiviruses (CMGs) and transmitted by whitefly *(Bemisia tabaci Gennadius)*, and cassava brown streak disease (CBSD), causing up to 80% loss in production.

The major constraint to improving virus resistance in cassava through genetic manipulation is the lack of a reliable and robust transformation method for cassava. The primary objective was therefore to expand existing technologies (RNAi).

Technology transfer from ETH Zurich to the University of the Witwatersrand (Wits) resulted in Wits becoming the first establishment to set up a robust cassava transformation and biotechnology platform on the African continent.

Exploration of the application of cassava starch in industry in South Africa was discussed at two successful workshops. The participants reached an agreement to initiate a cassava industry association, which was achieved in 2016.

The researchers also explored the possibility of conducting greenhouse and field trials in South Africa of ACMV-resistant cassava plants developed at ETH Zurich. A PhD student conducted greenhouse trials with several transgenic lines he developed, which led to capacity building in plant transformation and GM evaluation.

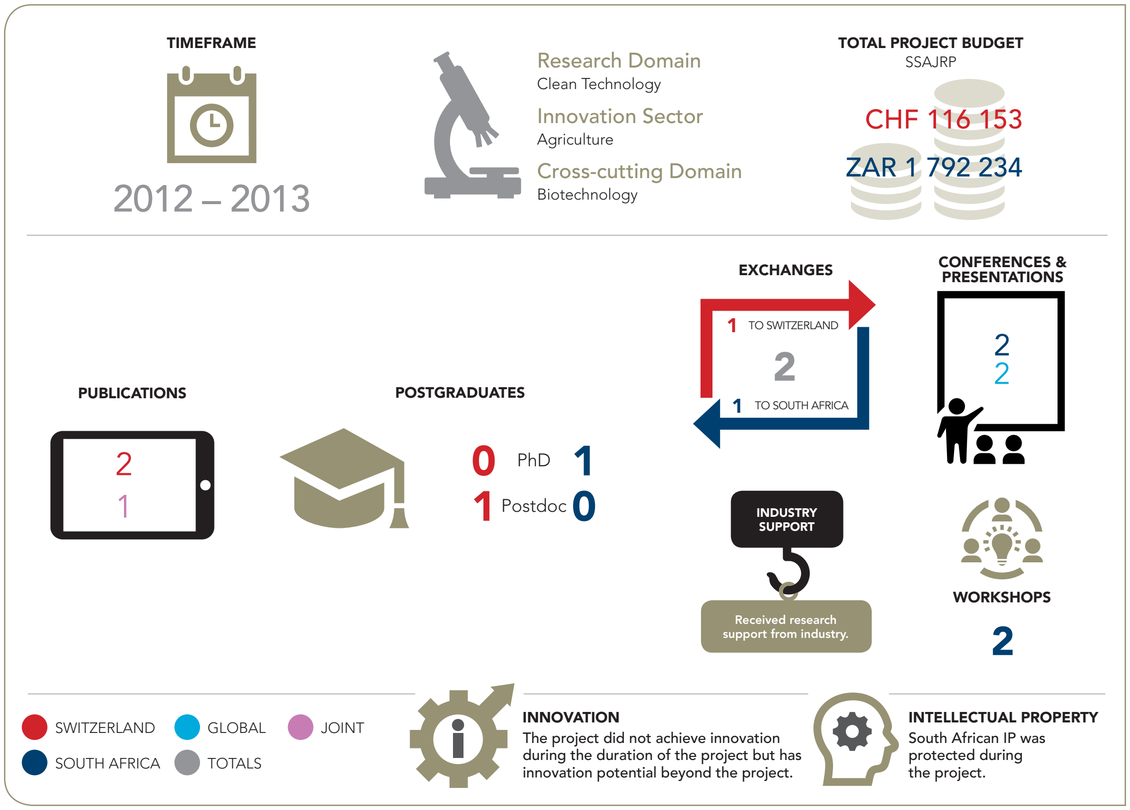
The research partners' engagement with Biosafety SA allowed them to explore the legislation required for GM trials in South Africa, which led to endeavours in initiating GM permit application and identification of a potential Agricultural Research Council (ARC) trial site in Mpumalanga Province.

This research collaboration was highly valuable. The Swiss partner was able to provide technical transfer of cassava transformation skills and is assisting in training capacity, which led to the establishment of a cassava transformation platform. The South African partner was able to provide the environment in South Africa where cassava can actually be cultivated and this is driven by starch industry needs and recognition in SA and the southern African region.

Photograph courtesy of VIB - UGent

Dr Hervè Vanderschuren

Professor Christine Rey



SAVUCA: South African Value-added Cassava

UNIVERSITY PARTNERS

Swiss Federal Institute of Technology Zurich
Professor Hervé Vanderschuren
University of the Witwatersrand
Professor Christine Rey

Close up of cassava leaves from cassava landrace T200.

This research was part of a larger initiative and framework to establish a cassava industry in South Africa and to promote cassava for small-scale farmers. In addition to genetic modification aims, the researchers worked with industry and government to establish cassava trials with small-scale farmers and to engage with industry and other stakeholders through the Cassava Stakeholders Meetings. Since the formation of the Cassava Association (CIASA), all stakeholders engage through this forum. The South African Principal Investigator continues to engage, advise and assist to promote cassava.

In 2016, the researchers continued to undertake national cassava germplasm trials initiated in three provinces in 2014. This was supported by the TIA and the ARC. Seven ARC cassava cultivators and four Ukulinga cultivars, which were part of the trials, were also established in tissue culture in the laboratory at Wits University. The researchers screened them for the presence of putative cassava mosaic resistance-associated genes in an honours project.

The ETH Zurich-Wits project was initially aimed at investigating biotechnological approaches to control viral diseases in cassava, including RNAi and peptide aptamers. As part of an effort to develop broad spectrum virus resistance, the project also developed cutting-edge approaches to investigate natural virus resistance (the so-called CMD2 resistance) in cassava leading to a detailed analysis of candidate resistance genes. The pioneer molecular work of Rey and Vanderschuren laboratories on CMD2 is particularly important as it remains a robust and broad spectrum resistance in the field.

Several GM cassava lines displaying virus resistance phenotype have been characterised as part of the SAVUCA project and their assessment in the field will be carried out in ongoing collaborations between the Vanderschuren and Rey Laboratories. Both laboratories are also continuing their effort towards characterisation and utilisation of natural virus CMD2 resistance that was pioneered as part of the SAVUCA project.

Photograph courtesy of Hervé Vanderschuren

Swiss and South African researchers discuss cassava virus resistance assays in confined plant growth facilities (University of the Witwatersrand, Johannesburg).

The team drafted an application to obtain a permit to bring GM cassava from ETH Zurich into South Africa, with involvement of both the Swiss and South African partners. They secured a potential GM site, which they are leasing from the ARC. As part of another collaboration with African teams, ETH Zurich has shown in field trials in Kenya and Nigeria that, despite improved performance of several transgenic lines, immunity to virus infection has not yet been achieved. They decided therefore that the field trail application in South Africa should also include the additional constructs and transgenic lines generated as a part of the ongoing activities that have emerged from the SAVUCA project.

Other ongoing activities in both laboratories are targeting the development of cassava varieties with high value for industries, particular traits related to modified starch and disease resistance. Collaboration between the Vanderschuren (University of Liège, Belgium) and Rey laboratories has been continued through newly-funded projects.