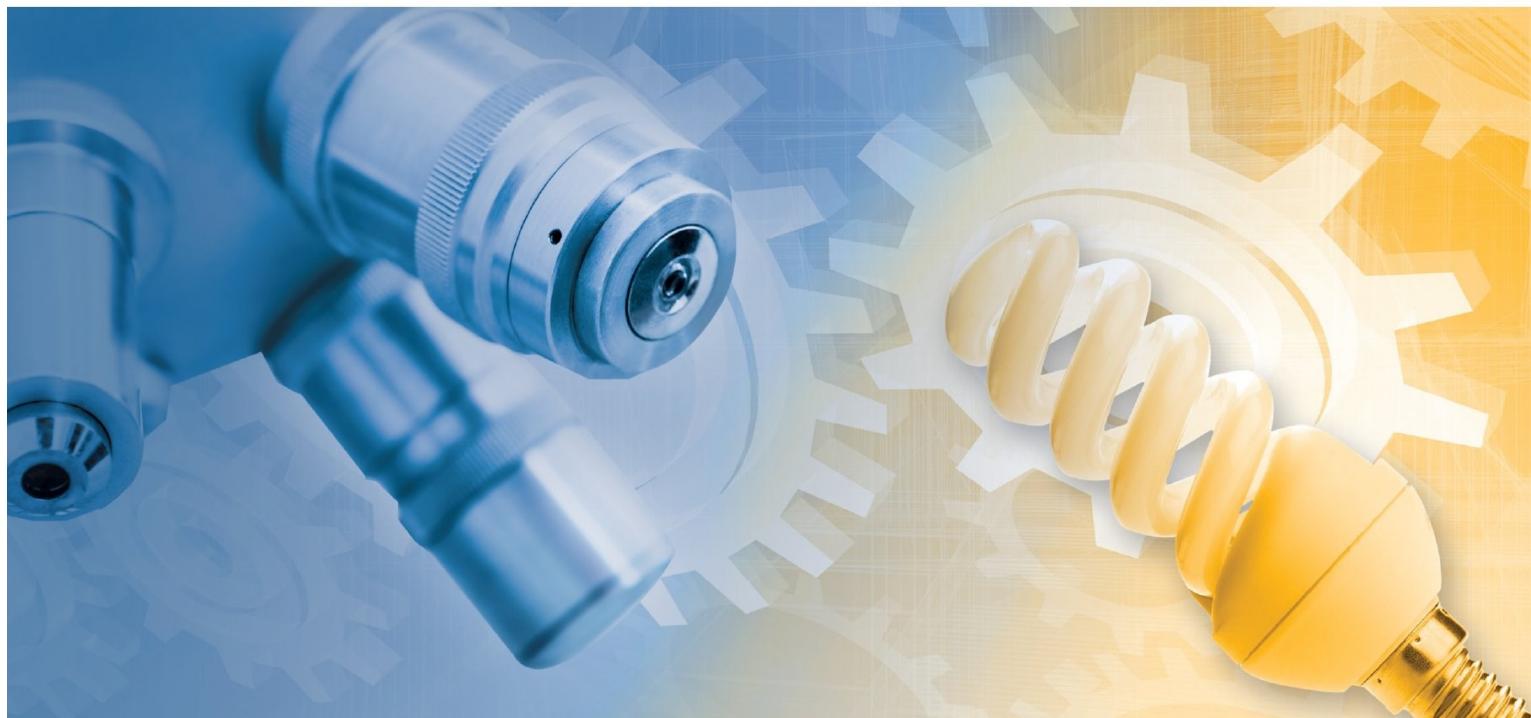


Science, Technology & Innovation Policy Review

Rwanda

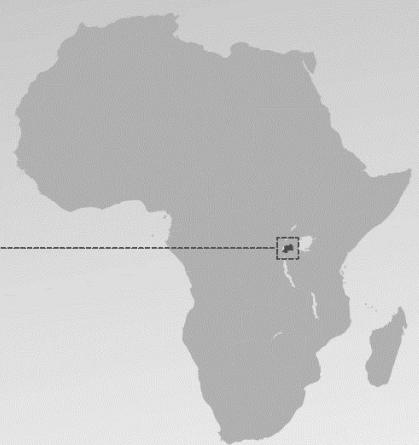
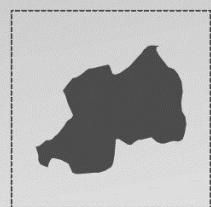


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Science, Technology & Innovation Policy Review

Rwanda



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Preface

The Science, Technology and Innovation Policy (STIP) Reviews prepared by UNCTAD aim to contribute to the development of national capacities in this field in order that national science, technology and innovation plans and programmes make an effective contribution to development strategies and improve the competitiveness of the productive sectors in a global economy in which knowledge is an increasingly important factor. This review is intended to be a tool for learning and reflection. It is an analytical instrument, not a rating mechanism, which examines a set of proposals from an external and neutral perspective.

This publication has three fundamental goals. Its first goal is to offer Rwanda an assessment of the framework conditions and interactions required for a functional national innovation system. The second goal is to draw attention to the main policy challenges for strengthening the national innovation system based on review four sectors: energy, information and communication technologies (ICTs), agriculture and industry. The third goal is to provide recommendations for strengthening policies and propose measures that may improve national technological capacities and encourage innovation.

The review of the science, technology and innovation policies of Rwanda was conducted in response to a request by the Rwanda Ministry of Trade, Industry and East African Community Affairs and with the support of the National Commission of Science and Technology (NCST). The work on the STIP Review of Rwanda was funded by the German Federal Ministry for Economic Cooperation and Development with the German Corporation for International Cooperation acting in an advisory role.

During visits to Rwanda, the UNCTAD team held nearly 50 interviews and meetings with representatives of government agencies, research institutes, universities, chambers of commerce and businesses. An initial draft of this document was presented and discussed at a national workshop held in Kigali on 1 December 2016, with the participation of more than 60 experts and national science, technology and innovation stakeholders. The comments and suggestions made there have been taken into account in the preparation of this review.

This review would not have been possible without the cooperation of the Ministry of Trade, Industry and East African Community and the NCST and, in particular, Honourable Minister François Kanimba and NCST Director Generals Dr. Ignace Gatare and Prof. Manasse Mbonye. A special appreciation is owed to the NCST STIP team. Gratitude is also extended to all participants in the national workshop and to the persons and entities, too numerous to be listed, that generously contributed their comments and ideas.

National partners, counterparts and experts may not necessarily concur with the entirety of the STIP Review's analysis and recommendations while they have advised on its content. The data cited in the Review is established by UNCTAD research staff. The assessments, opinions and conclusions expressed in this document are entirely those of the UNCTAD secretariat.

Acknowledgements

The review was prepared as part of the work programme of the Science, Technology and ICT Branch of UNCTAD's Division on Technology and Logistics. The document was produced by UNCTAD economist Dimo Calovski with inputs from expert consultant Jean-Eric Aubert.

The document benefited from comments from Nikola Šahović (UN ECE) and Robert Hamwey (UNCTAD) on chapters dedicated to energy and agriculture respectively.

The manuscript was copy edited externally by Jennifer Gal-Or. Magali Studer designed the cover.

Abbreviations

4G LTE	Fourth generation long-term evolution wireless standard	NAEB	National Agricultural Export Development Board
ACE	Africa Centres of Excellence	NCBS	National Capacity Building Secretariat
ADB	African Development Bank	NCBS	National Capacity Building Secretariat
AIESEC	International Association of Students in Economic and Commercial Sciences	NCST	National Commission for Science and Technology
BDF	Business Development Fund	NICI	National Information Communication Infrastructure
CAADP	Comprehensive Africa Agriculture Development Programme	NIP	National Industrial Policy of 2011
CIP	Crop Intensification Program	NIRDA	National Industrial Research and Development Agency
CMU	Carnegie Mellon University	NISR	National Institute of Statistics of Rwanda
CO2	Carbon dioxide	NRIF	National Research and Innovation Fund
CPCs	Community Processing Centres	NSI	National system of innovation
CST	College of Science and Technology	ODA	Official Development Assistance
EAC	East African Community	OECD	Organisation for Economic Co-operation and Development
EAPP	Eastern Africa Power Pool	OPEC	Organization of the Petroleum Exporting Countries
EDC	Energy Development Corporation	PSDS	Private Sector Development Strategy
EDPRS	Economic Development and Poverty Reduction Strategy	PSF	Private Sector Federation
EICV4	Integrated Household Living Conditions Survey 4	PSTA	Strategic Plan for the Transformation of Agriculture in Rwanda
EPD	Energy Private Developers	R&D	Research and development
ESSP	Education Sector Strategic Plan	RAB	Rwanda Agriculture Board
EU	European Union	RCA	Rwanda Cooperative Agency
EUC	Energy Utility Corporation	RDB	Rwanda Development Board
FDI	Foreign direct investment	REG	Rwanda Energy Group
FONERWA	Green Fund (National Climate and Environment Fund)	REMA	Rwanda Environment Management Authority
GDP	Gross domestic product	REP	Rwanda Energy Policy
GII	Global Innovation Index	RIEF	Research and Innovation Endowment Fund
HDI	Human Development Index	RIMP	Rwanda Industrial Master Plan 2009-2020
IAESTE	International Association for the Exchange of Students for Technical Experience	RISA	Rwanda Information Society Agency
ICT4RAg	ICT for Rwanda Agriculture Strategy	RSB	Rwanda Standards Board
ICTs	Information and communication technologies	RURA	Rwanda Utilities Regulatory Agency
IEA	International Energy Agency	RWF	Rwandan Franc
ILO	International Labour Organization	SDG(s)	Sustainable Development Goal(s)
INSEAD	Institut Européen d'Administration des Affaires	SMEs	Small and medium-sized enterprises
IP	Intellectual property	SRMP	Smart Rwanda Master Plan
IPCC	Intergovernmental Panel on Climate Change	STEM	Science, technology, engineering and mathematics
IPRCs	Integrated Polytechnic Regional Centres	STI	Science, technology and innovation
KIC	Kigali Innovation City	STIP	Science, Technology and Innovation Policy
KSEZ	Kigali Special Economic Zone	TVET	Technical and Vocational Education
LPG	Liquefied petroleum gas	UNCTAD	UN Conference on Trade and Development
MINAGRI	Ministry of Agriculture and Animal Resources	UNECE	UN Economic Commission for Europe
MINALOC	Ministry of Local Government	UNESCO	UN Educational, Scientific and Cultural Organization
MINEACOM	Ministry of Trade, Industry and East African Community	UNIDO	United Nations Industrial Development Organization
MINECOFIN	Ministry of Finance and Economic Planning	UR	University of Rwanda
MINEDUC	Ministry of Education	WDA	Workforce Development Authority
MININFRA	Ministry of Infrastructure	WEF	World Economic Forum
MINIRENA	Ministry of Natural Resources	WHO	World Health Organization
MYICT	Ministry of Youth and ICT	WIPO	World Intellectual Property Organization

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Executive summary

Part I: STI policy and innovation in Rwanda

1. Introduction

The Science, Technology and Innovation Policy (STIP) Review of Rwanda was conducted at the request of the Government of Rwanda and under the work programme of the UNCTAD Science, Technology and Information and Communication Technologies Branch. The STI Policy Review is based on interviews and field observations gathered during a first mission to Rwanda from 17 to 29 April 2016, as well as on the analysis of published documentation and economic data.

Rwanda has had a successful development trajectory during the last twenty years. It has benefited from determined leadership that has achieved a high degree of policy strength. It aims to become a regional leader in Science, Technology and Innovation (STI), with a particular focus on Information and Communication Technologies (ICTs). Industry and agriculture are, as well, of great importance to policymakers. The awareness that STI is the root enabler of economic growth is firmly established in Rwanda's economic thinking. An important policy aim is for investments in STI to have an increasing impact on business and industry.

There exist several specific challenges for STI policy. The key issue is innovating and using technology to build competitive and comparative economic advantages. The question of generating demand for technology in industry requires greater attention. The technological dynamism among firms is at levels appropriate to the development stage of Rwanda and will require focused policy attention in order to support national development ambitions. A related objective is strengthening linkages among key STI stakeholders: firms, academia and training institutions, government, and public and environmental interests. This diversity of challenges means that STI policy needs to be formulated and implemented using a conceptual framework of a national system of innovation (NSI).

2. A unique country

Rwanda has experienced a growth rate of gross domestic product (GDP) at about 13 per cent per year for more than a decade.¹ It is praised as one of the most competitive countries of Sub-Saharan Africa. Total GDP is about \$8 billion, while GDP per capita is about \$700. The country's progress in human development is also striking. The rate of poverty has been reduced from 56.7 per cent in 2006 to 44.9 per cent in 2011 and should be well below 40 per cent at the time of writing, assuming an annual poverty reduction rate of 2.4 per cent.² More than 80 per cent of the population is covered by a national medical mutual insurance scheme. There is, as well, notable progress on the Human Development Index (HDI).

These noteworthy changes have been made possible thanks to a strong and visionary leadership broadly supported by the population. This has been matched by a capable executive government with a heightened level of commitment developed through a unique system of individual performance contracts – *Imihigo* – implemented in the national administration and public service. It was introduced in policy implementation after evaluations of development policies in the late '90s had a negligible impact on poverty reduction. Its introduction demonstrates the capacity of Rwandan policymakers to identify weaknesses and failures and use these as inputs in a learning process. What seems at first glance to be a performance management competency is in fact a strong indication of the Rwandan potential to innovate.

There are, however, serious challenges to ensuring the long-term sustainability of Rwanda's development process. A high population growth rate of 2.4 per cent per year and a high population density more than ten times the Sub-Saharan average challenges the sustainability of its development trajectory. Rwanda needs to create around 200,000 off-farm jobs every year in order to absorb new job seekers from rural areas, where 80 per cent of the population still lives. A persistent trade deficit is becoming a major issue: exports of \$684 million cover just over one third of the \$1,917 million in imports while high transportation and logistics costs, due to Rwanda's landlocked position, decrease its export competitiveness.

3. Visions and actions

The development of the country is based on a strategic document entitled Rwanda Vision 2020. It envisions Rwanda as a middle-income country, with a services-oriented and knowledge-based economy. Vision 2020 aims to position Rwanda as a pioneering and dynamic knowledge economy and innovation hub in the East African Community (EAC). The objective is to generate a large quantity of jobs for an increasingly better qualified youthful population. Digital and other technologies will be key in growing industry and services, as well as developing and commercializing agriculture.

Vision 2020, is implemented through a series of medium-term planning frameworks among which are the Economic Development and Poverty Reduction Strategies (EDPRS 1 2008-2012 and EDPRS 2 2013-2018). Vision 2020 sets an ambitious targets of 11.5 per cent GDP growth per year, the percentage of the

population under the poverty line reduced to be less than 20 per cent, a GDP per capita of \$1,240, and a restructured economy where services and industry amount to 76 per cent of GDP in 2020, up from 68 per cent in 2011.

Vision 2020 establishes that becoming a knowledge-based economy is a key development objective for Rwanda. Through EDPRS 1 and 2, support has been given to education and training for science and technology and ICTs. Rwanda has the highest primary school enrolments in Africa: 98 per cent for girls and 95 per cent for boys. The Technical and Vocational Education (TVET) system has been expanded, with an almost doubling of enrolments in five years, from 51,000 in 2010 to 94,000 in 2014. The University of Rwanda includes a College of Science and Technology with more than 6,000 students.

Three successive plans have supported the development of the ICT infrastructure and services. Following the liberalization of the telecom sector in 2000, the first ICT strategy (2005-2010) saw the deployment of the ICT infrastructure, including the build-up of a fibre-optic network over the entire territory. Last mile connections were consigned for development by mobile telephony companies. For 2015-2020, the fourth five-year ICT plan – the Smart Rwanda Master Plan (SRMP) – aims to increase the private sector's involvement, narrow the digital divide, improve e-government, and engage the youth in digital society.

A National Commission of Science and Technology (NCST) was established in 2012 to advise the Government on policies, legislation and regulation in the fields of science, technology, research and innovation, and to monitor the implementation of such policies and legislation. NCST is ambitious about its proposal for a National Research and Innovation Fund (NRIF) that will support and promote national science, innovation, technology, and research in order to increase the national research and development (R&D) efforts to one per cent of GDP.

4. Strategic issues

The overall knowledge economy investment is impressive. Internet penetration has increased to around 33 users per 100 people, while mobile phone penetration is above 78 subscriptions per 100 people (RURA, 2016). It may be the case that fixed broadband Internet subscriptions underestimate the actual state of ICT development, as they present a technologically challenging solution for much of Rwanda's mountainous territory outside the main urban centres. Similarly, 4G LTE³ coverage is only meaningful as an indicator of digital development to the extent that it is actually used for large data transfers. The question is then: which factors can influence an increase in data use? One is the amount of e-commerce, both among firms and between firms and consumers.

The national research and development efforts are modest. What is perhaps of greater concern is that the low level of R&D activity in firms is difficult to document and empirically assess. While raising public and private R&D spending is important, Rwandan policymakers are keenly aware that an improvement in R&D indicators will be validated as impactful by actively linking STI and development policy with R&D efforts in firms and industry.

A critical review of EDPRS 2 suggests that the policy treatment of innovation focuses on institutional innovation, and innovation as a component of green-sustainable energy and ICTs sector development.⁴ Innovation is not a linear process – the activities of science, R&D and commercialization do not necessarily follow any particular order – and any improvement in science or R&D indicators will not automatically cause an increase in innovative outcomes and diversification in the national economy. Innovation originates in research efforts but it does not materialize until producers have developed and scaled production that is commercially feasible in the given market conditions. Whether scientific discoveries or technologies become innovations depends not on the amount of science and research activities, but on the receptiveness or technological culture of entrepreneurs, engineers, technicians and workers in industry, knowledge-workers and consumers (World Bank, 2010).

Rwanda's innovation efforts in promoting high-tech sectors, such as ICTs and life sciences, are commendable. However, their outcomes will only be sustainable if improvements are made to innovation performance in the more mundane but essential activities that form the economic backbone of industry and agriculture. The STI policy effort in Rwanda is primarily focused on ICTs which are an obvious choice as they are both a service sector which is of interest to international investors, as well as an enabler and a framework condition for the knowledge economy. While this is an indisputable policy proposition, a broader consideration of the nature of the technological progress of Rwanda is needed.

Rwandan policymakers may need to infuse EDPRS 3 with a macro-level understanding of innovation. This should not be a challenge because, as the UNCTAD mission witnessed, the general understanding of innovation among policymakers is current and not lacking in any significant way. The question that inevitably arises is how to move this understanding of innovation into the policy domain? The strategic response lies in developing an NSI framework and operational strategy and improving the absorptive capacity and technological receptiveness of the economy as a whole.

5. Firms, entrepreneurs and supportive measures

Rwanda's firms and entrepreneurs, in particular those outside of ICTs and related business, will need to improve their innovation capacities in order to increase their impact on the Rwandan economy and society. Expectations of industrial development have yet to be fulfilled and the current growth is underwhelming and insufficient to enable significant structural transformation. Agriculture loses only about 0.75 per cent of its share of GDP every year, with industry and service splitting the difference as their modest gain. Adding together manufacturing, construction, mining, water and power gives a tally of about 15 per cent of GDP for industry. Services account for 48 per cent of GDP.

The Rwandan business culture appears rather conservative, although efforts towards quality improvements, industrial design, and branding have been made, notably for import substitution or to improve export performance. The most proactive entrepreneurs operate in the ICT sector. President Kagame affirmed that he considered internet access to be a public utility and there is confidence in the enormous potential of a Rwandan ICT-based industry.

Financial conditions for entrepreneurship are difficult. One obstacle is the relatively high-level of interest rates for loans available from banks. These hover around 17 per cent. Another issue is the absence of an efficient investment framework with clear incentives for local investors, in contrast with the favourable conditions on offer to foreign investors. There is a need to energize early innovation stages and start-ups, and enlarge the pipeline of venture proposals with strong innovation components. Policymakers have reacted and there are encouraging developments in the STI funding landscape. The establishment of large funding mechanisms is in the works: the Rwanda Innovation Fund and the National Research and Innovation Fund. Once operational, a bias towards the innovation component of STI needs to be considered.

6. Technological research services and sector programmes

Technological research services and sector programmes are present the greatest challenges for the national innovation support structure. There exists a relatively well-equipped RSB. However, its mandates may need strengthening in order for it to have a broader impact on innovation. The most developed research infrastructure is in the agriculture sector where there are noticeable achievements. The R&D infrastructure for industrial technology is very modest and needs strengthening. The most significant effort to-date concerns the high-tech sectors, with the planned development of Kigali Innovation City (KIC), for which support and funding have been pledged to an estimated \$100 million.

The Government has launched ambitious plans for the high-tech sectors and developing Centres of Excellence in advanced technologies. However, it is important that the agro-food sector, industry and medicine and health-related sectors receive due policy attention. Vision 2020 established that developing technological research services is a primary policy element. To this end, the National Industrial Research and Development Agency (NIRDA) was established in 2013 as a department of the Ministry of Trade, Industry and EAC Affairs (MINEACOM) and to support R&D projects of economic value for industry. NIRDA funding in 2014/2015 was about \$ 1.2 million or 4.5 per cent of the total MINEACOM budget while its R&D expenditure was approximately \$210,000 or 0.8 per cent (MINEACOM, 2016). Some strengthening of NIRDA's R&D activities may thus be needed in order to better match development ambitions.

7. Education structures and initiatives

The Rwandan transformation of its education system is a remarkable success. The policy objective is summarized as, "... ensuring equitable access to quality education focusing on combating illiteracy, promotion of science and technology, critical thinking, and positive values" (MINEDUC, 2013b). Improvement in science and technology environments in schools, and developing demand-driven and relevant science and technology curricula, will require interaction with other STI stakeholders, including financial firms and industries. The Ministry of Education, recognizing the importance of leading in the practice of innovation, launched an Innovation for Education fund in 2012. The fund finances innovative pilot projects on improving children's learning. The Innovation for Education has so far supported 26 pilot projects with funding worth \$15 million provided by the Department for International Development (DFID). Rwanda spends around five per cent of its GDP on education, including tertiary education.

In spite of progress, the problem of mismatches between work competencies and qualifications is acute and more than 13.5 per cent of higher education graduates do not find a job in the year following graduation (NISR - EICV4, 2016c). On the other hand, the supply of technical skills for maintenance, service and repair of machines used in industry fall short of demand and are often imported. To monitor the achievements of education and training efforts the Government has established a Capacity Building Services and Employment Board (CESB). It oversees the identification of training needs and gaps, and coordinating an institutional and policy response. The Board of Directors of CESB is composed of seven members appointed by a presidential order. All major ministries are present in the overall governance and take on roles appropriate to their mandates.

8. STI and the institutional setting

A knowledge-based development strategy requires strong leadership and this implies some level of formalization of the national system of innovation. The NCST, the key national STI policy body, manages and evaluates the outcomes of the NRIF activities. In order to bring Rwanda's performance in innovation to a higher level, policy activities that emphasize more the innovation aspects of STI processes may deserve preferential treatment from NRIF. This is acknowledged by new policy orientations. The establishment of a high-level national innovation body with decision-making powers may merit consideration.⁵ It should be chaired by the highest level of leadership from Government, business and academia and would ensure that the overall STI strategy is well integrated into the broader development strategy of the country.

To ensure policy success, it may be necessary to consider ways in which the *Imihigo* performance contract system can be leveraged to respond to the challenges of an innovation-driven economy. One possibility may be to, on evaluation, give increased merit to innovation-led performance commitments. *Imihigo* could increase the inclination of individuals and institutions to be more open to risk-taking and improve their innovation performance.

The current deliberations on developing a follow-up to the 2006 Policy on Science, Technology and Innovation will produce a strategic document that will govern STI in the next decade, and therefore utmost care needs to be taken in setting the context and in proposing goals and actions. The process of developing a future STI policy document may reflect on a number of critical issues. Innovation should be at the core of the national STI & Research strategy. The share of the funding and R&D activities that comes from the business sector will be an important success indicator. The question the institutional location of funding vehicles is important. Current best practice favours a separation of implementation and funding to increase the level of accountability and can improve financial control. Finally, institutional arrangements needed to support a national innovation system may need deeper consideration.

Part II: STI policy in sectors and industries

9. The energy sector, development and STI

Energy production and access in Rwanda is an important framework condition for STI policy. With regard to the development of industry and technology intensive sectors such as ICTs, it is an important factor for profitability and international competitiveness. Energy is, as well, a services sector with substantial growth perspectives. On the other hand, a large segment of Rwanda's population lives in rural areas, attains its livelihood through subsistence agriculture, and is responsible for 80 per cent of national energy consumption mostly generated from biomass – mainly wood and charcoal used for cooking.

Rwanda's energy policy is established in the Vision 2020 development plan. It proposes that by 2020 at least 75 per cent of the population will be connected to electricity (up from two per cent in 2000 and 11 per cent in 2010) and the consumption of biomass will decrease from the current 86.3 per cent to 50 per cent of national energy consumption. Vision 2020 explains the need for the private sector to invest in energy production and distribution, instead of acting only as a consumer. Rwanda sees the development of energy capacity through multiple smaller projects, distributed throughout the country and using a mix of carbon and renewable sources and technologies. Policies feature a pronounced pro-market and pro-industry character aiming at reducing energy costs for firms while, at the same time, eliminating subsidized electricity tariffs.

Planned energy capacity development will cost in excess of \$2 billion.⁶ However, success in attracting private sector investment partners makes it more likely that the Government will not be the only, or even the main, source of funding for future projects. The key element in the build-and-operate model in contracts, recently pioneered with Chinese and Turkish investors, is the confidence in the ability of Rwanda Energy Group to purchase electricity from the investor-operator at the agreed prices and terms and conditions.

Linkages between energy and ICT policy is an important consideration. An underperformance of ICT use in business and industry and declining use when moving away from urban centres is observed. While it would be an oversimplification to say that poor energy access leads to declining ICT use, these phenomena are related. Industry has different requirements for its ICT environment, compared to private use, and these include energy access. It would therefore be prudent to review the policy environments for energy and ICTs, with a view to strengthening policy synergies. A more general issue is that near-term operational energy capacity targets vary widely. Forthcoming policy revisions may benefit from producing implementation programmes as business plans or logical frameworks. This would contribute to developing assessment and evaluations that would easily feed back into policy, and provide a clear base for policy learning.

10. Information and communications technologies and economic transformation

The Government of Rwanda has committed to developing a world-class internet and mobile telecommunications infrastructure. It proposes using ICTs "... to deliver better services, create jobs and

transform the Rwandan society and economy" (SRMP). President Paul Kagame has declared that, "*The internet is a needed public utility as much as water and electricity.*" Rwanda policymakers see the move towards an ICT-fuelled knowledge economy as a long-term project of transformation. Vision 2020 encourages the use of ICTs as "... a tool for self-employment, innovation and job creation." It also sees ICTs as an important element for developing the economic potential of the country's youth. From the Government's own perspective, it is committed to improve the use of ICTs in public services delivery.

Since 2000 the information and communications sector has grown more than tenfold and is steadily increasing its stake in GDP. Currently, there are 12.8 million mobile subscriptions – more than double compared to 2012 – with penetration rate exceeding 100 per cent.⁷ Mobile coverage is almost 100 per cent while 4G LTE⁸ mobile broadband services are available through the three mobile providers. There has been much progress in e-governance with the *Irembo* platform providing diverse services such as immigration, registrar services, driving licences, and land title transfers. There has been progress in telemedicine, with almost all health centres connected to the Internet. Linking the agriculture sector with ICTs is a critical element for energizing Rwanda's development and the National ICT 4 Agriculture Strategy (2016-2020) underscores the need for developing linkages with other national STI stakeholders. The use of ICTs to increase access to financial services is implemented thorough mobile payment technologies. The year 2015 saw mobile transactions in Rwanda exceed \$1.2 billion (MYICT, 2015).

A number challenges can be identified. The first challenge is to transform and improve the quality of governance in Rwanda using ICTs. The second challenge is to develop an ICT sector beyond mobile telephony services.⁹ The third is to develop an ICT sector which would evolve into an ICT hub for the EAC. This will require, among other things, increasing institutional capacities, as well as building awareness among firms as to the purpose and practical application of intellectual property (IP). The fourth is to have ICT start-ups benefit from government procurement to launch production or to scale-up operations to levels that are competitive internationally and with established firms. Care should be taken not to use the provisions given in article 5.8 of the Public Procurement User Guide to discriminate against domestic ICT SME. A fifth policy consideration is the issue of funding ICT start-ups and scaling-up. A sober appreciation is required of the unsurprisingly high business failure rates in the ICT sector. A broad range of investors need to be present, including angel investors, and venture capital – both private and in public-private partnership, capital markets and private equity. Finally, linking ICT policy and commercial activities with the rest of the national economy needs to be a primary focus.

The Kigali Innovation City project will, by design, provide support for tackling some of these policy challenges. Policymakers should take care that knowledge transfers generated by KIC grow and develop in depth, that tenants and supporting institutions do not retreat into operational silos and that KIC operations are not assessed and evaluated as a real-estate project. However, not all ICT start-ups will be able to become KIC tenants and support for alternatives providing hosting and interaction with trainers, researchers and academics should be established as a long-term policy. These may be established at Rwanda's university and vocational training institutions across the country.

ICT policy is currently implemented under the SMART Rwanda Master Plan 2015-2020 (SRMP). It highlights the need to use ICTs to transform Rwandan society and its economy. SRMP establishes six key deliverables, three of which deal with the effective use of ICTs to provide quality government services, while the other three focus on developing private sector business opportunities, job creation, and the overall contribution of the sector to economic growth and GDP. The success of SRMP is critical. However, it is also a policy vision of great complexity. This presents challenges in implementation and evaluation. Two policy directions may be helpful in assisting with this complexity. The first would be to establish an *ICT sector innovation system* locus. Its objective would be to develop and energize the linkages and interactions among ICT stakeholders that are needed to make SRMP work. The second would be to advance a very practical business plan or logical framework for SRMP implementation.

11. Agriculture and STI policy

Agriculture accounts for 35 per cent of GDP and employs 80 per cent of the workforce. Agricultural policy in Rwanda has multiple objectives and unavoidably engages in common issues of rural development: poverty alleviation and income distribution, the transformation of the informal economy, health, education and gender, etc. Policymakers are also tasked with transforming agriculture into an engine of growth, with developing and commercializing the sector, and with exploring its export potential beyond the traditional coffee and tea trade.

The response to this challenge in Rwanda can be seen in all the positive developments on the ground. As a component of the EDPRS, the Strategic Plan for the Transformation of Agriculture in Rwanda (PSTA) was developed and implemented by the Ministry of Agriculture and is now in its third phase (PSTA 3: 2013-2018). The ultimate goal of the PSTA is to rapidly increase agricultural output and incomes under sustainable production systems and for all groups of farmers, and to ensure food security for the entire population. To accomplish this, it sets out several lines of action, including production intensification,

commercialization and agribusiness development. PSTA 3 intensifies STI policy prerogatives with its Program 2 entirely reformulated to address the area of research, technology transfer, and professionalization of farmers. PSTA 3 has a budget and broad donor support of more than \$1.2 billion (World Bank, 2014). However, budgetary allotments for the STI oriented Program 2 are only about seven per cent of total planned expenditure.

The application of technology and success in innovation for commercial production in Rwanda's rural economy will create a certain disparity among farmers. Land access and use policies, particularly for land under government management, will be a differentiating factor. Government support for exportable commercial agriculture should not result in the risks of mono-cropping being shifted to poor farmers who agree to go commercial and reduce farming for their own consumption. Technology and innovation bring their own specific problems to agriculture. For any given technology, an important question is: how does it scale? Does it travel well from the lab to the testing ground, and then into the real economy? What will the source of revenue be to sustain the technology?

The key policy challenge is that of prioritization and structure. Many PSTA policy goals have similar or equal levels of importance and priority. That *everything is important* in a development context is an unavoidable truth. However, resources are limited and some differentiation by scope or purpose should be considered useful, especially when looking to technology and innovation for solutions – an endeavour that is inherently risky and which requires enduring occasional failure in order to generate success. More generally, soft innovation in policy and practice will be also important. Redefining consumer preferences and expectations, in concert with the development of commercial agriculture, will be important, as developing products for export only, without a domestic consumer base, is doubly and unnecessarily risky. For example, while coffee is a major export, annual coffee consumption per capita is about 35 grams, compared to 5.8 kg for Brazil or 1.8 kg for Colombia. There is no need to repeat this kind of outcome in other agricultural sectors and products.

12. Industry transformation and STI

Rwanda's development goal is to become a middle-income nation. The change in the relative size of industry and its contribution to economic growth can be an indicator of the strength of economic transformation processes. Between 2006 and 2015 industrial output grew at an average yearly rate of 9.3 per cent and its share of GDP grew from 12 per cent to 14 per cent during this period. This was slightly faster than the 7.7 per cent average growth in the entire economy, but was not sufficient to have a major transformative effect on the economy. Industrialization is a difficult process for many developing countries as it requires long-term perspectives on finance, STI and governance. The difficulties of industrialization are compounded by the dynamism of the global economy and the processes of globalization, financialization and the fourth industrial revolution should be considered during policy formulation.

The Rwanda Industrial Master Plan 2009-2020 (RIMP) focused on four key inputs: energy, transport, water and ICTs. It aimed to create a good business environment, enable export, and develop human capacities. RIMP was succeeded by the National Industrial Policy of 2011 (NIP). NIP sets out goals in terms of industry participation in GDP, investment and employment. It proposes three objectives: increasing production for domestic consumption, increasing exports, and developing an enabling business environment. NIP expounds an evolved level of understanding of innovation and how it relates to commerce and entrepreneurship on the one side, and to science, R&D and applied research on the other. However, there is some uncertainty about whether such an understanding is fully shared with national STI funding mechanisms. A general impression is that firms commercializing innovation – the part that carries the bulk of the risk and uncertainty of the process – are left to explore funding from banks. Such funding mechanisms may be suitable for trade and business where turnover is quick while capital investment is small, but not for industry and especially not where there is a significant innovation component.

Given Rwanda's limited resources, any science and R&D programmes that do not have clear innovation outcomes either commercial or through the provision of public services, may potentially crowd out more useful R&D activities. R&D which is not in concert with specific industry and economic development goals may not find its expression in a process, product or service. It follows that it will also not be able to contribute to generating a return for its financers, which would be the entirety of Rwandan society in the case of public R&D funding.

NIP is keenly aware of these issues and MINEACOM has set up NIRDA to operationalize some of these concerns. However, the job is much greater than establishing a responsible agency while the need to develop better coordination and coherence between policy and action among a broad spectrum of stakeholders is a key concern. One policy option is to develop an industry innovation system coordination framework. At this point, a better proposal may be to ensure that industrial policy and innovation needs become the cornerstone of a national system of innovation. The rationale is that much, if not all, of the top-level STI concerns will perfectly map from an industry sector innovation system to the national one.

Part III: Conclusions

13. Conclusions

Rwanda has made remarkable progress in the last twenty years. Nevertheless, there is no letting up and policy ambitions and development aspirations are at a high point. Becoming a knowledge-based economy is the target. Technology, and in particular ICTs, are central to this strategy and therefore STI policy becomes a key factor. Innovation is happening in Rwanda and policymakers are keenly aware of innovation as an enabler of economic growth. The idea that development requires knowledge and technology comes naturally to Rwanda's policymakers, entrepreneurs and youth. The conviction is there, the test is in the details of implementation.

There is a prominent level of coherence in high-level policy, unified behind Vision 2020 goals. A key factor in implementing Vision 2020, development and STI policies and targets, is the system of *Imihigo* performance contracts. *Imihigo* is an example of the capacity of Rwandan policymakers to identify systemic weaknesses and use these as inputs in a learning process. However, *Imihigo* may need to better address the challenges of STI by differentiating the merit awarded to specific commitments, depending on their innovation potential.

An important challenge is developing the national system of innovation. This means increasing cooperation across policy domains, the development of linkages among STI stakeholders and evolving a broad consensus on the meaning and role of innovation. It is critical for enabling cooperation and coordination between various sectoral and thematic policies and their institutions. The establishment of a mechanism for better and greater involvement of all concerned frontline ministries in STI policy design and implementation processes, with appropriate oversight of their engagement at the highest level of governance is recommended. The National Council for Science and Technology could play this role if by providing a platform for long-term, active involvement of key ministers and develops beyond an advisory role. This would follow international best practice and could help develop an innovation governance model suited to Rwanda's development ambitions.

There are many factors that will affect the ability of Rwanda to take advantage of STI and that require the acute attention of policymakers. For the purpose of this summary, five may be highlighted.

The first is the development of policy and actions supporting the strengthening of a Rwandan national system of innovation. These should necessarily be established at the highest level of leadership and their institution should result in decision-making rather than the providing of guidance.

The second factor is investment in human capacity development relevant for the knowledge economy. This necessarily means establishing strong links between education and training institutions, and proposed or functional centres of excellence with support and funding from NCST and NRIF. This may require aligning the skill demands of industry with the output of schools, universities and vocational training institutions and revisiting the enrolment intake for degrees and qualifications that have poor employment results.

A third factor is the development of absorptive capacities in mainstream services, sectors and industries, and using high-tech innovation loci, such as the ICT industry, innovation hubs and centres of excellence, to leverage the development of technological receptiveness throughout the entire economy. This requires energizing the business community. Outside ICTs, the business culture is conservative and concedes that incentives for investment, let alone technological upgrading, are insufficient.

The fourth factor is the consolidation of the innovation funding and financing ecosystem. There are several funding agencies, all with slightly different funding capacities, and looking for different but more-or-less overlapping deals. Improved clarity on the possibilities of funding the innovation end of the STI spectrum, including commercialization and scaling-up, is needed. The establishment of the NRIF may contribute to resolving this important issue.

The fifth factor is achieving a critical mass of R&D programmes and projects that will tip Rwanda's development into a knowledge economy trajectory. R&D must squarely aim at contributing to solving the problems and challenges in production, in the real economy. Rwanda's continued progress and participation in regional integration and EAC processes will stimulate its industries and sectors to increase their innovation performance as its firms and entrepreneurs are challenged by larger and more competitive markets.

Part I: STI policy and innovation in Rwanda

1. Introduction

1.1 STI Policy Review rationale

This Science, Technology and Innovation Policy (STIP) Review of Rwanda is conducted on the request of the Government of Rwanda and under the work programme of the UNCTAD Science, Technology and Information and Communication Technologies Branch. It is a qualitative assessment and aims to produce policy recommendations for the consideration of the Government.

The STIP Review is based on interviews and field observations gathered during a first mission to Rwanda on 17 to 29 April 2016, as well as on the analysis of published documentation and economic data. Revisions to an initial draft are made in two rounds. The first revision was made after a national workshop held in November 2016. The second revision was conducted at the end of 2016 year after a final round of consultations with stakeholders and counterparts. This UNCTAD analysis builds on recent reviews of the Rwanda science, technology and innovation (STI) system and policies.¹⁰ UNCTAD's approach takes a broad perspective, treats the STI and development agenda in a holistic manner and uses an innovation system framework. Box 1 presents the basic elements of the national system of innovation concept.

Rwanda has had a successful development trajectory during the last twenty years, in spite of an unfavourable start. It has benefited from determined leadership that has achieved a high degree of policy strength, both at strategic levels and in implementation. The values of professionalism, determination and the overarching goal of peace and security are evident in their daily implementation. Rwanda's development goals are ambitious. The challenges the country faces are inspiring and motivating the nation to become a regional leader in STI, with a particular focus on

Information and Communication Technologies (ICTs).

Industry and agriculture are of no less importance to policymakers. Much has been done to facilitate the establishment and operation of firms and enterprises. Rwanda is open for business. Still, many challenges lie ahead. The Government has engaged in study and dialogue with many reputable international institutions and experts. Regarding the STI Policy Review conducted by UNCTAD, the key concern is the integration of STI in the overall development strategy of the country and the use of STI policy instruments to transform and further energize Rwanda's economic development. There are several positive policy developments addressing these challenges, including the new National STI and Research Policy which will be discussed in chapter 8.3.

1.2 Challenges for science, technology and innovation policy

Rwanda faces a series of macro challenges in the development of its STI policies and innovation system. These challenges are well known and several are particularly important. Growth is robust but a high population growth moderates gross domestic product (GDP) growth per capita. Rwanda's high population growth generates youthful dynamism, but also creates an immense demand for education and employment, both in the rural and farming economy and in industry and services. As a result, immediate development opportunities and entrepreneurial dynamism are focused in Kigali, while rural areas are challenged to move out of the informal economy. The trade deficit has become a permanent fixture and seems difficult to reverse. Its landlocked geography, a lack of diversified and competitive export sectors – coffee and tea are the core national exports – and large receipts of Official Development Assistance (ODA) funds, negatively influence Rwanda's trade and export competitiveness. ODA represents 40

Box 1: What is a national system of innovation?

A national system of innovation is a framework for developing and implementing STI policy. Its original objective was to better understand what causes the often significant differences between countries in terms of their capacity to innovate and, as a consequence, to then develop. To answer this question, Ludvall (1992) proposed exploring the "elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge". In other words, policymakers are guided to develop an understanding of why the intensity and quality of relationships and interactions among institutions such as firms, academic establishments, and government bodies are critical to STI outcomes and, as a consequence, to economic development. If these relationships are weak and various policies act in isolation, the development effects of investments in STI will be sub-optimal.

Why are interactions the key issue? While innovation takes place essentially within firms, firms do not engage in learning and innovation activities in isolation. Firms interact with other firms, institutions and society at large, in order to participate in knowledge and technology creation and flows. The sum of their capabilities, interactions and knowledge flows, among themselves and with their environment, in any one country, is often referred to as the national system of innovation (NSI). An NSI exists regardless of the intensity of interactions, which can be weak in many developing and least developed countries, or the formal support that these interactions receive as a matter of government policy. The nature of the NSI in any country will largely depend on the interplay of many economic, historic and cultural factors. This means that the characteristics of an NSI are dynamic and constantly changing. They are also affected by diverse public policy activities. The NSI is a framework for implementing STI policy. The relationship between STI policy and NSI is symbiotic and mutually reinforcing.

Source: UNCTAD (2016)

per cent of the national budget – a position incompatible with aspirations to become a middle-income developing country.

There exist several specific challenges in developing a functional national innovation system. The key issue is positioning STI policy as the main contributor to building Rwanda's competitive and comparative advantages as an actor in the global economy. However, economic structural transformation is rarely even-handed or egalitarian. STI led development is a transformative process that requires the broadest participation of all of society's stakeholders. Left outside the scope of public policy, it can create antagonism between the inevitable winners and losers in the process. The key concern is balance, and in Rwanda this manifests itself in several ways. The first is a balance between human capital and job creation, often described as the skills gap, but which appears as under- or unemployment. A second is the balance of STI policy outreach by economic sector and by geographic region, and especially from an urban-rural perspective. A third is the policy balance for support between high technology sectors and activities and the traditional or mainstream industries and services.

Observations on specific technology policy issues raise a number of questions in the Rwandan context. The awareness of the need and role of technology-push policies is present and commendable. However, the question of generating demand for technology on the ground, and its place in STI policy, requires greater attention. A primary challenge here is the problem of underdeveloped linkages among key STI stakeholders: firms, academia and training institutions, government, and public and environmental interests. Another issue is the need to make greater use of regulation on technical standards and procurement policy. The challenge of scaling up – of graduating from a micro or small enterprise to a medium or large firm – is another concern with important technological factors, and where firms, in particular start-ups and new businesses, benefit from assistance programmes. Tacit knowledge transfers need greater support and this is mostly related to operational conditions and knowledge cultures within firms and among firms, as well as between firms and academia.

Given the diversity of challenges, STI policy needs to be formulated and implemented using a conceptual framework of a national system of innovation, and there are indications that the new National STI and Research Policy is being considered in this sense. Likewise, it is of prime importance that Rwanda builds a knowledge base and corresponding human capital that is in sync with its development aspirations. A key concern is the insufficient impact of STI policy on business and industry. The technological dynamism among firms is at levels appropriate to the development stage of Rwanda, but insufficient in keeping pace in a climate of forward acceleration. The idea that innovation is an outcome of research and development (R&D), rather than an entrepreneurial

activity, is not uncommon and needs changing. However, internal resources are inadequate and, as has been the case in other countries, policymakers may be guided towards considering foreign direct investment (FDI) and international partnerships, including development aid, as important sources for technological upgrading. With the above in mind, the STIP Review will look at several specific issues which are here noted in brief.

1.2.1 Firms and entrepreneurs

Most firms and entrepreneurs in Rwanda, like in many other countries, remain on the periphery of STI and, with the exception of the ICT sector, few of them engage in innovation. Policies that aim to fund R&D are a necessary component of STI policy. Nevertheless, these may not necessarily affect the key concerns of market oriented innovation, which are the development of technological absorptive capacities in firms, and the structure of incentives in the economy that motivate or discourage entrepreneurs to innovate. To-date, Rwanda has developed a number of enterprise support programmes. The policies that govern these activities however, need to be extended to produce more substantial innovation outcomes. A significant impediment to innovation is the low level of interaction and collaboration among firms and with academic and research institutes. When policy aims to facilitate the development of productive sectors and industries by supporting a pro-growth economic environment, this should necessarily mean exerting a positive influence on all players in the innovation system, going beyond providing financial support, by coaching firms in accounting and business planning.

1.2.2 The challenges of education

There are a number of positive initiatives at universities and institutions of higher learning in Rwanda. There is growing awareness of the need to create an innovation culture among science, technology, engineering and mathematics (STEM) students and technical trainees, as well as among those training in and studying soft disciplines relevant to commerce. Technical and vocational education programmes are well founded and valued among the business community. Central national policy is developing a factual and timely assessment of skill gaps and their effective narrowing through a combination of incentives and support measures. The issue is all the more serious given that Rwanda has a relatively young and growing population. Education and training must therefore be relevant to the youth as future job-seekers. Policy needs to work to strengthen the linkages between the productive sectors and training and educational institutions, both in establishing feedback loops to manage the nation's human capital, as well as in conducting joint R&D and innovation projects and programmes.

1.2.3 STI and the institutional setting

The importance of the determined commitment of top-level leaders in the Rwandan setting is self-evident. The presence of diverse STI stakeholders in policy formulation is robust, as far

as government authorities are concerned, while a greater involvement of academia, and especially industries and service sectors, would be beneficial. The main advantages to be found in this involvement would be in the energizing of stakeholders and their interactions, and the stimulating of positive changes in perspectives on innovation as a process firmly rooted in the activity of firms and institutions that aim to deliver commercial or social value. An important component in the institutional setting is the consideration of linkages between diverse STI funding instruments and the actual STI objectives as elements of a national development strategy.

1.3 Development and STI policy

Economic policy often starts with getting trade and finance issues right. In addition, it will address specific sectors in industry, agriculture and services, and will consider a range of cross-cutting issues such as gender, intellectual property, entrepreneurship, technology transfer, sustainability, or human capital development, to name a few. Among these is STI: a dauntingly broad policy domain. Fundamentally, it must be closely linked to the national development strategy. However, its own domain of action is complex. STI policy is challenged to address science at one end, and innovation as an entrepreneurial activity of technical and economic experimentation at the other, with applied research and technological development somewhere in between. The relationships between these elements are by no means linear or ordered in a rigid cause-effect direction. STI policy also needs to relate itself to other sector policies where technology and innovation are important elements. In this sense, ICTs, energy, industry and agriculture will be highlighted here, in the STI Policy Review of Rwanda. It follows that the challenge of development reveals itself to be more complex than simply correctly evolving a set of policies tailored to the local context.

Policies need to work together to accomplish a common goal, so achieving complementarity and coordination becomes a key issue. STI policy can successfully be holistic and comprehensive if it commits to assessing, developing and implementing programmes and activities using a national system of innovation framework.

Rwanda's development agenda, as defined in Vision 2020 and the Second Economic Development and Poverty Reduction Strategy (EDPRS 2), proposes a comprehensive catalogue of detailed policies. Horizontal linkages among policy fields are strongest at the strategic level. Moving towards implementation, various agencies engage with the detail of the work at hand, so that horizontal linkages become less obvious. They become implied, rather than explicit. However, while details matter, development is not a matter of mere details. The role and impact of policy areas that lie at the heart of the development process require clarity, with reference to the national

strategy as well as to their relationship with other policy domains.

Such a demand may be particularly challenging for STI because of the complexity of the issue and the difficulties in substantiating evidence of long-term progress. There are many indicators and synthetic indexes that can be used to assess a nation's STI capacity or capability. However, until recently, most of these have focused on assessing inputs into STI processes, rather than outcomes. This is a difficult proposition for many developing and least developed countries and should not deter policymakers from moving forward. For example, UNESCO data notes that Rwanda had about 12 researchers per 1 million people (the world average is 1,282), which begs the question: how is this, if at all, a meaningful indication of innovation for Rwanda?¹¹ The Rwandan nation is visibly developing, and every year new and improved products and services emerge from both the public and private sectors. The awareness that STI is the root enabler of economic growth is firmly established in Rwanda's economic thinking. The idea that increasing economic output, in physical and value terms, with less than corresponding increases in inputs, requires technology, comes naturally to its economic policymakers, entrepreneurs and youth. The conviction is there. The challenge is in the intricacies of implementation.

1.4 STIP review outline

The STIP Review has three parts. Part I begins with this introduction (chapter 1) before revisiting the remarkable rebuilding of the nation after the genocide of 1994, as well as the exceptional economic and social development experienced in the two decades that followed (chapter 2). The STIP Review then sketches out the main policies related to the development of a knowledge and innovation economy in Rwanda (chapter 3). The limits of the strategy and policies pursued so far are discussed, with a view to broadening the concept of innovation among policymakers, and more generally among all STI stakeholders and the population at large (chapter 4). The note then focuses on actions taken, and further actions needed, to support innovation in the business sector (chapter 5). The development of infrastructure for technological research and services is examined (chapter 6). Education structures and initiatives are reviewed (chapter 7). The Review discusses key aspects of institutional settings for the coordination and management of STI policies (chapter 8).

Part II takes a closer at two framework conditions – the energy sector (chapter 9) and ICTs (chapter 10) – and the economic sectors of agriculture (chapter 11) and industry (chapter 12).

Part III proposes conclusions and summarizes the main recommendations of the Review (chapter 13). The Review ends with an annex and bibliographical references.

2. A unique country

2.1 An exceptional recovery

Rwanda has experienced a growth rate of GDP at about 11 per cent per year for more than a decade. It is praised as one of the most competitive countries of Sub-Saharan Africa. Total GDP is about \$8 billion, while GDP per capita is about \$700. Rwanda scores very highly relative to its development level in the World Bank's Doing Business surveys. Its landlocked geography and difficult transport logistics make trading across borders its key challenge. According to the World Economic Forum,¹² the main positive factors explaining the economic performance of the country include the quality of its institutions (ranked 17th), its low level of corruption and high-level of security, the efficiency of its labour market, and the level of primary education. As recently as May 2016, Fitch Ratings has affirmed Rwanda's ratings as "B+ with stable outlook."¹³

The country's progress in human development is also striking. The rate of poverty has been reduced from 56.7 per cent in 2006 to 44.9 per cent in 2011 and should be well below 40 per cent at the time of writing, assuming an annual poverty reduction rate of 2.4 per cent.¹⁴ More than 80 per cent of the population is covered by a national medical mutual insurance scheme. That a least developed country such as Rwanda has committed to developing a health financing system as an essential and fundamental element of social and economic development is remarkable.¹⁵ There is notable progress on the Human Development Index (HDI), which has increased from 0.232 in 1995 to 0.483 in 2015. However, Rwanda still ranks 163rd among 188 countries in 2015.¹⁶ Nevertheless, policies that influence people's livelihoods have medium- to

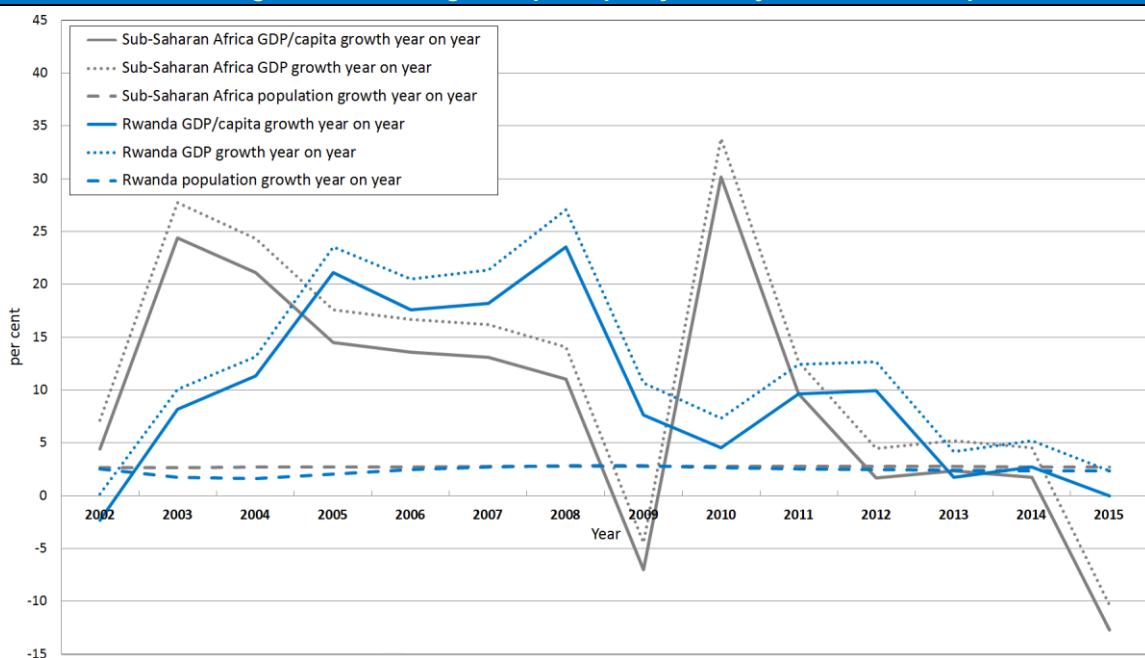
long-term impacts, and therefore continuous improvement in the HDI can be expected throughout the next decade.

These noteworthy changes have been made possible thanks to a strong and visionary leadership broadly supported by the population. This has been matched by a capable executive government with a heightened level of commitment developed through a unique system of individual performance contracts – *Imihigo* – implemented in the national administration and public service. The engagement of highly educated expatriates returning home to discharge assignments, both in the public and private sectors, is also an important development factor. However, Rwanda's development success is not at all an exclusively top-down exploit. This exceptional recovery owes as much to a series of far-reaching, home-grown activities aimed at reconciling communities. These include local tribunals, established on an extensive scale throughout the territory, to judge those implicated in the genocide, *Gacaca*, which is the practice of engaging all citizens to work in the collective interest every month, *Umugunda*, which refers to solidarity measures such as the One Cow per Poor Family¹⁷, and *Girinka*, which aims to reduce malnutrition and improve welfare.

2.2 Challenges ahead

There are, however, serious challenges to ensuring the long-term sustainability of Rwanda's development process. First, despite excellent economic performance, the Gross Domestic Product (GDP) per capita is not progressing as fast as it can and is still slightly below the average in Sub-Saharan Africa. There are many factors influencing this outcome, including a high population growth rate of 2.4 per cent per year.

Chart 1: GDP growth and GDP growth per capita, year-on-year 2002-2015, in per cent



Source: World Bank

Such a population growth is near to Sub-Saharan averages. However, Rwanda has a high population density more than ten times the Sub-Saharan average.¹⁸ This, on its own, challenges the sustainability of its development trajectory. Chart 1 presents an overview of growth trends since 2002.

Secondly, there is a need to create around 200,000 off-farm jobs every year in order to absorb new job seekers from rural areas, where 80 per cent of the population still lives. Efforts to commercialize agriculture will create some employment opportunity, however labour in small-hold and subsistence agriculture is already under-employed. There is a prominent contrast between the capital Kigali, where more than half of Rwanda's urban population lives, and rural areas, with considerable differences in standards of living and economic productivity. Although some progress has been made to reduce the inequality at the macro level, Rwanda seems to be evolving in two different worlds: a highly modern one in its capital, with a growing segment of relatively well paid urban professionals, and a traditional world in the countryside, with a large population close to the poverty line but managing to avoid severe economic hardship.

Thirdly, Rwanda's economic development is threatened by a persistent trade deficit: exports of \$684 million cover just over one third of the \$1,917 million in imports.¹⁹ The country's landlocked position, with distant access to international ports and trade routes, and the corresponding and significantly high transportation and logistics costs that decrease its export competitiveness, are among the factors that make it difficult for Rwanda to reduce its trade deficit. There are also structural issues in the economy. Export trade has always been difficult, meaning the incentives to develop export competitive sectors have remained low. This has a knock-on effect on the dynamism of the entrepreneurial culture and the appetite for innovation and risk taking.

Countries that are important trading nations will often score highly on innovation benchmarks.²⁰ The export side of the trade balance relies heavily on coffee and tea exports – two commodities that have fallen far from their recent highest international trading prices. Coffee peaked at around \$6.60/kg in 2011 and is currently trading at about \$3.3/kg. Tea is currently trading between \$2.3/kg and \$2.9/kg, also significantly lower than the peak price of \$4.0/kg in 2015 or the \$3.5/kg price average of 2011-2012.²¹ Due to price volatility, export earnings from coffee and tea are fickle and, at the time of writing, there are no indications that demand and prices will surge in the near future.

Finally, Rwanda is dependent on foreign financial assistance. ODA was about \$1 billion in 2014 and this needs to be referenced not only against GDP and the trade deficit, but also against the national budget, which is about \$2 billion. This situation is not compatible with a Rwanda's aspirations to become a middle-income developing country.

However, willing international support for Rwanda is a great advantage.

3. Visions and actions

3.1 The 2020 Vision and its implementation

The development of the country is based on a strategic document entitled Rwanda Vision 2020. Declared in 2000, and revised in 2012, it envisions Rwanda as a middle-income country, with a services-oriented and knowledge-based economy. The aspirations are organized into six pillars: good governance and capable state, human resource development, a private sector-led economy, infrastructure development, productive and market-oriented agriculture, and regional and international integration. There are also three cross cutting areas: gender equality, protection of the environment and sustainable resource management, and science and technology, including ICT.

Vision 2020, actively articulated and supported by the national leadership, is implemented through a series of medium-term planning frameworks: the Poverty Reduction Strategy Plan (PRSP 2002-2007), the 7-Year Government Plan (2010-2017), and the Economic Development and Poverty Reduction Strategies (EDPRS 1 2008-2012 and EDPRS 2 2013-2018). The basic objectives of the EDPRS are economic transformation, rural development, productivity and youth employment, and good governance. Vision 2020 sets an ambitious target for economic development of 11.5 per cent GDP growth per year, the percentage of the population under the poverty line reduced to less than 20 per cent, a GDP per capita of \$1,240, and a restructured economy where services and industry amount to 76 per cent of GDP in 2020, from 68 per cent in 2011.

The rebuilding of the country has also been made possible thanks to the establishment of a solid local administration organized in five provinces and 38 districts. A key factor in working towards Vision 2020 policies and targets policies has been the implementation of performance contracts, the so-called *Imihigo*. *Imihigo* is a Kinyarwanda word that refers to the setting of goals in an act of public commitment which will be evaluated. *Imihigo* was introduced in policy implementation after the evaluation of PRSP, which revealed that weaknesses in policy coordination, monitoring and evaluation contributed to a negligible impact on poverty reduction (ADB, 2012). Beyond the actual *Imihigo*, its introduction demonstrates the capacity of Rwandan policymakers to identify weaknesses and failures and use these as inputs in a learning process. What seems at first glance to be a performance management competency is in fact a strong indication of the Rwandan potential to innovate.

Vision 2020 recognizes the challenge of urban development and the need to avoid the creation of urban poverty. Like in many other countries in

Africa, there is a strong rural to urban migration, especially among the youth seeking employment outside of agriculture. The programme on developing secondary satellite cities aims to create jobs and livelihoods beyond those available in the capital Kigali. Currently, six satellite cities are under development based on existing urban centres. They are located across the country in order to nurture more geographically balanced development. However, there is an important caveat. STI, and especially the innovation end of the process, where commercial and social value are created, tends to happen in environments that attract large numbers of young, creative and ambitious people. This is a demographic that has a high-level of competitive energy and who bring together financiers, industry and consumers in numbers that make learning from experience – failure included – possible and, most importantly, survivable. Large cities are such places and, from an innovation perspective, no city can be too large. Therefore, while the satellite cities project is well placed to address the pitfalls of urban-rural migration, its implementation should not sterilize innovation by disabling the creation of critical mass needed for innovation conditions.

The Ministry of Industry and Trade, the Ministry of Finance and Economic Planning, and the Rwanda Development Board, among other equally important development stakeholders and institutions, have pursued a series of policies to raise the country's performances in these areas. A new investment code aims to stimulate FDI flows. Incentives include tax holidays for firms investing more than \$50 million, and a 15 per cent preferential flat corporate tax for investors in priority industries.²²

A new industrial zone has been established in Kigali, in which international investors have set up a number of manufacturing and transport firms employing more than 10,000 people. While conclusions must be carefully drawn, policies have already had positive results, as net inflows of FDI (as a percentage of GDP) have grown from an average of 1.7 per cent for the 2005-2012 period, to 3.7 per cent for 2013-2015, on a par with Uganda and Tanzania.

With a focus on local development opportunities, several Community Processing Centres (CPCs) have been established throughout the country, with more planned to commence activities. CPCs are active mainly in agricultural processing and related industries (dairy, Irish potatoes, leather, ceramics, honey and banana beer and wine). The National Industrial Research and Development Agency (NIRDA) developed the CPCs programme as district industrial projects. Starting out as government-managed pilots, they would be passed on to private firms once their commercial viability had been established. In this way, the Government is acting as an angel investor spurring innovation.

Vision 2020, EDPRS 1 and EDPRS 2 aim to position Rwanda as a pioneering and dynamic knowledge economy and innovation hub in the East African Community (EAC). The objective is to generate a large quantity of jobs for an increasingly

better qualified youthful population. Digital and other technologies will be key in growing industry and services, as well as developing and commercializing agriculture. However, a relative reduction of the share of the agriculture sector in the economy will be a sign of transformative processes succeeding. In the next decade, Rwanda will become a dynamic and modern middle-income country.

3.2 Regional integration

Rwanda has three prominent objective conditions, two of which are practically unchangeable and which pose clear development challenges. Firstly, it is a small territory and this has unavoidable implications for the availability of natural resources, including arable land. Secondly, Rwanda is a landlocked country, without a sea port or viable marine transport. Thirdly, while it is a very densely populated country, the part of the population identifiable as a consumer base for innovation in commerce and industry is somewhat limited. It may not consist of more than a third of its population, i.e. about four out of approximately twelve million citizens.²³ Therefore, it is no surprise that Rwanda is actively engaged in enlarging its economic reach and scope as an active member of the EAC.

Apart from increasing its export market, a major issue for Rwanda is the transport and logistics investment in the region, in particular the activation of the Northern Corridor, which should facilitate trade between Rwanda, Kenya, Uganda, and South Sudan. Beyond potentially helping to resolve Rwanda's logistics issues, the EAC is a customs union, with common tariffs on imports from third countries, duty-free trade between members, and common customs procedures.

In order to take full advantage of EAC opportunities, Rwanda needs to energize its firms and entrepreneurs and increase their innovation performance. The creation of large customs unions can incentivize firms to move or expand into areas with lower production costs. For example, processing industries may relocate near commodity sources or near large ports, depending on their costing structure. More generally, firms will need to channel their response to regional competition by seeking regulatory assistance and protection towards technological innovation, as well as through commercial innovation in marketing, product differentiation and market segmentation.

During the UNCTAD mission in April 2016, several entrepreneurs discussed the EAC and international trade, and their expectations of government policy with a view to increasing the protection of their interests from international competition. While protectionist policies have worked for some countries in the past, their success is by no means easily replicable because today's globalized economy bears little resemblance to historic circumstances. Therefore, a positive response based on innovation should be favoured, rather than a defensive protectionist reaction.

3.3 Developing the knowledge economy

Vision 2020 establishes that becoming a knowledge-based economy²⁴ is a key development objective for Rwanda. Through EDPRS 1 and 2, support has been given to key knowledge economy policy areas: education and training, science and technology, and ICTs. These are commendable policy goals, requiring continuous investment, while the development outcomes are long-term and can be difficult to link to specific inputs in a cause-effect manner. Many indicators will present education and science as inputs into the development process in terms of number of graduates, referenced academic papers or issued patents. The outcomes will be innovation and growth. In between lies the complexity of economic interaction and this guides policymakers to think strategically by embracing an innovation systems framework.

Education is fundamental to developing innovation capabilities and a knowledge economy. Rwanda has the highest primary school enrolments in Africa: 98 per cent for girls and 95 per cent for boys. In 2013, the expected years that every four-year-old, on average, would be enrolled in formal schooling was 12.3 years. This is a significant development from 4.9 years in 1980. Learning English is mandatory, starting in primary school. The Technical and Vocational Education (TVET) system has been expanded, with an almost doubling of enrolments in five years, from 51,000 in 2010 to 94,000 in 2014. There are some 90,000 students at the tertiary level, of which 40,000 are in the public university system. Seven public institutions have been assembled to form the University of Rwanda in 2012, which includes a College of Science and Technology with more than 6,000 students. Eighty-five per cent of students receive government financial support during their studies.

Three successive plans have supported the development of the ICT infrastructure and services. Following the liberalization of the telecom sector in 2000, the first ICT strategy (2005-2010) saw the deployment of the ICT infrastructure, including the build-up of a fibre-optic network over the whole territory, reaching all people up to the last mile. The final last mile connections were consigned for development by mobile telephony companies. Secondly, a large plan was launched in 2010-2015 focusing on the improvement and diversification of ICT services, notably in government services and in education.

Under this policy, the *One Laptop per Child* programme aimed to distribute 1,000,000 laptops in primary schools. At the time of writing, over a third of the Rwandan total population had access to the Internet and more than 78 per cent had mobile phones. In 2015 the ICT sector grew by 16 per cent, while contributing to three per cent of GDP (Ministry of Youth and ICT, 2015). For 2015-2020, the fourth five-year ICT plan – the Smart Rwanda Master Plan (SRMP) – aims to increase the private sector's involvement, narrow the digital divide, improve e-government, and engage the youth in digital society. To assist in complexities in

implementation, policymakers merged the Ministry of Youth and ICT into a single agency, the MYICT. Youth empowerment and the ability of ICTs to drive economic development are considered symbiotic policy areas.

A National Commission for Science and Technology (NCST) was established in 2012 to advise the Government on policies, legislation and regulation in the fields of science, technology, research and innovation, and to monitor the implementation of such policies and legislation. NCST is ambitious about its proposal for a National Research and Innovation Fund (NRIF) that will support and promote national science, innovation, technology, and research. Development programmes would be earmarked a budget that can increase the national R&D efforts to one per cent of GDP.

There are important plans to develop and expand the work of centres of excellence for Vaccines, Immunization and Health Supply Chain Management, Regional eHealth and Biomedical Engineering, Programmatic Management of Drug Resistant Tuberculosis and Biodiversity and Natural Resources Management, in cooperation with the EAC and international partners. The development of Kigali Innovation City (KIC) was launched in May 2016. It will focus on developing interaction between Rwanda's human capital, digital technologies and innovation friendly finance. KIC, which is to be built on the grounds of the Kigali Special Economic Zone, will host Carnegie Mellon University Rwanda, Ericsson, the African Institute for Mathematical Sciences, the International Centre for Theoretical Physics-EAC, as well as an industry skills academy and the SMART Rwanda and Innovation Growth Centre. KIC will initially weigh heavily in favour of digital technologies. Policy issues regarding STI parks will be revisited in chapter 10 on ICTs in this STIP Review.

4. Strategic issues

4.1 Policy impact on the knowledge economy and innovation climate

The overall knowledge economy efforts and investments are impressive. However, meaningful benefits and impact will be seen once the overall economy transforms and grows to allow for more substantive traction of policies. Several indicators shed more light on the actual situation. Internet penetration has increased to around 33 users per 100 people, while mobile phone penetration is above 78 subscriptions per 100 people (RURA, 2016). It may be the case that fixed broadband Internet subscriptions underestimate the actual state of ICT development, as they present a technologically challenging solution for much of Rwanda's mountainous territory outside the main urban centres. However, 4G LTE mobile broadband is scheduled to cover 95 per cent of Rwanda's territory before 2017, and is supported by a pervasive national optic fibre infrastructure. It should be noted that, as an indicator of digital development, 4G LTE coverage is a meaningful

indicator in conjunction with data on network usage for large data transfers.

The question is then: which factors can influence an increase in data use? One is the amount of e-commerce, both among firms – business-to-business (B2B) – and between firms and consumers – business-to-consumer (B2C). A second factor is the penetration of smartphones and computing equipment that can access the 4G LTE network. Finally, there is the cost of subscriptions with mobile operators that can enable data transfers. Table 1 presents a number of ICT indicators with regional and developed country references. The UNCTAD mission in April 2016 learned that most internet access in Rwanda was through smart mobile devices.

The national research and development effort is modest. What is perhaps of greater concern is that it is difficult to document and empirically assess the low level of R&D activity in firms. While this is understandable considering Rwanda's development level, R&D activities require strengthening to bring them in step with national development aspirations as expressed in Vision 2020. Table 2^{25,26} presents several R&D indicators with regional and developed country references.

Traditional technology and innovation indicators, which mainly account for the inputs into STI processes, need to be understood with two caveats in mind. The first is that they were established at a time when STI policy and R&D policy were practically interchangeable terms. Since the development of innovation systems theory in the '90s, we know that they are not interchangeable. The second caveat is that as innovation is not a linear process – the activities of science, R&D and commercialization do not follow any particular order

– any improvement in science or R&D indicators will not necessarily cause an increase in innovative outcomes and diversification in the national economy.

In this sense, national R&D investments and activities are necessary but insufficient elements for innovation. Rwandan policymakers should therefore not be content to see an improvement in R&D indicators only, without active policy linking R&D efforts to firms and industry. However, it is an empirical fact that countries with high human development indexes also spend more than 1.5 per cent of their GDP on R&D. The direction of causation is nevertheless ambiguous.

In the coming years, policymakers will have to look at other data to discover if investment in education and ICTs has moved Rwanda towards becoming a knowledge-based economy. One indicator will be the diversification away from exporting coffee and tea, to manufacture and services. A second indicator will be the nature and structure of unemployment and, particularly, youth unemployment.

During several discussions, the UNCTAD mission noted a deep concern about youth with higher education diplomas experiencing an above average rate of unemployment, as high as 13 per cent, while firms agreed that it was often difficult to find qualified people for industrial jobs. The mission observed that industry often relies on foreign technical experts. Sometimes these experts are staff, other times they travel to Rwanda to effect repairs, often at a relatively high cost from a local perspective.

A general mismatch of human capacities and opportunities in the labour market is a signal that

Table 1: Selected ICT indicators, 2015

	Internet users (per 100 people)	Fixed broadband subscriptions (per 100 people)	Mobile broadband subscriptions (per 100 people)	Secure internet servers (per 1 million people)
OECD	77.24	29.02	86.7	1086.54
<i>World</i>	44.00	11.34	47.2	208.71
Kenya	45.62	0.28	9.1	9.14
Tanzania	5.36	0.20	3.0	2.04
Rwanda	18.00	0.17	11.1	4.13
Congo, Democratic Republic	3.80	0.00	7.9	0.35
Uganda	19.22	0.32	14.7	1.92

Source: World Bank

Table 2: R&D inputs into the STI process

	Research and development expenditure (per cent of GDP)	Researchers in R&D (per million people)	Patent applications	Trademark applications	Scientific and technical journal articles
OECD members	2.46	3,834	1,356,182	1,507,650	1,363,074
<i>World</i>	2.12	1,282	2,506,409	4,886,846	2,184,420
Kenya	0.79	231	207	5,806	872
Uganda	0.48	38	8	2,666	474
Rwanda	0.40	12	12	1,206	91
Zambia	0.28	41	39	2,672	117

Source: World Bank

there is a need to improve linkages between educational and training institutions and the productive sector.

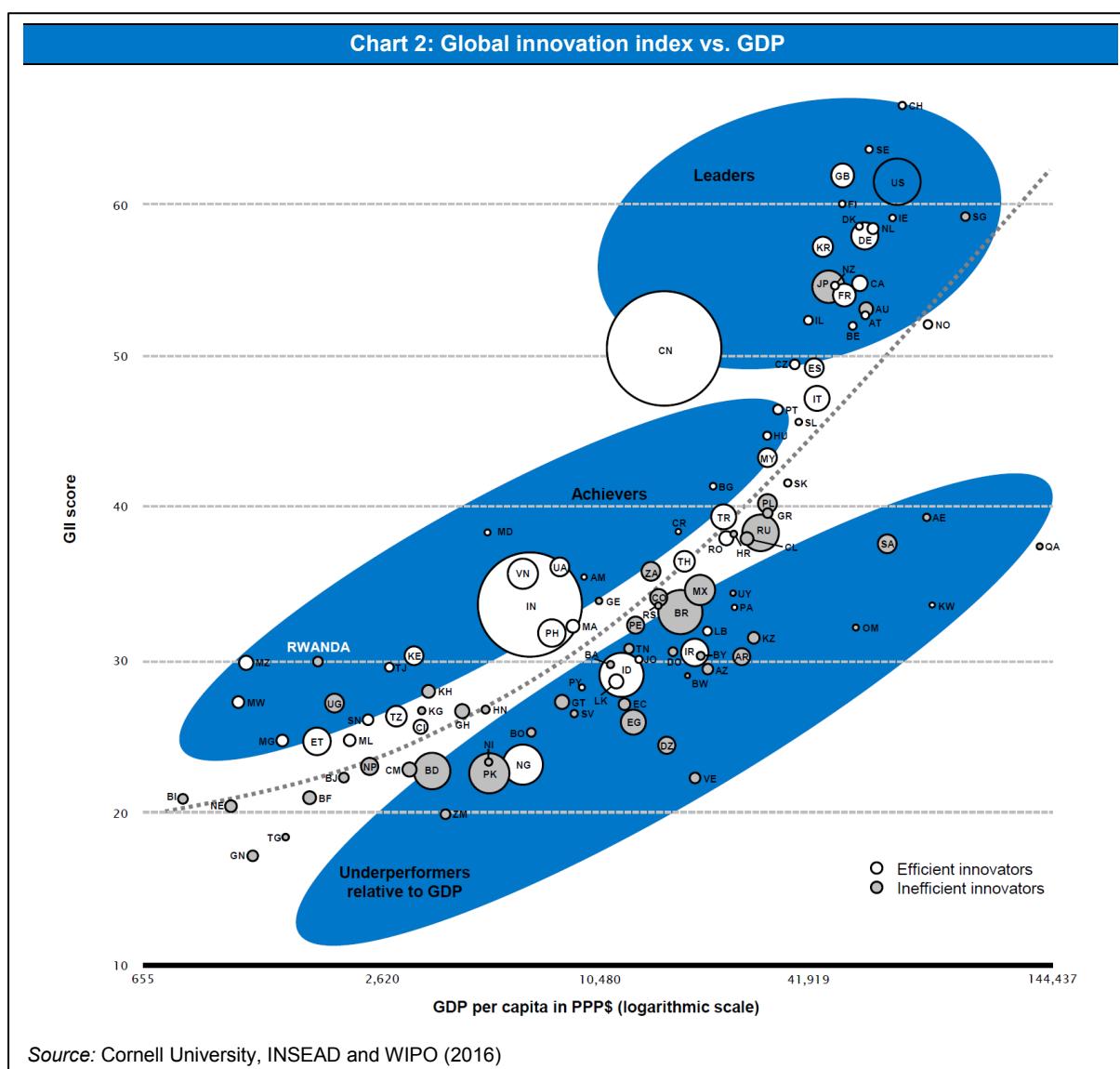
One worthwhile consideration is to increase support for programmes that provide opportunities for students to engage in paid professional internships internationally, such as the International Association for the Exchange of Students for Technical Experience (IAESTE) or the International Association of Students in Economic and Commercial Sciences (AIESEC). Such programmes prepare students entering the job market by providing them with experience in their technological field, as well as giving them a head start in aspects of professionalism and work culture.

The quality of the innovation climate is measured by international benchmarking exercises such as the Global Innovation Index (GII).^{27, 28} The GII, which measures performances on both innovation inputs and outputs, describes the Rwanda STI challenge and position among other African competitors, while documenting noticeable progress in recent years (see chart 2²⁹ and table 3). In 2016, Rwanda was ranked 83rd among 128 countries, close to Kenya, and ahead of Uganda and Tanzania.

However, the efficiency ratio, which measures relations between STI input efforts and innovation performance achievements, is low. The results validate the important investments made in education and ICTs, which is reflected in the country's ranking, but reveals their limited impact so far, in terms of technological innovation and productivity performances, which is reflected in the innovation efficiency ratio. Assessments of the business sector, such as World Bank Doing Business Ranking,³⁰ present a more optimistic picture than the "hard" objective data used by the GII. Such assessments do not compensate for challenges elsewhere. Rather, they indicate that there is a need for serious improvement in getting more out of current policy efforts and those planned for the future. This requires an enlarged vision of innovation and its process.

4.2 The need for an enlarged vision of innovation

A critical review of EDPRS 2 suggests that the policy treatment of innovation is somewhat narrow.³¹ While this STIP Review is not a didactic



tool, it may be useful to assert innovation in the STI policy setting as of greater importance than the science and technology components, particularly in a development context. Innovation is the process of turning inventions into products, services and activities that have value in terms of commercial impact or social benefit. Innovations may be new globally or new in their locality – in their town, region or country. Put simply, innovation should be understood as anything new that is adding value locally. Even modest improvements count.

Innovation should not be confused with science, research and development, and not even with invention.³² Innovation requires entrepreneurial activity and commercialization. Public institutions can also innovate when they act as public entrepreneurs and provide improved and better value products and services to society. Innovation originates in research efforts but it does not materialize until producers have developed and scaled production that is commercially feasible in the given market conditions. Innovation cannot happen until consumers have been able to extract value from the product or service using their own technological competencies, and by developing a positive economic assessment in terms of value-for-money. If considered as something consumable, with commercial or social value, innovation is the end that justifies the means of all that science and technology bring it to fruition. Without innovation, science and technology are sunk costs: failed investments at worst and experiences in learning at best.

Whether scientific discoveries or technologies become innovations depends not on the amount of science and research activities, but on the receptiveness or technological culture of entrepreneurs, engineers, technicians and workers in industry, knowledge-workers and consumers (World Bank, 2010). The ability to recognize the potential value of new or novel technology and knowledge, to appropriate and use it, is often called absorptive capacity and determines if and to what extent a firm, an industry or an economy, can be called innovative (UNCTAD, 2014). The higher the technology, the greater and more sophisticated the needed absorptive capacity. Long-term aspirations aside, a reality check necessitates an evaluation of the economic mainstream, technological competencies, absorptive capacities and ability to generate employment. Rwanda's innovation efforts

in promoting high-tech sectors, such as ICTs and life sciences, are commendable. However, their outcomes will only be sustainable if improvements are made to innovation performance in the more mundane, but essential activities, that form the economic backbone of industry and agriculture.

The STI policy effort in Rwanda is primarily focused on ICTs, both in terms of resource mobilization and development strategy. ICTs are an obvious choice as they are both a service sector which is of interest to international investors, as well as an enabler and a framework condition for the knowledge economy. While this is an indisputable policy proposition, a broader consideration of the nature of the technological progress of Rwanda is needed. The current balance in the policy perspective is reflected, among other things, in the differences of budget allocations given to, or planned for, different sectors. When investments in ICT or centres of excellence are envisioned and implemented, their orders of magnitude are several times larger than those earmarked for agriculture and industry. Clearly, funding availability is dependent on both the capability to envision programme outcomes, as well as on the existence of entrepreneurs to provide engaging proposals for ventures – to provide a significant deal flow for potential funding.

It is an encouraging detail that EDPRS 2 references mainly the innovation component of the STI complex. This is a step in the right direction, as development requires urgent attention to outcomes – i.e. innovation – rather than inputs. EPDRS 2 immediately proclaims that one of its guiding principles is, "Innovation: emphasising new ways of thinking, working and delivering because the status quo will not be adequate to achieve Rwanda's ambitious targets." Further to this, EDPRS 2 highlights the need for innovation in policy and in the implementation activities of institutions. However, as the policy discussion on innovation evolves in EDPRS 2, a number of issues surface that need consideration and heightened attention in preparation for EDPRS 3.

Much is made of green innovation in EDPRS 2. While the importance of working towards Sustainable Development Goals (SDGs) 6, 7, 11 and 13³³ are praiseworthy, there is no discussion of a national system of innovation that would link up the diverse policies and stakeholders in order to realize these ambitions. In a similar manner,

Table 3: Global Innovation Index – Selected Sub-Saharan Africa Countries

	GII rank 2016	GII rank 2015	GII rank 2014	Innovation efficiency ratio 2016	Innovation efficiency ratio 2015	Innovation efficiency ratio 2014
South Africa	54	60	53	0.6	0.7	0.7
Kenya	80	92	85	0.8	0.8	0.8
Rwanda	83	94	102	0.4	0.4	0.5
Malawi	98	98	113	0.7	0.8	0.7
Uganda	99	111	91	0.5	0.6	0.7
Tanzania	105	117	123	0.8	0.8	0.6
Burundi	123	136	138	0.4	0.4	0.5
Zambia	125	124	121	0.6	0.7	0.8

Source: Cornell University, INSEAD, and WIPO (2016): The Global Innovation Index website, www.globalinnovationindex.org

EDPRS 2 gives a nod to innovation in the energy sector. It suggests that private firms may be involved in off-grid infrastructure deployment as well as in the development of alternative biogas and biomass technologies. Finally, the discussion addresses ICTs as the locus for innovation. Neither of these policy directions addresses the need for a systems approach to innovation. As a result, innovation risks being demoted in policy implementation and STI activities become susceptible to producing unremarkable outcomes. Innovation, which is broadly accepted as a primary driver of productivity, growth and diversification – and by consequence, of economic development – merely decorates the policy discussion in EDPRS 2.

To counteract this inopportune path of policy development, Rwandan policymakers may need to infuse EDPRS 3 with a macro-level understanding of innovation. This should not be a challenge because, as the UNCTAD mission witnessed, the common understanding of innovation is current and not lacking in any significant way.

The question that inevitably arises is, given the evolved level of understanding of innovation, what could be the challenge in moving it into the policy domain? The answer may be a weak macro-view of how technological receptiveness develops in the whole economy, as well as an underappreciation of the need to deploy a structured national system of innovation framework³⁴ for the development and implementation of STI policy. Chart 3 describes the contrast between the current and the required policy domain for innovation.

4.3 Increasing the contribution of STI to national development

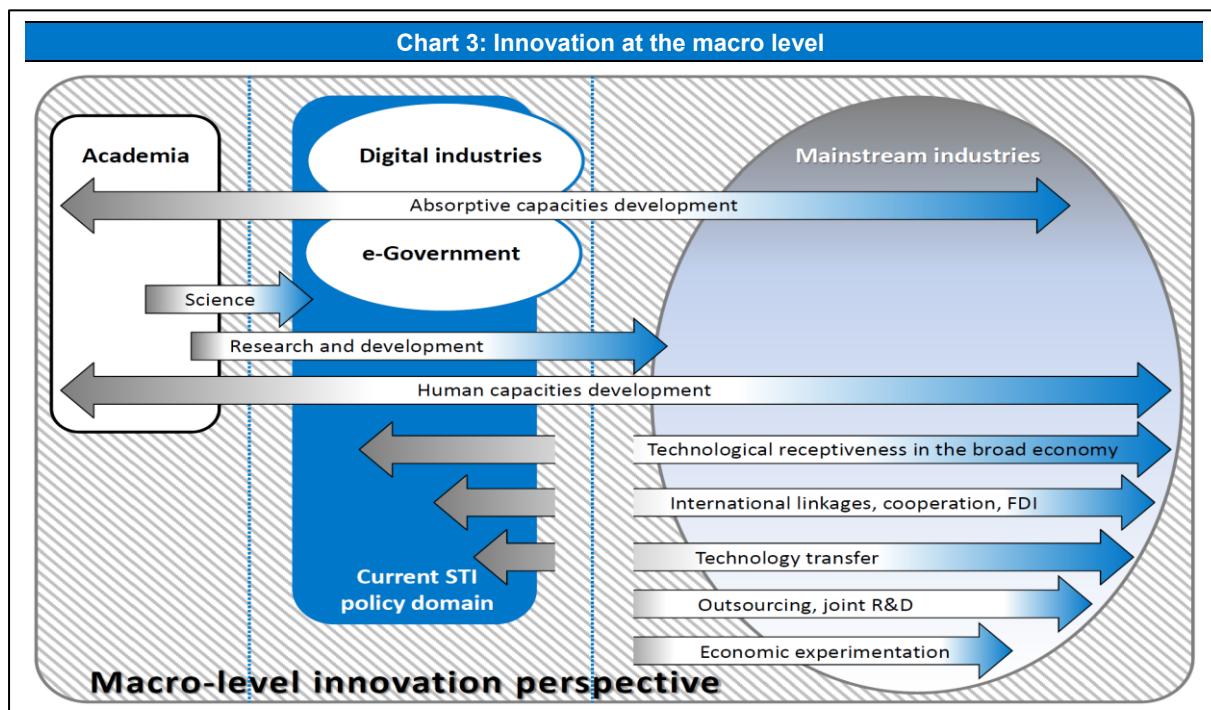
The major challenge for Rwanda in transitioning from a poor agriculture-based country to a dynamic

knowledge-based economy is the annual creation of 200,000 off-farm jobs. This challenge requires a broad, gradual and holistic STI and development policy approach. There has been a sustained shift in past decades from agriculture to non-agriculture sectors that has its own dynamism. However, the speed of transformation may need to be increased. Between 1999 and 2015, the contribution of agriculture to GDP was reduced by only four per cent which may have had an impact on employment opportunities. Such conditions may also be a factor limiting the contribution of technological progress to economic growth and to overall labour productivity. Box 2 discusses this problem in greater detail.

These considerations show the need for a revised and well-articulated STI strategy with multiple and complementary objectives:

- Developing an NSI framework and operational strategy;
- Significantly improving the absorptive capacity and technological receptiveness of the economy as a whole;
- Developing a strategy of linkages, and enabling the transfer of innovation processes from highly visible national STI projects to the mainstream economy and its firms;
- Developing industry and services, by any means available, as source of jobs and income; and
- Improving productivity in agriculture, supporting its growth and commercialization through the development of an agro-food and processing industry.

While it is a difficult proposition, it is unavoidable that a large segment of the working population is going to work part-time jobs. To a certain extent,



on-going and unstoppable technological progress contributes to this situation, with the *uberization* of economic activities and the development of the gig economy.³⁵ In practice it is often perceived as a challenge, or even a threat, to traditional firms from a network of individual contractors. Depending on the circumstance, the growth of a gig economy and *uberization* in a developing country can mean moving out of the informal economy or the opposite – leaving the formal economy.³⁶

STI policy requires some reflection on the interaction between STI and policies and practice that affect job creation, enterprise and sector development, human capital development, industrial and agriculture productivity, technological upgrading, and the development absorptive capacities in the economy as a whole. Policymakers need to develop STI measures and incentives that complement each other, including, for example, support for agro-food start-ups and small- and medium-sized enterprises (SMEs), that may in turn complement large-scale, ambitious investments, such as the nationwide optic fibre network, 4G LTE, KIC, and regional centres of excellence in biomedical research. Facilitating technology adoption, adaptation and use by “average” businesses and the population at large should be considered a valuable policy cause. This applies to many sectors, including agriculture, services, craft industries, tourism, etc. The primary concern here is the current state of the business sector, which urgently needs to enhance its entrepreneurial and technical culture and dynamism.

5. Firms, entrepreneurs and supportive measures

5.1 Business structures

Rwanda's firms and entrepreneurs are at the forefront of the national innovation challenge and will need to strengthen their technological and innovative capacities to increase and sustain the impact of innovation on the Rwandan economy and society. GII and World Bank data, as well as UNCTAD mission findings, confirm this assessment. This is an objective situation and a result of historical conditions and path dependencies of economic development. Up to the

early '90s, most of the enterprises operated in trade and retail activities. In the post-genocide period, the business sector expanded principally into import-export, services and construction. Expectations of industrial development have yet to be fulfilled while transformation is slow, if constant and seemingly inevitable. The share of agriculture in GDP decreases on average about 0.75 per cent per year, with industry and service splitting the difference as their gain (NISR, 2016). Today the manufacturing sector,³⁷ which represents about five per cent of GDP, is distributed roughly as follows: 70 per cent in agro-processing, seven per cent in wood, paper and printing, with the rest split evenly between textiles, chemical production, non-metallic minerals, metals, and machinery and furniture production. Construction, which is treated as a distinct category in Ministry of Finance and Economic Planning (MINECOFIN) reporting, represents about seven per cent of GDP – more than the entire manufacturing sector.³⁸ Adding together manufacturing, construction, mining, water and power gives a tally of about 15 per cent of GDP for industry. Services account for 48 per cent of GDP, with the wholesale-retail trade, real-estate management and education standing out as marginally more important.

The last decade has seen a significant acceleration of business creation and growth. In 2014 there were 9,991 new limited liability companies created, compared to only 201 in 2003.³⁹ This is the result of significant improvements in the business environment and the growth of the economy. The quality of the business climate is impressive, as measured for instance by the World Bank Doing Business surveys. Improvements are particularly noticeable in the conditions of business creation and the conditions of recruitment and firing of employees. The main issues and weaknesses affecting the business environment (see tables A and B in the annex) are the insufficient competencies and qualifications of job-seekers. Transport and especially energy, where the lack of reliable power supply is a source of serious concern, reveal the state of infrastructure to be similarly inadequate.

There are myriads of small firms⁴⁰ – about 123,000 according to some estimates – but the majority are operating in the informal sector and are not registered in the tax system (UNESCO, 2015).

Box 2: Rwanda at work

There has been a sustained shift from the agriculture sector to industry and services in Rwanda. The share of agriculture employment in total employment was 90 per cent in 2000 and it is about 70 per cent now. This shift from agriculture to non-agriculture sectors has been the main source of labour productivity gains of the economy, measured over the period 2006-2011. On the other hand, the contribution of the Total Factor Productivity, which indirectly measures technological efficiency and progress in the economy, beyond increases of labour and capital, is negative (- 41 per cent). The result is replicated by the low GII innovation efficiency score.

This surprising outcome can be interpreted as the consequence of a poor use of available capital, due to a low level of skills and/or a high-level of underemployment. Both factors are affecting the Rwandan economy. The education level of the available labour force is low, with 70 per cent not reaching secondary school. Underemployment is estimated to affect 50 per cent of the labour force, in particular in rural areas and among youth. The youth are looking for part time jobs with multiple activities. The lack of labour demand (job offers) can be explained by a formal economy that is too small for a population of 12 million and growing at more than 2.5 per cent per year.

Source: World Bank (2016)

Rwanda's private sector also includes a significant group of home-grown medium-sized and large companies. The business culture appears rather conservative, although efforts towards quality improvements, industrial design, and branding have been made, notably for import substitution or to improve performance in export markets. Access to materials and transport costs are important challenges, as well as the labour qualifications. Packaging has also become a primary issue. Manufacturers are at a competitive disadvantage because of a lack of appropriate packaging materials, both for domestic use and for export. The ambition is to innovate towards a solution to the challenge but also opportunity created by the 2008 law banning the production, import and use of polyethylene bags.⁴¹ This can establish Rwanda as a leader in research and production of biodegradable packaging in the EAC and further afield. The task at hand is to develop an environment that will incentivize entrepreneurs and researchers, foreign and domestic, to rise to this unique challenge.

Today, the most proactive entrepreneurs operate in the ICT sector. They are hosted by kLab, a dynamic incubator in Kigali, a structure that currently supports 25 start-ups. Ambitious visions are elaborated by kLab, such as evolving 100 ICT companies, each valued to be worth \$50 million by 2025. Today, the ICT sector represents about three per cent of GDP and while this may seem underwhelming, it has more than quintupled in size in the last ten years. As the Government is committed to deploying first-world connectivity and President Kagame affirmed that he considered internet access to be a public utility, there is confidence in the enormous potential of a Rwandan ICT-based industry. The major investment, beyond infrastructure, will be in human capacity, directed particularly at its youth. To bridge ICTs and youth in this way, as Rwanda has done in establishing its Ministry of Youth and ICT, is a positive policy development.

There are several challenges for the ICT sector. The first is purely a policy issue. Depending on who is asked, ICT can mean very different things. For some, it is primarily an enabler for development and is inseparably linked to health, education and economic empowerment. For others, it is a business platform to be used to develop new products or services, or new ways of doing commerce. Finally, others still see it as a business sector in itself that needs to be profitable and provide a return for its investors, just like any other industry. This situation may be suboptimal in terms of desired development results. A policy rapprochement may be needed and best achieved using an innovation system framework to involve, energize and secure the commitment of all stakeholders. The second challenge is developing a domestic market commensurate with the investment in optic fibre and 4G LTE broadband infrastructure. This issue has two components: developing the use of e-commerce, e-services, and the Internet more generally, and increasing the

penetration of smartphones and other computing hardware that can run data-intensive applications and software. The Internet is increasingly accessed through mobile phones and this brings total internet penetration above 35 per cent. Survey data from 2014 indicates that only 9.2 per cent of households had internet connection and almost all were in Kigali. Only about 22 per cent of the population claimed to feel confident using a computer and most of them lived in urban areas and were of the 15-34 age group (NIS, 2016). A third challenge is the need to generate more local content and to host it locally. In a recent study (Kende and Rose, 2015) of the 20 most popular Rwandan websites, only government websites were hosted locally, as they are subject to a binding regulation for public agencies. ICTs will be further discussed in chapter 10 of this report.

5.2 Finance for business development, innovation and research

5.2.1 Finance for business development

The Business Development Fund (BDF) is the principle provider of financial and business support for firms in Rwanda. Although fulfilling an important task, so far it has not been much involved in the support of innovative firms. The BDF, created in 2011, supports small- and medium-sized businesses through various schemes, and principally through loan guarantees and grants.⁴² It operates local antennas in all districts. More than 15,000 companies have benefited from its support in various forms. Twenty-eight per cent of loans (in value) have been placed in Kigali.⁴³ BDF is in the process of establishing a venture fund of \$75 million, partly funded through a capital infusion from government of \$8 million based on equity and debt. This would be helpful for funding innovative and, consequently, higher risk projects that are not operating in the ICT sector. There are also several private equity funds and investment groups that can join in such venture operations.

Another important source of funding for product design, quality improvement and marketing efforts comes from the Export Promotion Fund, provided through the new Export Development Strategy, based on a Matching Fund component. Firms will receive government subsidies equivalent to the financial effort they will put in themselves. Some \$25 million have been allocated for the next three years (MINEACOM, 2013). Although such incentives will mainly benefit large established companies – so-called “million dollar exporters” – they could be useful to raise the innovation effort of any exporting firm and industry sector.

More generally, the financial conditions for entrepreneurship are difficult. Several factors limit the availability of resources for innovative but higher risk ventures. A first obstacle is the relatively high-level of interest rates for loans available from banks. These were about 17 per cent at the time of writing. Another issue is the absence of an efficient investment framework with clear incentives for local investors, in contrast with the favourable conditions

on offer to FDI. Thirdly, the stock exchange market is embryonic: there are seven companies listed on it – of which two are local and the rest are cross-listings from other countries – and the market capitalization at the end of 2015 was \$3.7 billion.⁴⁴ Fourthly, national procurement policies do not favour SMEs and are very restrictive regarding new products, inhibiting the purchase of untested items (WEF, 2015). Finally, tax incentives for R&D are provided for under the Rwandan tax law 15/2005 article 27, which allows all training and research expenses incurred and declared and previously agreed, and which promote activities during the tax period, to be considered deductible. However, these may not concern the purchase of immovable properties and expenses related to activities in mining, such as refining, rehabilitation, reconstruction and exploration.

Beyond increasing support for innovative projects, there is a need to energize early innovation stages and start-ups, and enlarge the pipeline of venture proposals with strong innovation components. This requires measures such as incentives for placements of scientists in enterprises, or support of joint R&D projects between private business and public entities. Such measures, principally provided in the form of matching grants, have proven their efficiency in developed and emerging economies, and they should be put in place in Rwanda, which has government staff capable of administering such schemes. One such initiative is the National Research and Innovation Fund (NRIF) to be managed by NCST.

5.2.2 Innovation funding landscape

There are encouraging developments in the STI funding landscape. The establishment of large funding mechanisms are envisioned for the support of the most crucial STI phases. Substantial resources would be available from the Rwanda Innovation Fund, jointly established with the African Development Bank (ADB), to support the early growth and expansion phases. A first call of \$ 100 million is taking place with closing at end of September 2016. Other major funding sources are expected from the Rwanda Research and Innovation Fund, administered by NCST, for the early stages, such as prototype development, testing, and market research.

The idea that financial support is necessary for promising high-tech firms and entrepreneurs seems well established. Following a pattern experienced worldwide, and most notably in innovation ecosystems such as Silicon Valley, digital

technologies start-ups see the development of innovative businesses through a series of key phases of financing. Table 4⁴⁵ describes their perspective on the process, starting from an initial idea, up to the exit, in the form of a public offering on stock exchange and financial markets.

The funding landscape in Rwanda is diverse. Chart 4 and table 5 present the various funding agencies and their role in the funding process.

The Rwanda Research and Innovation Endowment Fund (RIEF), is managed by the Ministry of Education. Operating since 2013, RIEF received 370 applications in its first phase, from which it awarded eight projects in total about \$50,000. In its second phase, it reviewed 299 project proposals from which six projects were selected and awarded between \$1,200 and \$16,000. The Fund is primarily aimed at university graduates and academics from university or public laboratories. Although the “entrepreneurial inspiration to start an innovative business” of the applicant is mentioned as a condition for getting the grant, the involvement of an entrepreneur or a firm is not mandatory, a point illustrating the STI push approach that has influenced the concept of the Fund in its early stages. However, NRIF will be geared to support innovation and R&D in including prototyping and beta development stages in order to increase the number of approved and implemented projects.

Funding STI requires performance monitoring, and this means assuming the practice of evidence-based policymaking. Data that is regularly used in STI policy work often deals with the size and quality of inputs into innovation processes. Typical examples would be graduates of the secondary and tertiary education systems, patents filed, number of researchers employed, percentage of GDP spent on R&D activities, or academic papers published by nationals. Examples of attempts to develop synthetic indexes to measure innovation performance are the Global Innovation Index,⁴⁶ the Bloomberg Innovation Index,⁴⁷ the Innovation in American Regions Index,⁴⁸ or the European Union (EU) Innovation Union Scoreboard.⁴⁹ Among often cited references for innovation measurement are the Organisation for Economic Co-operation and Development (OECD) Frascati Manual and Oslo Manual which guide the collection of national data on R&D and, more generally, surveys on science and technology by the UNESCO Institute for Statistics, as well as the collection and use of firm-level data on innovation activities.⁵⁰ The Frascati Manual, by its very nature, focuses on inputs. The Oslo Manual focuses on innovation in firms, but

Table 4: Innovation financing in high-tech sectors

Stages	Actors	Amounts (\$)
1. Idea	Family and friends	
2. Design	Seed funds	1,000-25,000
3. Early growth	Angel investors	25,000-250,000
4. Expansion	Venture capital	50,000-10,000,000
5. Development and exit	Banks and stock exchange	

Source: kLab

does not examine macro changes such as the emergence of new markets. The idea that data on innovation outcomes, in addition to inputs, can enhance policy development and management is generally acknowledged. For example, the EU Innovation Scoreboard includes assessments of innovation outputs by measuring employment in “fast growing firms in innovative sectors” or “sales of new to market or new to firm innovations”.

5.3 Capacity development and support to entrepreneurs

An important obstacle to business creation and development is the lack of business planning and management competencies among prospective and established entrepreneurs alike. Due to poor business plan proposals and presentations, more than 9,000 SMEs fail to get credit from banks every year. While management coaching may be provided by most of the funding agencies and can include training on

planning, there is the question of how coaching programmes are developed, what their innovation pitch is, and how the coaching interacts with banks and investment groups in order to provide the right capacity-building.⁵¹ Finally, planning and management competencies are necessary but insufficient for success. Funding agencies should rise to the challenge of increasing the technological absorptive capacities of firms and enable them to better conduct and survive economic experimentation.

The Ministry of Labour, with its National Employment Program (NEP), is also active on several fronts. Within a “Skill Priorities” policy framework, in consultation with Sector Skill Councils (Private Sector Federations) and the Capacity Building Secretariat (see below), various schemes are in place:

- An “Entrepreneurship and Business Development” scheme, through the Proximity Business Advisory Services, is an initiative implemented by the Rwanda Development Board;

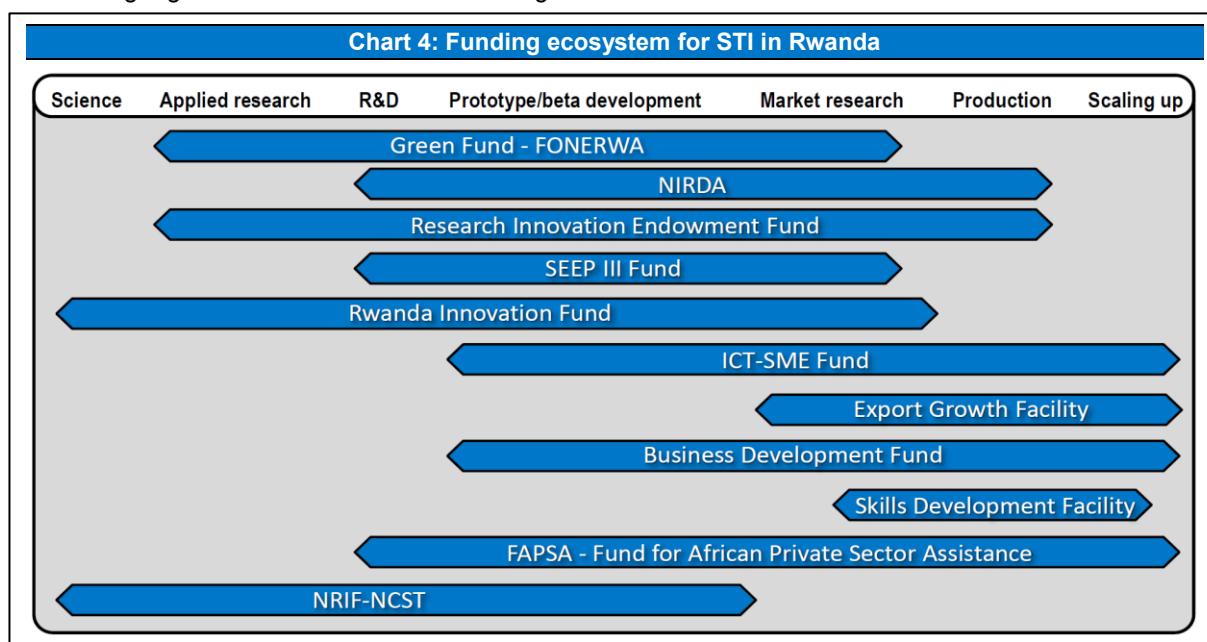


Table 5: STI funding in Rwanda

Fund	Implementing agency	Purpose
Green Fund (National Climate and Environment Fund)	FONERWA - MINIRENA	Environment and climate change fund
REIF - Rwanda Innovation Endowment Fund	MINEDUC	R&D for innovation priority, economic and social areas
SDF - Skills Development Facility	Workforce Development Authority	Expanding the number of individuals with the relevant skills in critical sectors
RIF - Rwanda Innovation Fund	Rwanda Development Board	Funding of KIC related STI programmes
NRIF - National Research and Innovation Fund	NCST	Align research with national priorities
BDF	BDF	SME support credit guarantees, credit lines, matching grants, quasi-equity and advisory services
FAPSA - Fund for African Private Sector Assistance	AfDB	Untied grants for technical assistance and capacity-building
ICT-SME fund	MYICT and RDB	Public-private funding for job creation
NIRDA	NIRDA	R&D for industry needs
EGF - Export Growth Facility	Rwanda Development Bank	Investment catalyst, matching grants for market entry costs, export guarantee
SEEP III Fund	WDA - AfDB	Skills, entrepreneurship development and job creation programme

- A “Youth Start-ups” scheme, implemented through the distribution of vouchers, from 2014 up to the end of March 2016, benefitting 23,000 youths evenly distributed throughout the country’s territory, with non-performing loans amounting to only about eight per cent;
- A “Technology Transfer” scheme for craftsmen and SME clusters in different trades such as construction and manufacturing, basing technical experts in Integrated Craft Production Centres, has been established, so far, in six districts; the scheme includes a skill-upgrading component, operated by the Work Development Authority (WDA) and an equipment modernization component operated by BDF (in form of leasing);
- A “Rapid Response Training” programme managed by WDA, operating in agriculture (irrigation, mechanization, etc.), benefited around 200 people last year; and
- A “Work Place Learning Policy”, recently put in place promoting apprenticeship, has benefited 2000 youths so far.

These different schemes seem to respond to both the expectations of individuals and demands of businesses for higher qualifications. As most of them touch a relatively limited number of people, it is important that they are rapidly and strongly scaled up to meet the demand of the 125,000 youths entering the job market annually, in addition to the labour leaving agriculture and seeking non-farm jobs.⁵²

Financing human capital development to meet the challenge of developing a knowledge economy brings with it the issue of a technological skills gap when the workforce is tasked to use modern, imported technologies. So far, none of the existing programmes seems to explicitly address this issue, even if some inevitably address it as a matter of fact. As a matter of policy, there may be a need to reconsider regulations or provide guidelines for foreign businesses that would stimulate partnerships with local programmes and firms to enhance the transfer of technological and managerial competencies.

Partnerships, and the resulting knowledge and competencies transfer, operate best when there are common business interests, such as subcontracting between foreign and local firms. Rwanda can find good examples in other countries’ experiences, such as Ireland and its Linkages Programme, implemented in the electronics industry in the 1990s (World Bank, 2010).

5.4 Community Processing Centres

Finally, in this review of schemes to support innovative entrepreneurship, it is worthwhile emphasizing a promising instrument put in place in the agriculture and agro-food sectors: the Community Processing Centres, established at the initiative of the Minister of Trade and Industry (with EU support and the involvement of BDF and

NIRDA, the National Industrial Research Development Agency). Inspired by the cottage industry in India, three centres are currently in operation for production of Irish potatoes, leather, and dairy products. Another three new centres are opening soon for ceramics, honey, and banana beer and wine. So far \$3 million have been invested. The Government is the seed investor and its stake is eventually “spun-off” to a private sector “anchor” firm that is a project partner from the earliest stages.

An evaluation of the three first centres is on-going, but there are indications that the scheme is efficient and adapted to the Rwandan economic environment. A key factor in the success of the scheme is a basket of support (technical, financial, commercial, etc.) provided in a fully integrated manner. Besides NIRDA and BDF, the Rwanda Development Board (RDB) and the Rwanda Standards Board (RSB) are also involved. The inter-agency and public-private collaboration components in the CPCs are highly indicative that there is a nascent national system of innovation operating in Rwanda, and that the various stakeholders will assemble once the proper incentives and processes have been established.

6. Technological research services and sector programmes

Technological research services and sector programmes are a fundamental pillar of the national system of innovation. In Rwanda there exists a relatively well-equipped and competent RSB. However, its role in innovation and elevating the quality of domestic production may need strengthening.

The most developed research infrastructure is in the agriculture sector, and to this extent there are noticeable achievements. Nevertheless, more needs to be done in view of the importance of such services for the economy and challenges ahead.

The R&D infrastructure for industrial technology is very modest and needs strengthening in line with Rwanda’s development context. Finally, the most significant effort, assuming current plans come to fruition, concerns the high-tech sectors, with the planned development of Kigali Innovation City, for which support and funding has been pledged to an estimated \$100 million.

The Government has launched ambitious plans for the high-tech sectors, and major investments have been made in Centres of Excellence in advanced technologies. However, it is important for sectors that are crucial to the future of the country, although with a reduced capacity to excite the public imagination with promises of technology, to also receive due attention. Among these sectors are the agro-food sector and the medicine and health sector, where there is a need for integrated efforts to generate the critical mass required for technological progress.

6.1 Standards, quality control and certification

The RSB is the main body for certification and quality control. Its annual budget amounts to \$4.5 million.⁵³ Half of the budget is spent for programme activity development.⁵⁴ Established in 2013, the RSB is tasked with the development of standards, conformity assessment and metrology services. The RSB is well equipped with laboratory equipment and instruments, some of which were acquired through international cooperation and assistance – an indication of the potential to strengthen linkages and cooperation.

The main challenge for STI is that the innovation agenda in RSB activities is implied, rather than explicit. While standards and certification are de facto critical components of any innovation process, particularly in industries such as agro-food, chemical or manufacturing, the UNCTAD team did not find indications of RSB programme activities conceived to address development challenges. Increasing demand for local production will necessarily stimulate investment in production capacities. Some of it will engage in knowledge, process or product innovation. The RSB, as a consequence, becomes a partner at the technical, production and marketing stages, but it may need to also certify what is really a Rwandan product, particularly if the policy target is decreasing the trade deficit, rather than promoting a handicraft industry.

There are several lines of action that may contribute to raising awareness among firms and entrepreneurs about the need for certification, independent third-party technical verification, and its role in increasing consumer confidence and demand for local produce. As in many other countries, anecdotes about preferences for imports are commonplace and were frequently heard by the UNCTAD mission.⁵⁵ Whether they are based on fact or conjecture and pre-judgement is immaterial: perspectives will change when confidence levels increase. Some possible approaches to addressing this are listed below:

- Capacity-building covers a large and diversified scope of action, including training for RSB staff in international testing methods and developing skills for safety auditing and certification.
- Strengthening conditions for application of standards. The RSB advised of the existence of around 1300 standards in Rwanda, but less than 300 are effectively applied. Raising awareness among industry management and its workforce, as well as among the general public, is necessary.
- A complementary agency, the Rwanda Inspectorate and Competition Authority, is in charge of consumer protection and standards enforcement, but it has only minor resources with a budget of about \$87,000⁵⁶ – five times less than RSB. This

reinforces the need for horizontal cooperation.

- There is also a need for an integrated approach at the EAC level, facilitating trading within the area. So far, 1500 standards have been harmonized.⁵⁷
- Improving efficiency in the RSB by expanding IT infrastructure and developing an e-library.

However, the greatest challenge is to develop a level of interaction between the RSB and industry, funding agencies, business incubators, and all other enterprise support mechanisms, to work in concert toward a common goal: to increase the innovation outcomes and diversification of the Rwandan economy. Here again, using a national system of innovation framework can contextualize the efforts at developing horizontal inter-agency linkages, as well as assessing outcomes according to Vision 2020 and EDPRS 2 development targets.

6.2 Medicine and health

The health and medical sector warrants critical attention. Rwanda has put in place a remarkable scheme that covers medical insurance for a large part of the population. Health infrastructure is developing at an extraordinary pace. There are around 500 health centres distributed in 37 districts and reaching potentially 45,000 communities. However, shortages in financial and human resources are a concern. Competency falls short when using new technologies. For example, new imaging technologies can be operated by technicians but there is a shortage of medical doctors to read and interpret the results. Looking at epidemics, the lack of financial resources, as well as articulated plans, explain why certain diseases, such as malaria, have recently shown an upsurge after having been almost eradicated.⁵⁸ For example, a lack of resources in the distribution of mosquito nets easily translates into insufficient preventive measures.

Exploring opportunities offered by the identification and exploitation of traditional knowledge for pharmaceuticals and medical applications would also be appropriate. Rwanda can find inspiration in foreign experiences. India, for example, put in place a systematic screening process through networks of social entrepreneurs and farmers, business incubating structures and, most importantly, a competent intellectual property able to negotiate with large pharmaceutical multinationals.

There is a need for a strong and integrated approach for developing a biomedical industry in Rwanda. This means, among other things, training a corps of biomedical engineers and engaging the private sector to invest in health care activities. The establishment of a Centre of Excellence and the development of a medical park to gather the different actors in one single place and facilitate interactions and critical mass needs serious

consideration. Rwanda may choose to develop its life science competencies and grow to become the biomedical hub for the EAC. There has been important progress in addressing rural issues, with bold innovations that aim to serve remote communities for delivering medications, such as the use of drones. Box 3 describes the Zipline drone project.

6.3 Agriculture research capacities and programmes

Agriculture is a critical sector for Rwanda and thus will be dealt with in greater detail in chapter 11 of this review. Here we will look at only a few issues related to capacities for technical assistance and research.

The key agency for R&D and extension is the Rwanda Agriculture Board (RAB). RAB supervises the research and technology infrastructure in this sector. The RAB budget for 2015/16 amounts to \$48 million,⁵⁹ of which \$20 million go to extension services and \$3.8 million to the research department that employs 108 scientists and 80 technicians.⁶⁰ The extension services are operated in the different districts in liaison with local agronomists. The main goal is to increase productivity and to reduce the yield gap, notably through farmer promoters and demonstration pilots.

Better seeds have been imported. Rwanda has also advanced on the development of drought and flood resistant seed varieties. However, impacts on yields at farm level are not commensurate to efforts made. There are, however, some impressive success stories of innovation resulting from research efforts. For instance, RAB created a Vitamin A-enriched cassava variety and orange-flesh sweet potatoes (GKI, 2013). Farming associations have partnered with private sector to create sweet potato biscuits that are bio-fortified with Vitamin A. Agricultural research has also catalyzed innovation in banana hull processing and silkworm cultivation, which are now benefiting Rwandan farming cooperatives and individual farmers (GKI, 2013). In addition to extension infrastructure that depends on RAB, some private establishments provide training activities.⁶¹ The TVET system does not train in the agriculture field, except in related techniques such as irrigation or agricultural machinery. Some

research on agro-food sector technology issues takes place at the University of Rwanda and by NIRDA.

RAB, while supporting agriculture by mandate, is inadequately linked with the concerned business interests in the agro-food industry. Financial support to farmers and cooperatives, although growing, is modest and the BDF is a key player enabling progress. Export support (financial, commercial and otherwise) is available through the new Export Strategy, but this needs to be coordinated with other actions to establish the case for an exportable product. It therefore seems appropriate to explore the launching of a large-scale programme to boost selected agro-industrial lines of action in close links with concerned agriculture communities and co-operatives. The programme could be seen as a scaling up of the Community Processing Centres and its integrated approach, once sufficient feedback, experience and learning has been amassed.

Many challenges are faced by the agricultural sector and most have an STI dimension. One is the lack of research in post-harvest and biochemistry fields. Packaging is also an issue, as Rwanda has banned plastic bags to lessen the environmental impact of plastic pollution. However, this has had the effect of reducing the availability of all polyethylene products. Linking ICT with agriculture needs to receive prioritized attention to enhance productivity during planting, production and harvesting, and improved access to meteorological information, as well as improved price discovery and efficiency of markets.⁶² This will be the priority for the ICT4RAg programme inaugurated in 2016. Smallholdings are a problem for applying both IT and mechanization, as well as for developing the most productive mix of crops and activities and linking these up to the agro-food and processing industries. Apart from smallholdings, the largely hilly terrain requires the development of specific agricultural strategies. The harmonization of phytosanitary standards and quality certification in the Northern Corridor and the EAC would incentivize investment in technology and improvement of absorptive capacities.

Apart from the encouraging action of the Community Processing Centres on specific agro-food products, the agro-food industry and its

Box 3: Drones in health services in Rwanda

President Paul Kagame formally inaugurated the Rwanda national drone delivery system on 14 October 2016. In a world premiere, drones will be used to deliver blood to patients in 21 transfusing facilities in the western part of Rwanda, where poor roads and healthcare infrastructure have often made it difficult to reach patients in need. The drones, known as "Zips," can fly up to 150 kilometres round-trip, and carry up to 1.5 kilograms of blood. Healthcare units can order blood via text message and have it parachuted to their location in 15 minutes. The neediest patients are mothers suffering from postpartum haemorrhaging, which is the leading cause of maternal mortality worldwide.

The Zips are fixed wing aircraft that have a large range compared with helicopter drones. Swapping out batteries for a freshly charged set readies the drones for their next delivery in several minutes. The project is led by a California-based drone start-up Zipline which has, among others, Microsoft co-founder Paul Allen and Yahoo founder Jerry Yang among its top investors. The project is implemented in partnership with the UPS Foundation and Gavi (The Vaccine Alliance), while the Rwandan Government is paying for the operational service as part of its social healthcare activities. From an STI perspective, it is important to assess the impact beyond the actual healthcare value and see what technological competencies, skills and tacit knowledge have been transferred, and how the experiences are replicable in the EAC region and further afield.

innovation capacities may be supported through innovation in packaging, improvements in product handling and logistics, and branding and marketing. The challenge to achieve scale economies quickly and efficiently, due in part to the smallholding structure of agriculture, may require increased policy efforts in particular when the objective is to attract foreign agro-food businesses and investors. The rural population makes its livelihood largely outside of the formal economy. This presents, therefore, an enormous conceptual challenge of not only bringing the rural population into the formal and monetized economy, but going further and turning its youth into entrepreneurs with access to capital, technology, and the national market.

6.4 Industry and research capacities

Industry includes the sectors of energy, (which is an important STI enabler and which will be considered in chapter 9), as well as manufacturing, construction and mining. Industry, with a primary focus on manufacturing, will be considered in chapter 12. This brief discussion will serve to highlight R&D activities in relation to industry in Rwanda.

NIRDA was established in 2013 to support R&D projects of economic value for industry.⁶³ It is

composed of an R&D department with four divisions (pharmaceutical and chemical, agro and biotech, environment, and process engineering), as well as a technology transfer and commercialization division. Researchers are supposed to prototype new products to be then further developed and commercialised by the business sector. A committee made of government and business representatives approves proposed projects for financing. NIRDA's plan is to recruit some 200 researchers and technicians. The annual budget of NIRDA is about \$3.1 million,⁶⁴ of which about 20 per cent is used for R&D programme development, beyond salaries, technical expenses and administration.⁶⁵ NIRDA is the key agency behind the Community Production Centres, which is implemented in cooperation with BDF and, in the case of Irish potatoes, with the local Cooperative Ibukwa Muhinzi.

As previously discussed, the level of R&D activates of NIRDA reflect the overall development level of Rwandan industry and its size vis-à-vis the national economy. However, they would require some strengthening in order to better match national development ambitions. Among noted challenges is the low level of R&D demand coming from firms in industry that would lead to NIRDA and partner agencies acting as entrepreneurs, technologists

Box 4: Kigali Innovation City

The Kigali Innovation City (KIC) project is established as a flagship initiative to accelerate Rwanda's development towards a knowledge-based economy. Digital and internet technologies and services will be its initial focus with other sectors interacting through innovation based around ICTs. It will host indigenous and innovative Rwandan technology companies that will serve the national market as well as the EAC and the entire African continent. It will also provide a world-class environment for multinational technology companies innovating and expanding their products and services for the African market. Given such ambitions, the KIC project will need the committed support of policymakers who will, in turn, need to distinguish between two sets of policies: a primary set directed at KIC and a secondary set for KIC to pursue with their partners and tenants. Many of these are already in place or under consideration but they bear repeating.

Regarding the first policy set, four key areas may require attention.

1. **Policy coherence:** There should be a close alignment between the national development strategy, the national STI policy and the sector profile of KIC. This requires functional linkages among line ministries and industry representatives, and an alignment of time horizons and incentives. The goal of Rwanda developing a knowledge-based economy is generally reflected in the KIC proposition.
2. **Financial sustainability:** KIC will initially require public funding to attract tenants and establish partnerships. It is unlikely that there will be many tenants with meaningful revenues and profits early on, and policies governing terms and conditions may need to reflect this reality. However, in the medium- to long-term, financial autonomy is desirable, though not at the expense of under-prioritizing the innovation impact.
3. **Outreach:** KIC will need to make their tenants attractive to national and international partners and this will depend on the actual innovation quality of KIC activities, as well as on the public relations and marketing activities of KIC management.
4. **Tenant funding:** Innovation is risky and uncertain and entrepreneurs that cannot secure funding may see the knowledge competencies they have assembled dissipate quickly. Financing the activities of KIC tenants may need to rely on diverse sources, including private investors, public investment vehicles and public-private partnerships.

Regarding the second policy set, KIC itself will need to develop strategies in the following three areas:

1. **Tenant selection:** Tenants are normally selected from a priority sector or industry. This will also involve encouraging universities and research organizations to become tenants. The establishment of Carnegie Mellon University at KIC is an important step forward. Organizations and firms that can provide IP consulting and training on developing entrepreneurship and management skills, as well as soft technologies (e.g. marketing or logistics), may be invited to become tenants.
2. **Incubation:** Business incubation facilities increase the chances of innovations maturing into commercial products and services. KIC may need to have its own on-site business support facilities that can guide tenants in the economic discovery of the commercial potential of their innovations.
3. **Capacity to assess innovation outcomes:** KIC will need to identify itself as an agent in the Rwandan national innovation system and avoid paths that may lead it to acting predominantly as a real estate investor. KIC performance indicators should include national development targets such as the creation of highly qualified jobs, new technology businesses and sectors, or the strengthening of export sectors and participation in international value chains.

and angel investors. There is a need to strengthen mechanisms and linkages that would improve the ability of Rwandan industry to formulate a clear expression of technology demand and increase the impact of the agency.

Vision 2020 establishes that developing a solid technological research and services infrastructure is a primary policy element, and NIRDA will act as the lead for significant industrial R&D projects. An important element in evolving the Rwandan national system of innovation will be extending linkages and cooperation with BDF, as well as all the other funding agencies listed in table 5.2, RSB, University of Rwanda, Carnegie Mellon and other academic institutions, the Private Sector Federation (PSF), and the Chamber of Industry. A focus on established industry should not, however, lead to neglect in R&D assistance provided to innovative SMEs and cooperatives. Improving and increasing collaboration between SMEs and vocational training institutions countrywide is a valid policy proposition. Collaboration may be useful for providing technical assistance, absorptive capacities and knowledge transfer among firms, trainees or budding entrepreneurs. It also provides students with more profound opportunities to evaluate and engage in their future career paths, beyond a basic internship, while entrepreneurs can have a better assessment and input into the development of the workforce.

6.5 Kigali Innovation City

Along the Kigali industrial zone, an innovation city, promoted by the Rwanda Development Board, is being built (61 hectares) with ambitious plans based around three platforms: digital innovation, human capital development and innovation-friendly financing. The infrastructure itself will house many elements beyond innovation and R&D facilities, such as corporate buildings, retail, leisure, sports, accommodation, education, and health care facilities. The research infrastructure would gather resources from outposts of the International Centre for Theoretical Physics (based in Trieste, Italy), Carnegie Mellon University, and the African Institute of Mathematical Science, among others. A set of global high-tech companies would form an industrial skills academy. An innovation platform would host promising clusters that are part of digital innovation or digital transformation processes, such as ICT for financial services, biomedical, or energy innovation. Bright and numerous start-up businesses, with high growth potential, are expected to result from this combination of efforts and partners, while supported by the substantial funding mechanism of the RDB Rwanda Innovation Fund and its in-house incubator, the KIC Accelerator Hub.

The KIC is a large project by any measure and its success is dependent on the growth of linkages and collaborations both among its tenants, and with its immediate environment. In this way, it is a test of whether Rwanda will see acceleration in the development of its national system of innovation. The development of supporting mechanisms that

would energize interaction and collaboration should be considered, particularly, among experts, entrepreneurs and firms associated with activities of the Accelerator Hub. The monitoring of the quantity and quality of interaction at KIC, as well as the actual innovation outcomes, should feed back into policy development processes. Policymakers will, nevertheless, find themselves with a plethora of decisions to make, as running an innovation park has its own challenges (UNCTAD, 2015). Box 4 highlights several policy issues relevant for the KIC project, but which are equally relevant for other STI parks and incubators in general.

7. Education structures and initiatives

The Rwandan transformation of its education system is a remarkable success. The policy objective is summarized as, "... ensuring equitable access to quality education focusing on combating illiteracy, promotion of science and technology, critical thinking, and positive values" (MINEDUC, 2013b). The Education Sector Strategic Plan (ESSP) is fully aligned with EDPRS 2 and, from the perspective of this STIP Review, of particular note is its Goal 3: "To strengthen the relevance of education and training to the labour market." In its discussion of strategies for achieving outcomes the ESSP recognizes that STI is a dominant factor behind rapid economic and industrial growth, and commits to addressing issues of underdeveloped skills in science and technology.

Improvement in science and technology environments in schools, and developing demand-driven and relevant science and technology curricula, will require interaction with other STI stakeholders, including financial firms and industries.

The recognition of the need for inter-institutional linkages is also well established in the ESSP. The Ministry of Education, recognizing the importance of leading in the practice of innovation, policies aside, launched an Innovation for Education fund in 2012. The fund finances innovative pilot projects on improving children's learning. The Innovation for Education has so far supported 26 pilot projects with funding worth \$15 million provided by the Department for International Development (DFID). Rwanda spends around five per cent of its GDP on education, including tertiary education.

In discussions during the UNCTAD mission, the problem of mismatches between work competencies and qualifications, and economic needs and job opportunities in industries and services, was raised on multiple occasions. According to recent surveys, more than 13.5 per cent of higher education graduates do not find a job in the year following graduation (Integrated Household Living Conditions Survey 4 – EICV4, 2016). On the other hand, technical skills for maintenance, service and repair of machines used in industry fall short of demand and are often imported.

More generally, Rwanda has a youthful population of 12 million, more than 3.5 million of which are under 25 years of age. Rwanda's youth has the potential to be its most industrious asset if properly educated and trained. With this in mind, the discussion will briefly comment on several basic educational issues before discussing in more detail the TVET and university systems.

7.1 Basic education

Rwanda has the highest primary school enrolment rates in Africa, and already has achieved, or is very near to achieving, universal access to primary education. Primary school net enrolment rates have increased to 97 per cent in 2012 and gender parity at primary level has been realized. Primary school completion rates have risen to 73 per cent in 2012 from 53 per cent in 2008. In 2012, the qualified teacher to pupil ratio at primary was 62:1, an improvement on 67:1 in 2008.⁶⁶ The secondary school net enrolment rate in 2012 was 28 per cent, with girls now claiming a 52 per cent majority of the student body.⁶⁷

With Rwanda's success at achieving near universal access to primary education, a strengthened focus has been placed in recent years on improving the quality of that education. Approaches to achieving this include building capacities to plan, implement and monitor programmes and interventions aimed at ensuring equitable access to quality education, including early childhood education services. It is important to continue this momentum. As noted, a strong and sustained effort has been made to ensure all youth are in school. Programmes that aim at developing their IT literacy are commendable.

Some challenges remain and need to be taken into account in assessments of the overall investment in education. One important issue is the development of soft skills, such as autonomy, creativity, problem-solving and social skills for work environments. Another is the need to continue to strengthen analytical, problem solving and critical thinking aptitudes of pupils and students. Adjustments will be inevitable in the processes of developing the country's human capacities, in order for development ambitions that focus on the knowledge economy and use of ICTs to transform sectors and industries to be realized. Familiarization with the nature of entrepreneurial activity and with the basics of business creation and management should ideally begin in secondary school.

7.2 Higher education

In the higher education segment, a major merger has given birth to the University of Rwanda (UR). The University has 14 campuses, four of which are in Kigali. Twenty per cent of teachers have a Ph.D. A first in-depth evaluation of university outcomes was conducted in 2016. A major conclusion was that knowledge is not anchored in practical applications. This led to several initiatives to renovate the curricula of students, notably the creation of institutes focused on specific issues, such as food science, and interdisciplinary studies. It also highlighted the need to have consultations between academic institutions, firms, enterprises and government bodies that are primary STI stakeholders. This should ensure that the curricula address the needs of the economy, and that the balance of degrees and specializations is in concert with development prospects and ambitions. Table 6 presents the number of students enrolled at University of Rwanda colleges.

In the UR College of Science and Technology (CST), there is a profound concern for the employability of graduates and their engagement in the economy. Each year, 1400 engineering students successfully graduate. In the last promotion, 300 had found a job in government structures and 200 in the private sector, while the others are searching for a job, and this in spite of an unresolved skills gap.⁶⁸ In response to this unsatisfactory outcome, several innovations have been introduced in the curriculum. Entrepreneurship training is now mandatory in the 2nd year. Students must formulate thesis projects in response to local community needs (in group work), and there is a competition among projects called, Creating Job Creators. Twenty-two such projects were presented in August 2016.

Important developments are envisaged that will align the UR with international trends. A further increase in research capabilities is planned, notably in concert with the establishment of Centres of Excellence. E-learning is evolving with a commitment to put 50 per cent of all courses online, in alignment with policy targets in ESSP. A change in the tuition fee system is under review and may bring fees in line with real costs for students, 96 per cent of whom receive a scholarship.

Several regional Centres of Excellence are being created with the support of the World Bank, with significant funding. Following a first wave of Africa Centres of Excellence (ACE) focusing on West Africa, a second wave – ACE II – focusing on East

Table 6: Number of students enrolled at University of Rwanda colleges (January, 2015)

		Number of	in %
STEM studies	College of Science and Technology	6,056	19
	College of Medicine and Health Sciences	3,677	12
	College of Agriculture, Animal Sciences and Veterinary Medicine	3,594	11 42
Liberal arts studies	College of Education	6,415	20
	College of Business and Economics	9,717	31
	College of Arts and Social Sciences	2,301	7 58

Source: University of Rwanda, <http://ur.ac.rw/?q=node/100>

Africa has been launched. Twenty-two applications were received from the sub-region. Four have been selected to be established in Rwanda, and will receive in total 20 million US\$ in loans. Four centres of excellence will be funded by ACE II and hosted in three UR colleges. The college of Business and Economics will host the ACE for Data Sciences. The College of Education will host the ACE for Innovative Teaching and Learning Mathematics and Science. The CST will host two centres: the ACE for Energy for Sustainable Development and the ACE for Excellence in the Internet of Things. The objective is to build a critical mass of African scientists and engineers and to set up a lab for open innovation and development. These initiatives are needed to improve the STI human capital foundations of Rwanda. However, there should be concerns as to how the operations of the centres link up with the institutions and enterprises and how their outcomes will make it beyond publishing research papers.

7.3 Technical and Vocational Education and Training

In the Technical and Vocational Education and Training (TVET) system there is a solid infrastructure, organized into three levels: regional centres, senior high schools, and vocational training. At the regional levels, there are five Integrated Polytechnic Regional Centres (IPRCs) – one per province. The largest centre, based in Kigali, hosts 3800 students or 8000 in total, if students of the two lower levels who come for occasional courses are included. Women, who were only three per cent in 2008, account now for 20 per cent of students. The Centre covers all disciplines except agriculture and agro-food. Industry is involved in curriculum development and internship provision. Two months of in-company training is part of the curriculum. Major investments have been made in the Kigali centre with the support of the Government of the Republic of Korea and of the Kuwait Fund. The Centre plans to have 2000 more students next year. The students seem to find employment with ease, and 20 per cent go on to create their own business. An innovation competition is organized each year and the Kigali IPRC has opened an innovation and incubation centre in which students can test and prototype their ideas, and receive some marketing and technical support.

In addition to the IPRCs, there are TVET structures in all districts and around 100 are operational. An in-depth examination would be useful to review the quality of teaching and learning. As they operate under the supervision and with the assistance of IPRCs, it would be easier to raise and maintain quality courses. A key point would be to introduce courses in entrepreneurship and business management, and facilitate internship training within firms, as is the practice at IPRCs. Moreover, as proposed above, it would be important that the TVET structures, in each district, open innovation workshops. In these workshops, local innovators

and entrepreneurs can receive needed technical assistance, design and prototype their products (e.g. through 3D printing), while having access to all needed information, through ICT links with appropriate data bases.

7.4 Capacity-building and evaluation

In view of the challenges of human capacity development, there is need for good monitoring of achievements of all education and training efforts. To monitor the achievements of education and training efforts the Government has established a Capacity Building Services and Employment Board (CESB). It oversees the identification of training needs and gaps, and coordinating an institutional and policy response. The Board of Directors of CESB is composed of seven members appointed by a presidential order. All major ministries are present in the overall governance and take on roles appropriate to their mandates. The annual resources of the organization amount to \$5 million and it employs some 50 staff. The resources are essentially used for channelling investment into training the different entities, including private companies and government institutions, and then linking them with training providers (TVET, universities, and private consultants). The NCBS resources would represent about six per cent of the total financial engagements in training nationwide. The NCBS strategy is formulated in consultation with the private sectors federation that form Sector Skill Councils. In liaison with the NCBS, the National Commission for Science and Technology (NCST) has conducted some pilot, in-depth skill assessments in the energy sector. This has led to the establishment of a detailed manual of qualification profiles.

NCBS initiatives are clearly purposeful, but the question is whether they respond to the economic development ambitions as expressed by Rwandan policymakers? In order to assess this, systematic skill audits in the different parts of the economy, similar in nature to those carried out with NCST, would need to be organized and implemented. The objective would be to ascertain how policy can better respond to the demands of the economy and society in order to reduce the observed skill mismatches and gaps.

8. STI and the institutional setting

8.1 STI policy coordination

A knowledge-based development strategy requires strong leadership at the top level of government, as well as efficient coordination of the diverse horizontal linkages that it will inevitably generate. In practice, this implies some level of formalization of the national system of innovation. Mechanisms for systematic consultation among concerned ministries and institutional STI partners and stakeholders should be part of broader efforts for best practices in governance and policy management. Mechanisms would include joint

performance contracts bringing together two or more STI stakeholders, public or private, which share common targets.

There are several signs that coordination in STI policy action can and should be improved. These signs usually manifest themselves when policymakers consider a specific challenge and ask whether the balance is in the right place. For example, the skill mismatches – the lack of balance between competencies on offer and those in demand – affecting large parts of the economy, may be improved through enhancing coordination between training and educational institutions and employers. The imbalance between innovation inputs and outcomes makes Rwanda an inefficient innovator, according to GII parameters. This may require strengthening coordination among line ministries on joint activities, as well as a more general review of how each line ministry sees its role in the national STI strategy and its implementation. A perception that the STI policy balance is off-kilter from a sectoral perspective can lead to overinvestment in funding and budgets, when work on establishing synergies through better coordination may be a better first call. For example, the agriculture sector may seem underfunded compared to ICTs but the most immediate solution would be to better connect ICT and agriculture research to increase innovation that can serve farmers and agro-food businesses. Similarly, imbalances in policy attention between new high-tech projects and established sectors and industries may be better addressed through increasing coordination and cooperation, rather than disrupting current policy prerogatives.

The Government may wish to examine whether the current coordination mechanisms that are assigned to the NCST require strengthening. The NCST is designed and adapted to the Rwandan context after an examination of best practice in other national systems of innovation. It operates with reporting lines directly to the highest levels of policy making. However, its structure is overloaded. Eleven experts are charged with covering two strategic themes addressing nine national science and technology issues in ten national priority areas.⁶⁹ In addition, NCST is planning to host and manage the new Research and Innovation Fund. NCST is science and research-oriented in its approach to the STI process. This particular characteristic may have an effect on how it manages and evaluates the outcomes of the Research and Innovation fund. If the assessment of Rwanda as an unnecessarily inefficient innovator is correct, policy activities that have at least a minimal bias towards the innovation side of the STI process may have a more purposeful impact.

In the light of the above, the establishment of a high-level national innovation body with decision-making powers may merit consideration.⁷⁰ It should be chaired by the highest level of leadership from Government, business and academia and would ensure that the overall STI strategy is well integrated into the broader development strategy of the country. The main objective of this body would

be to make sure that the overall STI strategy is well integrated into the broader development strategy of the country. It would insure that the different STI policy actions are well coordinated, properly funded and balanced in manner, efficiently implemented, and adequately evaluated. Such a council can be served by the NCST, which would provide analytical inputs and backstopping. The effectiveness of strong coordination at the top level of government is illustrated by the recent STI success stories of Finland and Singapore and is highlighted in box 8.1.⁷¹

NCST will need to continue to play its unique and essential role in coordinating the national science and technology (S&T) and R&D effort. It performs also the highly useful role of energizing the nascent national system of innovation through cluster activities that involve various STI stakeholders on specific topics,⁷² as well as the work on skill needs in liaison with the NCBS. The NCST foresight activities are useful and should be expanded. These activities would benefit from incorporating experiences of international practice, based on a systematic exploration of future technologies and innovations with the help of the different actors, spanning from scientist to industrialist and foreign experts. Strengthening cooperation with the UNIDO Technology Foresight Database project may be a natural extension of the UNIDO Country Programme agreement established in 2016. NCST should maintain and strengthen its role in the development of structured and durable relations with foreign S&T policy institutions, such as the Singapore Agency for Science, Technology and Research or the Korea Science and Technology Policy Institute.

8.2 Performance evaluation and STI policy competencies

To ensure policy success, it may be necessary to consider ways in which the Imihigo performance contract system can be leveraged to respond to the challenges of an innovation-driven economy. One possibility may be to, on evaluation, give increased merit to innovation-led performance commitments. Imihigo could increase the inclination of individuals and institutions to be more open to risk-taking and improve their innovation performance. A favourable and enabling circumstance was, as the UNCTAD mission learned and in contrast to situations in many countries, Rwandan social attitudes towards entrepreneurial failure are not unsympathetic but, to the contrary, inspire solidarity.

A complementary issue concerns the learning process and competencies in STI and NSI theory, and policy of the staff involved in the promotion of innovation. The UNCTAD mission observed that innovation is generally well understood among policymakers and there was an appropriate grasp of policy issues in academia and among entrepreneurs. However, a tendency to withdraw into considerations of science and R&D was noticeable. Such a tendency is understandable as these categories can be measured and accounted

for, while innovation outcomes are, however practical, more difficult to quantify or predict. It is simpler to count STEM graduates and published articles, or investment in R&D facilities, than how many new or novel processes/products/services have been introduced into the national economy or market. As a result, innovation is often interchanged with invention and R&D. What is somewhat lost in translation is the firm-level and entrepreneurial essence of innovation.

Experience with designing and managing innovation policy measures is growing and will improve, particularly in the process of developing the new National Science, Technology, Innovation and Research Policy. Rwanda has sought the advice and inputs from a broad array of international experts and agencies and such initiatives are an excellent indicator of the capacity of policymakers to cooperate and engage on STI issues. To complement efforts at the highest levels, staff of agencies with important STI-related mandates should be incentivized to reinforce their learning by developing horizontal linkages and cooperation with counterparts from other national agencies, educational institutions and industry associations, as well as counterparts abroad and in international organizations.

8.3 STI policy development post 2017

The current deliberations on developing a follow-up to the 2006 Policy on Science, Technology and Innovation will produce a strategic document that will govern STI in the next decade, and therefore utmost care needs to be taken in setting the context and proposing goals and actions. The discussions have been comprehensive and all the policy components are present. The relationship between STI and Rwanda's development trajectory is of great concern and the notion that it must use STI to build competitive advantages is well-established. With this in mind, the process of developing a future STI policy document may reflect on a number of critical issues.

Innovation should be at the core of the national STI & Research (STI&R) strategy. Innovation is the end that justifies the means and the measurable outcome that validates the renewal and improvement of the technological basis of the country. It seems, however, that the general understanding of the innovation process is linear: innovation outcomes are a result of preceding research activities and investments which are estimated at 0.4 per cent of GDP (UNESCO, 2015) and are therefore insufficient. Increasing R&D spending thus becomes a logical policy proposal. In reality, things are more complex and, as discussed in this report, the technological receptiveness and the capability of the different sectors of the economy and its firms to innovate are what matter.

The overall objective seems to increase the percentage of R&D spending to one per cent of GDP by 2020 and four per cent in 2050, from an estimated 0.4 per cent today. Fixing such a target is useful, but what also counts is the share of the

funding that comes from the business sector. In light of this, fixing a 50/50 split between business funding and government funding of R&D, within a ten-year horizon, would be an appropriate additional target for Rwanda. To complement this, it would be useful to provide targets for increasing the number of scientists and engineers employed in firms, farms, industries and sectors.

The question of STI&R funding and coordination, and their institutional location is important. Except in the ICT sector, current policies aimed at boosting R&D, innovation and technical capacities in the productive sectors are weak, and the necessary linkages between science and technology research activities and educational institutions are underdeveloped.

Best practice tends to favour a separation of implementation and funding. Such a separation increases the level of accountability and establishes financial control at a higher level of scrutiny than in the case where a single institution develops policy, implements it, and reports to itself on established KPIs, as well as on financial compliance. More generally, the institutional arrangement needed to support a national innovation system may need deeper consideration. Examples of implementation in other countries may be drawn upon to decide what is appropriate in the Rwandan context. Regardless of the model, it is imperative that all stakeholders – i.e. industry, government agencies, training and academic institutions, environmental concerns and the general public – are involved from the outset in developing the goals and strategies, and that they have a committed ownership over the policy tools they will need to use and of the outcomes they will need to evaluate.

Strategic partnerships will need to be broadly developed and reach beyond centres of excellence to involve firms and industries, directly or through their associations, such as the PSF and its sector departments. Centres of excellence are a key factor in increasing the amount of scientific and R&D activities. However, their impact on innovation is dependent on how well they are linked to firms and institutions that show innovation in the production of goods or in the provision of services. Centres of excellence themselves should not be expected to take a lead role in energizing innovation processes in a holistic manner. Their academic and research strengths often translate into goals that are overweight in KPIs such as published papers or intellectual property outcomes. These are, no doubt, important but they might underserve the STI process. On the other hand, the proposals for an innovation system approach to STI and research development, the development of sustainable STI and research-based industry clusters, and fostering technology innovation incubation and entrepreneurship need to be given top distinction.

The support for STEM studies can be valorized only if there is comparable support for soft technology education such as management, logistics or marketing. It should be stressed that soft technology studies do not include the entirety of

liberal arts programmes. However, and as has been noted in other parts of this review, the UNCTAD mission observed that there is a general hesitation about competition that is largely based on the strength of a marketing message. While more research may need to be done on the entrepreneurial and business culture of Rwanda, the underlying issue may be addressed by enabling STEM studies to have a learning and practical exposure to the soft technologies they will eventually engage with in the real world. Staying on the theme of marketing, awareness-building campaigns will need to go beyond explaining the role of STI for development. Campaigns must seek out industry champions and develop a narrative of professional and economic success that is underpinned by STI. Such campaigns must fully engage the printed and broadcast media as part of

the national system of innovation.

The current policy discussions have a level of complexity that may cause problems in implementation. At present there are four guiding principles, four general objectives, five policy outcomes, 13 specific objectives and 20 core strategic policy actions. There is a proposed relationship between policy outcomes and actions, while the relationship with and among the others is implied and left to interpretation during the eventual operationalization. Establishing unique hierarchies, as opposed to multifaceted complexities, may facilitate execution, as well as facilitate the development of business plans or logical frameworks as implementation tools. It should be noted that developing a monitoring and evaluation framework without or outside of a logical framework implementation tool risks bringing unsatisfactory

Part II: STI policy in sectors and industries

9. The energy sector, development and STI

9.1 Policy background

Energy production and access in Rwanda is an important development challenge. Energy production and distribution has at least five significant aspects. Firstly, it is a fundamental human development issue in the broadest sense. Secondly, energy is a framework condition for STI policy, especially in regard to the development of industry and technology intensive sectors such as ICTs. Thirdly, energy production and distribution is an innovation, entrepreneurial and investment opportunity. Fourthly, affordable and reliable energy is an important factor for the profitability and international competitiveness of Rwandan firms. Finally, developing the energy sector brings policy attention to sustainability issues and environmental concerns. When looking at policy options, a certain multidimensional complexity becomes apparent that may be better addressed by reframing the current inventory of policy priorities in a policy matrix. Complexity should not cloud development ambitions. Rwanda's goal is to have an energy sector appropriate for a middle-income developing country while ensuring access to affordable and modern sources of energy.

At the highest international policy level, UN SDG 7⁷³ guides policymakers to ensure access to affordable, reliable, sustainable and modern energy for all. However, many SDGs are in fact co-dependent on achieving SDG 7, such as SDG 8, on decent work and economic growth, and SDG 9, on industry innovation and infrastructure. In concert, the *UN Decade of Sustainable Energy for All 2014-2024*⁷⁴ (SE4ALL) calls for universal access to sustainable and modern – i.e. affordable, economically viable, socially acceptable and environmentally sound – energy services to be treated as a priority development concern. It notes that 1.3 billion people do not have access to electricity and many are unable to afford it, while 2.6 billion people rely on traditional biomass for cooking and heating. This global assessment mirrors conditions in Rwanda and provides a policy setting that is highly relevant for the country. Rwanda is a signatory to SE4ALL and shares policy goals in its official Rwanda Energy Policy (REP).

International policy deliberations on energy tend to be dominated by the agendas of developed economies and oil-rich nations. However, and as witnessed by the process leading up to UN SDG 7, the discussion has started gradually shifting from a geopolitical context to a development context.⁷⁵ For example, membership in the International Energy Agency (IEA) is open only to OECD member countries. Nevertheless, the IEA monitors developments in non-member economies and takes part in UN development initiatives. The Organization of the Petroleum Exporting Countries (OPEC) narrowly focuses on oil market stability in order to secure income to producers and returns for

investors. However, its OPEC Fund for International Development increasingly engages in development projects, including alleviating energy poverty by addressing climate change issues.

On the African continent, in November 2010, energy ministers adopted the Maputo Declaration, which highlighted the importance of energy policy for poverty alleviation, climate change and social and economic development. It noted that while Africa had substantial natural resource endowments, energy security was still a problem, with knock-on effects on food security and stable, sustained economic growth. Sub-regional, regional and continental cooperation, including pooling of resources, were to be given priority in national energy and development policies. Moving to a regional level, the Eastern Africa Power Pool (EAPP) was established in 2005 by energy ministers from seven Eastern Africa countries including Rwanda.⁷⁶ The EAPP was operationalized in 2010 by agreement among national power utilities. Its goals are to provide a framework for pooling energy, developing interconnections and promoting power exchanges, optimizing regional energy use, and reducing the cost of electricity.

As a matter of national strategy, Rwanda's energy policy is established in the Vision 2020 development plan. It proposes that by 2020 at least 75 per cent of the population will be connected to electricity (up from two per cent in 2000 and 11 per cent in 2010) and the consumption of biomass will decrease from the current 86.3 per cent to 50 per cent of national energy consumption. Of note is how Vision 2020 has established explicit linkages between energy policy and the development of ICTs, transport and industry. It also explains the need for the private sector to invest in energy production and distribution, instead of acting only as a consumer. In implementing Vision 2020, EDPRS 2 provides more insight on energy policy in its discussion of economic transformation and Priority Area 1 on infrastructure development. Several elements stand out in particular. The first is the idea of developing energy capacity through multiple smaller projects, distributed throughout the country and coming online more quickly, instead of through one or several mega projects. The second is to achieve energy objectives using a mix of carbon and renewable sources and technologies. The third is a prominent pro-market and pro-industry character to its guidance on energy: reducing energy costs for firms while, at the same time, eliminating subsidized electricity tariffs. This implies a substantial increase in productivity in the energy sector and an efficient distribution network. Finally, the locus of energy and problems of rural development are given due consideration, as well as the relationship of energy policy and employment, productivity, and its significance as a cross-cutting and macro-economic policy issue.

Implementation is governed by the Energy Sector Strategic Plan 2013-2018 (ESSP) and the Rwanda Energy Policy, both under the responsibility of the

Ministry of Infrastructure (MININFRA). ESSP builds on EDPRS 2 and highlights that energy is both a sector as well as an input for development. It also explains that Rwandan energy policy will necessarily be a mix of grid and off-grid solutions and will be based on a variety of resources, both traditional and alternative. The most recent policy REP revision of 2015 reaffirms that modern energy services are required for growing economic activities, poverty reduction and social services. It notes that shifting consumption from biomass to cleaner energies "... like electricity and LPG reduces pressure on forest resources, protecting land arability and mitigating climate change."⁷⁷ REP explicitly aligns itself with EDPRS 2.

In practice, energy policy is implemented by the Rwanda Energy Group (REG)⁷⁸ and the Rwanda Utilities Regulatory Agency (RURA). REG has two subsidiaries: the Energy Utility Corporation (EUC) and the Energy Development Corporation (EDC).⁷⁹ RURA is an autonomous entity that reports to the Prime Minister and is mandated to regulate the sector, promote competition, protect consumers, approve distribution and transmission contracts for electricity, gas and oil, and approve price tariffs.

9.2 The challenge of energy development

A large segment of Rwanda's population lives in rural areas and attains its livelihood through subsistence agriculture. At least 80 per cent of national energy consumption comes from biomass – mainly wood and charcoal used for cooking. Demand for electricity and fuel is generated by around one fifth of the population living in cities, as well as by urban utilities and services, and from the transport sector and various industries, including agro-food. Therefore, indicators such as per-capita electricity consumption appear low. However, policymakers and industry representatives broadly agree that current electricity production capacities are inadequate, particularly with regard to Rwanda's development ambitions. The electrical grid is also underdeveloped. Table 7^{80,81} gives an overview of electricity access and consumption in Rwanda and several nearby countries.⁸²

Access to electricity is low and the electricity grid does not reach many rural areas. The Government plans to improve access dramatically by 2020. As the grid develops and grows, so the relative cost of

reaching decreasingly accessible communities grows as well. Therefore, the problem is not merely how to build and finance a grid in need of expansion, but understanding what other complementary infrastructure and energy policies are in need of support.

In Rwanda, rural households are dispersed over a wide area, presenting a major development challenge. Dispersed settlements make extending infrastructure relatively expensive compared to urban and more concentrated areas. The success of the Imidugudu programme⁸³ is in part due to its enabling effect on grid access – closely grouped housing reduces the cost of last mile grid development. From an STI policy perspective the research question is: what off-grid technologies can be adapted and implemented in rural Rwanda to alleviate energy poverty?

For a variety of development and environmental reasons, policymakers would wish to see a decline in wood fuel use, in absolute and relative terms. The food culture of cooking on fired stoves is an important, albeit slowly changing practice. A move to replace wood fuel with charcoal harvested from planted and managed eucalyptus forest is an improvement. Innovation is as much an entrepreneurial as a technological outcome, so a further challenge is for modest business interests to venture into solving rural energy problems. However, the fast growth rates of the Rwandan economy and the steady commercialization of agriculture may change all this in the medium-term. Those who chose to be first-mover innovators will reap the rewards.

9.2.1 Electricity

The greatest policy push is behind the development of electricity production and distribution infrastructure. Rwanda had low investment in electricity production in its recent past and no capacities came online between 1989 and 2010. Funding is a major issue, particularly as REG-EUC has been, and still is, selling electricity at a price below production cost and is thus unable to provide working capital for REG-EDC investment. Hydropower provides 50 per cent of electricity production, diesel generators provide 33 per cent, ten per cent is imported and the rest is from methane and solar (RURA, 2015).

Table 7: Electricity access and energy consumption in several countries in Africa (2012)

	Population without electricity (%)	National electrification rate (%)	Urban electrification rate (%)	Rural electrification rate (%)	Electricity consumption (kWh per capita)	Total energy use (kg of oil equivalent per capita)
Africa	58.1	42.5	68.0	25.6	698.0	744.3
Ethiopia	80.9	23.3	85.2	10.4	57.5	492.0
Kenya	80.2	20.0	60.0	7.1	156.8	477.6
Tanzania	76.1	24.0	70.6	6.6	94.6	462.4
Uganda ¹	87.1	14.8	55.4	7.1	78.4	329.0
Democratic Republic of Congo	86.5	9.0	23.6	1.2	104.8	292.4
Rwanda⁸²	88.0	16.8	67.0	4.7	33.2	161.3
Burundi ⁸²	84.0	10.0	34.1	7.0	28.3	141.7

Sources: IEA (2014) Africa Energy Outlook, World Bank Development Indicators, CIA World Factbook, Energypedia.info

Production costs are relatively high because of the inefficiency of old equipment and grid infrastructure, as well as due to the small scale (capacity) of the installations. Electricity rates are reported to be subsidized with EUC pricing tariffs below production costs. Even so, electricity prices adjusted for purchasing power are high, even if they seem to hover around the lower end of global prices at \$0.15/kWh.⁸⁴

Table 8⁸⁵ provides an indicative list of installed and planned capacity. In light of existing capacities, the planned expansion up to 2025 seems appropriately ambitious. However, the actual individual capacity of the planned power stations is small and therefore build-out should be swift. The capacities proposed are like those of other projects in the neighbouring region.⁸⁶ Some of the planned projects will be constructed in partnership with neighbouring countries and the output will be shared.

Energy capacity development faces two challenges. The first is the problem of an underdeveloped grid. Any costing of new plant capacities needs to include extending or upgrading the grid. The second is a funding issue. Planned capacities will cost in excess of \$2 billion.⁸⁷ However, success in attracting private sector investment partners makes it more likely that the Government will not be the only, or even the main, source of funding for future projects. Hopefully, the positive experience of projects such as the Chinese Sinohydro Nyabarongo II hydroelectric development, or the Gisagara thermal peat-fuelled power plant, to be built and operated by a Turkish investor, should

contribute to increasing private sector interest. The key element in the build-and-operate model in contracts with investors is the confidence in the ability of REG-EUC to purchase electricity from the investor-operator at the agreed prices and terms and conditions. Regarding domestic financing sources, the RDB has earmarked \$165 million for investment in the energy sector for the period 2016–2020.⁸⁸

Nevertheless, a macroeconomic and fiscal perspective should be maintained. Given that annual fiscal revenues are about \$1.7 billion, and that MININFRA is allotted only about ten per cent of the national budget, and that its REG-EUC is selling electricity below cost, some public finance may have to be used to keep REG-EUC operating. This also means that for the time being, REG-EUC has no capital accumulation and REG-EDC has to seek out grants or borrow in order to act as an investor.

As Rwanda's debt to GDP ratio is a very moderate 30 per cent, financing the planned energy projects should not be a problem, even if debt-to-GDP ratios increase. The development effects are expected to counteract an increased financial burden, as improved energy infrastructure supports robust growth throughout the economy.

This overview is not complete without noting the many micro or pico power plants and generators throughout the country, many of which are not attached to the grid. Some are hydroelectric plants in the kW range, others are diesel powered generators. Installed small hydro capacity is 10 MW, while planned capacity is around 18 MW.⁸⁹ Solar

Table 8: Electricity generation capacity in Rwanda

Operational	District	Type*	Capacity (MW)	Investor - producer	Year completed
Rusizi I Hydroelectric Power Station	Rusizi	hydroelectric	30.0	GoR/REG**	1958
Ntaruka Power Station	Ntaruka	hydroelectric	11.5	GoR/REG	1959
Mukungwa Power Station	Mukungwa	hydroelectric	12.0	GoR/REG	1982
Rusizi II Hydroelectric Power Station	Rusizi	hydroelectric	44.0	GoR/REG	1989
Mukungwa II Power Station	Mukungwa	hydroelectric	2.5	GoR/REG	2010
Rukarara Hydroelectric Power Station	Rukarara	hydroelectric	9.5	GoR/REG	2010
Ngoma Solar Power Station	Ngoma	Solar	2.4	GoR/REG	2011
Kibuye Power Plant 1	Karongi	thermal methane	3.5	GoR/REG	2012
Nyabarongo I Power Station	Nyabarongo	hydroelectric	28.0	GoR/REG	2014
KivuWatt Power Station	Karongi	thermal methane	25.0	ContourGlobal	2015
Rwamagana Solar Power Station	Rwamagana	Solar	8.5	Scatec/GigaWatt	2015
<i>Total capacity 2016:</i>				176.9	
Planned					
Gishoma Thermal Power Station	Rusizi	thermal peat	15.0	GoR/REG	2016
Rusumo Power Station	Rusumo	hydroelectric	80.0	GoR/REG	2018
Symbion Thermal Power Station	Rubavu	thermal methane	50.0	Symbion Power LLC	2018
Rusizi III Power Station	Rusizi	hydroelectric	147.0	PPP with EGL***	2020
Nyabarongo II Power Station	Nyabarongo	hydroelectric	120.0	Sinohydro	2020
Gisagara Thermal Power Station	Gisagara	thermal peat	80.0	Hakan	2020
Kayonza Solar Power Station	Kayonza	Solar	10.0	Goldsol II	2020
Rusizi IV Power Station	Rusizi	hydroelectric	97.0	PPL tba	2025
<i>Total planned capacity:</i>				599.0	
<i>Total capacity 2025:</i>				775.9	

* All hydroelectric stations are of the run-of-the-river type, whereby little or no water storage is used.

** Government of Rwanda/Rwanda Energy Group

*** PPP: Private-public partnership, EGL: Great Lakes Energy Organization.

power is also making progress, while research has been done on the potential of geothermal energy.

According to the US Energy Information Administration (2016), the cost difference between hydro, solar and geothermal is small and narrowing. Still, fossil fuel plants are the least costly solution to build even if operating and fuel costs vary widely historically and by region. In terms of equipment, at about \$1,000 per kW, they cost less than half compared with hydro, solar or geothermal. However, this does not take into account non-equipment costs specific to the locality, or pollution and carbon emission externalities: a coal plant with 30 per cent carbon capture may cost double that of hydro in equipment only. REG budgets 1kW of thermal methane capacity at \$3,700 in Rwanda. In terms of emissions, methane fired plants emit half the amount of CO₂ per kWh compared with coal, while oil fuel CO₂ emissions are somewhere in-between. Peat is more CO₂ intense than coal. However, biomass as an electrical power generating fuel is less CO₂ intense than methane (IPCC, 2014).

9.2.2 Biomass

Biomass in Rwanda consists mainly of firewood and, to a lesser degree, charcoal. Biomass represents 85 per cent of Rwanda's primary energy use and serves primarily for cooking. Firewood biomass is used mainly in rural areas while charcoal is used predominantly in urban areas. The Biomass Energy Strategy for Rwanda (2009) proposes a reduction of consumption of biomass so that it represents only 50 per cent of national energy consumption by 2020. However, it is not clear whether this will entail a real reduction or only a relative reduction due to the increase in consumption of other energy resources. Firewood and charcoal are also an important source of income for rural communities.

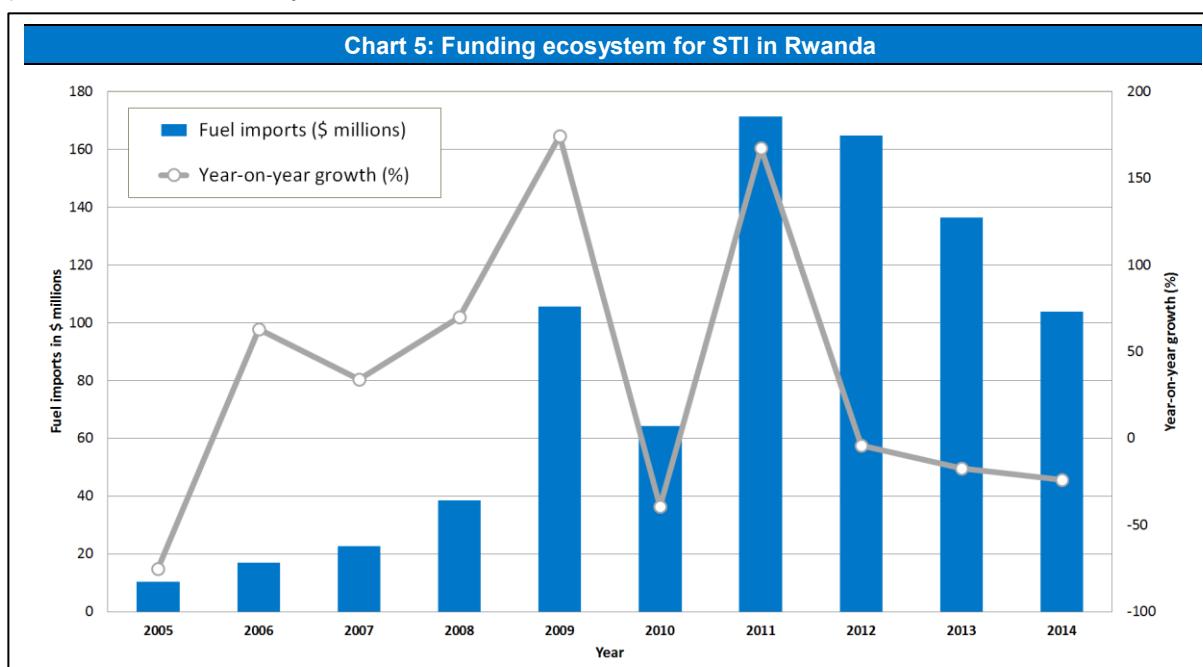
Policies that affect biomass use are under the purview of the Ministry of Natural Resources

(MINIRENA), MININFRA and the Ministry of Agriculture and Animal Resources (MINAGRI), with implementation and coordination responsibilities designated to local government, i.e. through with the Ministry of Local Government (MINALOC).

There are three key concerns regarding biomass use in Rwanda. Firstly, the use of firewood is a threat to forest resources if they are not managed in a sustainable manner. Secondly, burning biomass generates large levels of indoor pollution with serious problems for respiratory health (WHO, 2006), particularly for women and children (Hutton et al., 2006). Thirdly, technological propositions and alternatives are insufficient to affect change. From a technical perspective, biomass briquettes, kerosene, gas, solar and various off-grid solutions may be adapted and can be used as alternative fuel sources. Waste digesters and biogas production is another adaptable and tested technology. However, what is needed is a socio-economic framework for the move away from firewood. Since collecting firewood and biomass scraps is essentially free of charge for underemployed households living on subsistence agriculture, the framework must include awareness-building, income growth and incentives. Moving to charcoal or biomass pellets and using cleaner stoves, while maintaining sustainable forests and waste management, would present a transition phase for poor rural populations. In the medium- to long-term, economic structural transformation will change biomass energy use, needs and habits. Policymakers need to monitor these changes as indicative of the effects of development policy, particularly the pace of reduction of firewood use.

9.2.3 Fossil fuels

The main fossil fuel resource in Rwanda is the gas reserve trapped in the waters of Lake Kivu. Estimates of the size of the reserves vary between 50 and 60 billion cubic meters and these are shared



with the Democratic Republic of Congo. Methane extraction is currently used to power two thermal power plants with a joint capacity of 75MW.

Petroleum products represent 11 per cent of total energy use in Rwanda. Rwanda imports all its petroleum fuel and liquefied petroleum gas (LPG) products. Petroleum products are transported by road through the central or northern corridor and are therefore costlier to access in Rwanda compared with countries that have sea ports. Since 2010, fuel imports amount to about six per cent of total merchandise imports, or about 24 per cent of all merchandise exports. While the growth of fuel imports mirrors economic development, figures tend to vary excessively because of price volatility in oil and fuel prices and exchange rate fluctuations. Chart 5 gives an overview of changes in fuel imports in Rwanda. In dollar terms, fuel imports have experienced an average year-on-year growth of 35 per cent.

RURA expects fuel demand to grow annually by at least ten per cent in the coming years. A particular development ambition is to have LPG replace firewood biomass as the main national energy source. As noted earlier, RURA manages and regulates the national fuel and LPG infrastructure, including storage depots, petrol service stations, import, distribution and trade. RURA plans to increase its strategic storage capacities from 1.5 to four months of national consumption. In 2014 it set forward regulations governing the construction, installation and operation of petrol service stations in Rwanda.

9.3 STI and national energy policy

As previously noted, the main policy documents for the sector are the REP 2015 and ESSP 2013-2018. The ESSP and REP are mutually reinforcing, with ESSP concentrating on policy action and REP focusing on long-term priorities. From an STI policy perspective, REP recognizes several key problems. These include insufficient finance for R&D in the sector, a lack of programmes on energy studies at universities and technical schools, and inadequate human and institutional capacity. REP notes that energy-related R&D has been low, both in the private and public sector, while most energy technology is imported. Rwandan research institutions need to strengthen their activity in developing appropriate energy technologies and in sustainable energy resource use. Collaboration between MININFRA, the Rwanda Ministry of Education (MINEDUC) and the NCST can drive this process. NIRDA may need to strengthen its research on the current and future energy needs of growing industries, and to monitor the sustainability of industry energy use. Cooperation with RSB will be critical for establishing and enhancing energy production standards. Rwandan universities and the private sector will need to strengthen their cooperation and research on practical energy research and technological innovation. With a view to the list of power plants coming online and the future need to acquire and implement green and

sustainable energy technologies, vocational schools and TVET will need to increase their involvement as important stakeholders in energy STI. Finally, international cooperation and joint research will require continued support. While there is no mention of an innovation system for energy in the REP, most of the policy elements are in fact present.

ESSP underscores the guidance and linkages to EDPRS 2 and takes on the implementation of goals related to access and production. ESSP particularly highlights two technological issues. The first is the need for and the role of standards and, by consequence, of RSB as an STI stakeholder. The second is the need to focus on green and renewable energy technologies when and where possible. An important policy lesson from EDPRS 1, which has been taken on board, is the need to fully involve private sector investors and operators and to link them with other STI stakeholders in the sector and more broadly. While mention of academic, educational and research institutions is present, the linkages are not as obvious as in REP. Due to the fact the ESSP preceded REP, linkages between the two policy platforms in ESSP are only implied. Finally, RURA, in its annual report of 2014-2015, notes that while ICT's Vision 2020 targets may be achieved by 2017, there is underperformance in the energy (and water) sector. In the section on energy, a number of activities and achievements are listed and some concerns are expressed, such as delays in projects, and sporadic power outages, and breakdowns at plants and in distribution. The RURA annual report 2013-2014 does much the same, while highlighting the problems of unmet demand from local resources, grid stability, and delays in exploiting national methane reserves for power generation.

The policy work on energy is moving in a positive direction with a confident assessment of the situation and appropriate policy responses. Nevertheless, three issues at the policy level stand out. Firstly, while REP and ESSP have clearly developed a framework of objectives and have clear linkages to EDPRS 2, RURA reporting on activities is not explicitly linked to REP's Overarching Policy Goals or ESSP Strategies and Proposals. In fact, EDPRS 2 is only briefly noted. A further challenge and a key issue for stimulating innovation, is the absence of reporting on interactions with other stakeholders who are not direct subjects of RURA regulatory activities. Apart from reframing activities and outcomes along higher policy goals, it may be opportune to explore possibilities of strengthening linkages between RURA and other institutions, such as RSB, academic and research institutions and private sector firms and organizations, such as the Energy Private Developers (EPD).

Secondly, linkages to ICTs as an important sector and framework condition are indistinct. The UNCTAD mission found that progress on ICT was impressive and infrastructure build-out was quite advanced, including pervasive 4G coverage. The issue that surfaced was the underperformance of

ICT use in business and industry and declining use when moving away from urban centres. While it would be an oversimplification to say that poor energy access leads to declining ICT use, these phenomena are related. The success of ICT was mostly down to the growing penetration of mobile handsets and use in institutions, mainly for voice and text communications. Use of data services will grow with increasing ICT use in industry. However, industry has different mission critical requirements for its environment than private ICT use, and these include energy access. It would therefore be prudent to review the policy environments for energy and ICTs with a view to strengthening policy synergies.

Finally, there is the question of funding. There are two funds under proposal at the moment: the Energy Development Fund and the Renewable Energy Fund. This is a positive development. However, what requires policymakers' attention is the relationship between these two funds and how their goals will combine to solve problems and exploit synergies. As discussed earlier in the review, Rwanda is growing a complex funding ecosystem and much of it is very STI relevant. The challenge is to enable these funds to reach out to entrepreneurs and communities, and to have quality funding proposals with which to engage. An increase in information flows and cross-consultations among funding agencies and STI stakeholders would be beneficial.

9.4 Framing the policy issue for STI

There has been extensive strategic thinking and a comprehensive policy process on energy in Rwanda. The policy directions developed by MININFRA and REG, and as expressed in REP, ESSP and RURA reports, cover many essential issues and map a number of institutional and policy linkages. Through this, a core innovation system is emerging. Policies and strategies feature positive targets in order to secure funding and resources and develop a common purchase from all stakeholders. All of this is encouraging. However, policy directions and planned activities all seem to have the same priority and this may hinder planning, implementation and evaluation. For example,

operating electrical generation capacity should be, at the time of writing, around 200MW. This figure needs to be adjusted upwards to cover micro and mini power plants and generators. Near-term targets of capacity growth and grid access, however, appear to vary widely, between 500MW and 1000MW by 2020. Perhaps this is a result of a strategic framework where actions and outcomes are part of an integrated policy structure, rather than a matrix which separates targets and strategies. Table 9.3 proposes one possible matrix that can help simplify this issue.

Mapping fields 1A through 3B can assist in reviewing policy and developing a distinctive perspective on STI priorities. For example, prioritizing B1 and B2 will be have the greatest impact on industry. To achieve this, investment in physical capacity should be matched with investment in human capacity to run, manage and maintain grid and generation facilities. This will require engaging with academic and vocational training institutions and structures and agreeing to an alignment of programmes. However, technology will mostly be imported and transferred from abroad and thus research prospects may be modest. B1 and B2 will affect social development as a consequence of industrial growth and with a certain delay. The largest engagement of local STI resources and stakeholders may well be in the exploration of geothermal energy production, due to the fieldwork involved.

A1 and A2 have a primary focus on the 70 per cent of the population with no access to the grid and for whom most energy requirements are satisfied through burning firewood. Even if grid access becomes available, a large part of the population does not earn sufficient income to purchase energy in amounts that would make grid expansion commercially feasible. Therefore, STI policy focus may be on local generation and distribution, be it mini-grids, electricity kiosks, mini-hydro, mini-solar or biomass digesters. These are all technologies that require the development of local capacities to install, run and maintain and therefore linkages with education and training institutions are critical. The mode of access to the energy these installations generate may require experimentation and

Table 9: A policy matrix for energy and STI

Result	Strategy	A. Bottom-up	B. Top-down
1. Access		<ul style="list-style-type: none"> • Mini- and micro-grids • Charge points, electricity kiosks • Grid to institutions (medical dispensaries, schools...) 	<ul style="list-style-type: none"> • Grid expansion • Imidugudu programme • Transmission loss reduction
2. Production		<ul style="list-style-type: none"> • Small solar • Small hydro • Biomass digesters 	<ul style="list-style-type: none"> • Hydro • Thermal gas, peat • Solar • Geothermal
3. Sustainability		<ul style="list-style-type: none"> • Reduction in firewood (biomass) for cooking <ul style="list-style-type: none"> ◦ Improve distribution and development of clean-burning stoves ◦ Increase use of gas stoves • Biomass digesters for fuel and electricity generation • Gas distribution 	<ul style="list-style-type: none"> • Reduce oil as fuel source • Intensify use of Eastern Africa Power Pool • Regulations and standards for power plant operation and electricity transmission • Increase energy efficiency of institutions, firms and urban households

adjustment, because the concept of service provision may be novel and because energy service will enter many communities alongside existing and mostly non-commercial sources of energy in the form of firewood and biomass scraps. Thus, innovation policy will need to deal with traditions and cultures, including technical competency and energy use habits. In practice, technological failure often results in reversion to traditional means.

When looking at components in the sustainability issue in 3A and 3B it is important to consider that Rwanda has a rate of energy consumption per capita equal to ten per cent of that in Mexico or Turkey, and four per cent of that in France or Germany. Annual CO₂ emissions are between 0.05 and 0.1 tons per capita, which is low and commensurate to the low level of energy use.⁹⁰ Clearly sustainability issues regarding energy production and use have diverse and local dimensions, some of which will be outlined in the next two paragraphs.

The first is the problem of domestic use of firewood and biomass as a social development and health issue, closely linked to forest preservation and environmental management. There have been a number of attempts at solutions. However they all face the same problem: innovation is not a purely technological endeavour. Success in innovation requires trial and error, experimentation and repetition in failure before sufficient experience has been amassed to develop solutions that work in a living, social and cultural environment, i.e. outside a testing facility. In this sense, innovation is concerned as much with technology as it is with learning how to integrate technology and the social environment, including understanding existing incentive structures, economic flows and relationships. In the end, if social benefits are worthwhile, and in the case of reducing the use of firewood and biomass scraps they most surely are, STI policy will need to intervene and change the existing incentive structures and economic flows to make progress.

The second issue concerns the profile of alternative, green and sustainable energy resources. Development efforts can focus on the smallest capacities of generation and off-grid access in order to move remote populations out of total energy poverty. A strengthened cooperation with countries with similar and positive experiences in pico- and micro-power generation, such as Viet Nam and Indonesia, should merit international donor support. Although necessary, this may be insufficiently ambitious for Rwandan development aspirations. In planning, another criterion needs to be openly considered: where can energy be produced – i.e. where can energy resources or geophysical conditions be found – in a capacity and continuity that would incentivize extending the grid to that resource? This would mean going beyond considerations about what is sufficient to meet demands in that locality, using pico- or micro-size installations. Using a policy matrix also helps develop insight into what are the more STI intense

issues and where increasing cooperation among various stakeholders may be of benefit.

9.5 Conclusions

Energy policy in the Rwandan development context has multiple aspects. It is an enabler of economic and social development, as well as a services sector with substantial growth perspectives that can propose rewarding investment opportunities, provided incentives are properly structured. While there is general support for development prerogatives, there are also fundamental concerns about sustainability, which include climate change and environmental degradation. Rwandan policymakers will need to work on their policies to unify development and sustainability concerns. This can be achieved by contextualizing energy sector strategies and actions against the facts on the ground, which would include the availability of funding, human capacities and engineering capacities relevant to the sector.

The development of the energy sector will complement development in other parts of the economy. Therefore, energy policy development and implementation needs to be coherent with other policies. As part of an innovations system approach, continuous and regular interaction and consultations between REG, RURA, MININFRA, MINEACOM, MINAGRI, MINIRENA, the Rwanda Environment Management Authority (REMA), RDB and the NCST on energy policy issues would be a minimum requirement.

While linking the energy sector with industry development is a primary concern, due consideration needs to be given to addressing the access to energy of rural populations that earn much of their livelihood through subsistence agriculture. Achieving this requires a complex policy mix, as it addresses the consumption of diverse fuel and energy sources in the real world, i.e. outside the research laboratory. A key problem in rural energy development is the difficulty in modelling numerous feedback loops – social, cultural, economic – in a test setting. Therefore, it is important to allow a sufficient scope for trial and error and experiential learning in policy implementation. Apart from technology, what is needed is a socio-economic framework that includes awareness-building, subsidies and incentives, as the use of collected biomass scraps, mainly used for cooking, is essentially free for many rural households.

Unburdened by legacy energy technologies and interests, the underserved rural areas make promising prospective adopters of alternative and renewable energy resources. Encouraging results have been seen in solar production, as well as with biogas production. These are complementary technologies and research needs to continue as a matter of cooperation between REG and academic, research, and training interests at the University of Rwanda, the College of Science and Technology and TVET institutions such as the Kigali IPRC in order to extend and replicate the success of the

National Domestic Biogas Program and the 250kW Mount Jali and 10MW Nyagatare solar power plants.

Perhaps the greatest challenge is how to accomplish the important leap to 1000MW installed capacity that would unblock industrial development. The build-and-operate model is one possibility, and experiences and evaluations need to be fed back into the next policy cycle. These contracts fundamentally rely on the investors' perception of the security of long-term purchase contracts with REG-EUC. Confidence built through positive experience and successful projects should lead to an increase in projects. The involvement of foreign investors and the accompanying technology transfer is also an opportunity for interaction with domestic firms and SMEs, as well as institutions involved in training, research and education. The role of policymakers would be to ensure a level of cooperation between foreign and domestic entities that will produce some level of technological spill overs.

Finally, approaches to policy implementation may deserve revisiting as near-term targets vary widely, while policy actions, goals and strategies are deliberated from multiple perspectives to address their complexity in a comprehensive manner. Successive policy revisions may benefit from producing implementation programmes that are based on evolving a policy matrix that separates goals and strategies, identifies policy components, and allows for the development of implementation programmes as business plans or logical frameworks. This would contribute to developing assessment and evaluations that would more easily feed back into policy, and provide a clear base for policy learning.

10. Information and communications technologies and economic transformation

10.1 Policy background

The global and international economy is becoming increasingly competitive and overwhelmingly knowledge-based. For small developing economies like Rwanda, developing a strategic response is an enormous challenge. However, given its youthful demographics, economic profile and negligible legacy dependencies, the cliché that every challenge is an opportunity rings true.⁹¹ Information and communication technologies (ICTs) underpin the development of a knowledge-based economy and enable STI-led growth and development. Much as in the energy sector, when considering ICTs, it is important to keep in mind their complex nature as both a development enabler and a business and entrepreneurial opportunity. Pervasive ICTs are an important framework condition for the successful implementation of broader STI policies and the evolution of a national system of innovation. ICTs are, as well, a budding services sector in Rwanda.

Having positioned this proposition as a core component of national policy, the Government of Rwanda has committed to developing a world-class

internet and mobile telecommunications infrastructure. It proposes using ICTs "... to deliver better services, create jobs and transform the Rwandan society and economy" (SRMP).⁹² President Paul Kagame has declared that, "The internet is a needed public utility as much as water and electricity."⁹³ Rwanda policymakers see the move towards an ICT-fuelled knowledge economy as a long-term project of transformation, while considering ways to develop immediate returns as well.

The overall policy platform is charted in Vision 2020. It recognizes the complex nature and challenge of ICTs, and highlights this through establishing policy platforms for ICTs as infrastructure development as well as a cross-cutting issue. Vision 2020 encourages the use of ICTs as "... a tool for self-employment, innovation and job creation." It also sees ICTS as an important element in addressing the challenge of developing the economic potential of the country's youth. On a more practical level and from the Government's own perspective, there is a commitment to improve the use of ICTs in services delivery to citizens.

ICT policy is developed in EDPRS 1 and EDPRS 2, three successive National Information and Communication Infrastructure (NICI) plans covering the period 2000-2015, and is today implemented under the SMART Rwanda Master Plan 2015-2020 (SRMP). From an international perspective, ICT policy in Rwanda draws from the SMART Africa Manifesto 2013 which puts ICTs at the centre of development agenda and highlights their role in governance, commerce and sustainability.

EDPRS 1 considers ICT primarily as an enabler and as a component of national infrastructure. The main enabling functions are related to health, education and e-governance. ICT as a business sector is discussed mainly as an issue for FDI as this is the most straightforward way to transfer technology, build professional competencies and develop an ICT services sector. EDPRS 2 reflects on EDPRS 1 and concludes that there has been significant improvement in the delivery of government services using ICTs. It proposes that ICTs are important for promoting innovation and youth employment. EDPRS 2 develops several linkages between ICTs and rural development, including market information systems for farmers. More generally, ICTs are seen as cross-cutting technologies that are key to enabling firms to be more productive. This is conditional on developing ICT skills and competencies in the workforce and therefore ICT skills development is noted as a complimentary focus area. Finally, ICTs are seen as a major contributor to improvement in public service delivery.

The five-year National Information Communication Infrastructure (NICI) policy plans have treated the ICT development problem in greater detail and have drawn several conclusions. NICI-2005⁹⁴ established that the main challenges were funding, expertise and coordination among line ministries and stakeholders (RITA, 2005). NICI-2010 set out

the need for the monitoring and evaluation of programme activities. It introduced the notion of flexibility in implementation to reflect the permanently developing nature of ICTs and ICT services, and it decentralized implementation by proposing a network of implementation agencies. Substantively, NICI-2010 established ten action pillars. Some addressed the broader issues, such as economic development, while others focused on specific challenges, such as the legal and regulatory environment.⁹⁵ Building on previous work, it continues to address ICT infrastructure development as well as applications and systems which use this infrastructure. It devotes policy space to fostering private sector participation in its activities and goals. NICI-2010 saw the deployment of the current internet backbone linkup and important improvements in coverage of mobile and optic fibre networks. NICI-2015 set out five focus areas: skills development, private sector development, community development, e-government, and cyber security. It also incorporated lessons learned from the ICT policy process. NICI-2015 recognized the need to strengthen evidence-based policy management, improve information flows among stakeholders and improve coordination when multiple agencies were involved in same, or related, programme activities.

The year 2015 saw several changes in ICT policy. Following the merger of the Ministry of Youth and the Information Technology Commission, policymakers laid out a new policy cycle to succeed NICI-2015: the SMART Rwanda Master Plan (SRMP).⁹⁶ The plan highlights the need to use ICTs to transform Rwandan society and its economy. SRMP establishes six key deliverables, three of which deal with the effective use of ICTs to provide quality government services, while the other three focus on developing private sector business opportunities, job creation, and the overall contribution of the sector to economic growth and GDP. Reflecting on the NICI programmes, several elements of success are noted: leadership, resources, stakeholder buy-in, and clarity in

strategy and implementation. SRMP considers the ambitions and accomplishments of the NICI programmes, revisits Vision 2020 and EDPRS policy priorities, and lays out seven pillars and three enablers used to focus policy activities. The pillars are health, finance, business and industry, agriculture, education, governance, and cities, while the enablers are governance, capability, and secured and shared ICT infrastructure. Based on these it proposes ten objectives and a roadmap for implementation. SRMP concludes that: “*The ability for all to access and contribute information, ideas and knowledge is essential in building the prosperous and knowledgeable society...*” (SRMP).

10.2 Progress and achievements

The high-level objective of policy is to use ICTs to transform Rwanda into a knowledge-based economy, thus overcoming its landlocked position and modest natural endowments while taking advantage of its youthful demographics. The challenges for ICT policy and the way forward has been expressed at several levels of detail in Vision 2020, EDPRS, NICI and SRMP documents. Supported by such a high-level of policy commitment, Rwanda has achieved notable results to-date and ICTs represent an important part of the Rwandan non-agricultural economy. Since 2000 the information and communications sector has grown more than tenfold and is steadily increasing its stake in GDP. GDP is estimated to be three per cent, while annual FDI in the ICT sector is estimated at over \$55 million (MYICT, 2015). Table 10 provides data on this progress.

Leapfrogging from analogue to digital mobile communications has been successful. At the time of writing, there are 12.8 million mobile subscriptions – more than double compared to 2012 – with penetration rate exceeding 100 per cent.⁹⁷ Mobile coverage is almost 100 per cent while 4G LTE mobile broadband services are available through the three mobile providers.⁹⁸ In 2011 the Government completed the countrywide laying of an optic fibre network. The Government

Table 10: Growth of information and communication services in Rwanda, 2000-2015

	As a per cent of GDP							
	2000	2005	2010	2011	2012	2013	2014	2015
Agriculture, forestry and fishing	39.34	40.90	34.75	34.67	35.33	35.11	34.99	34.63
Industry	12.07	12.57	13.74	15.44	15.20	15.65	15.17	15.08
Trade and transport services	12.23	13.39	16.70	16.50	16.84	16.39	16.41	16.12
Other services	33.39	31.58	34.81	33.39	32.66	32.82	33.44	34.16
... of which information and communication	1.88	2.14	2.70	2.59	2.79	2.51	2.63	2.81
In Rwandan Francs, billions								
	2000	2005	2010	2011	2012	2013	2014	2015
Agriculture, forestry and fishing	251	553	1082	1244	1483	1624	1785	1908
Industry	77	170	428	554	638	724	774	831
Trade and transport services	78	181	520	592	707	758	837	888
Other services	213	427	1084	1198	1371	1518	1706	1882
... of which information and communication	12	29	84	93	117	116	134	155

Source: National Institute of Statistics of Rwanda

engaged with Korea Telecom to establish KT Rwanda Networks⁹⁹ to bring 4G LTE wireless broadband internet access cover to 95 per cent of territory. The country is served by nationwide optic fibre infrastructure and has been connected to the Internet backbone since 2009 through the undersea SEACOM cable operator. Prices for 30 GB, using 4G LTE of data over a period of 30 days, vary between \$50 and \$100.¹⁰⁰ The East African Community (EAC) created a single network area for Burundi, Kenya, Rwanda, Tanzania, Uganda, and South Sudan, to eliminate mobile roaming charges and international call surcharges with a tenfold increase in call volume (Kelly and Kemei, 2016).

The One Laptop per Child project has, at last count, distributed over 280,000 laptops to over 500 schools.¹⁰¹ In terms of hardware production, Positivo BGH, a Latin American IT company, started manufacturing laptops, computers and tablets in a plant in the Kigali Special Economic Zone. In response to these developments there has been an increase in enrolments at TVET and university courses that focus on IT and computer science. Table 11 gives a regional perspective on Rwanda's recent advances and position.

There has been much progress in e-governance with the *Irembo* platform providing diverse services such as immigration, registrar services, driving licences, and land title transfers. Apart from *Irembo*, there are various e-government services available, such as a Business Registration System that enables the online registration of a business in two hours, and the E-Tax Single Window System to facilitate the payment of duties and taxes. There has been progress in telemedicine, with almost all health centres connected to the Internet and with a growing use of RapidSMS, a platform that saves lives by tracking pregnant women and newborn children under three years of age, and enabling early identification of potentially serious health problems. The number of registered clinics and dispensaries using the Health Management Information System (HMIS) increased from 275 in 2014 to 301 in 2015. Since 2006 Rwanda has been using OpenMRS – a medical record system –

facilitating the management of patients' data, and connecting urban and rural hospitals to enable remote treatment with specialized care.¹⁰²

Linking the agriculture sector with ICTs is a critical element for energizing Rwanda's development. Therefore, the National ICT 4 Agriculture Strategy (2016-2020) underscores the need for developing linkages with other national STI stakeholders. It sets out a vision for ICT in agriculture and proposes an action plan as well as a methodology for monitoring and evaluation. The eSoko system for real-time market price information and the Fertilizer Voucher Management System are discussed in chapter 10.

The development of the financial services sector is a key policy lever to bring Rwanda's informal businesses into the formal and monetized economy. The use of ICTs to increase access to financial services is implemented thorough mobile payment technologies. Consumers are increasingly embracing mobile banking, with growing subscriptions to a mobile money system that operates with all three mobile telecommunications providers and has more than 7.5 million registered users. A result of close collaboration between the Government, banks and mobile operators, mobile payment increases financial literacy and payment systems performance, reduces fraud, and better serves people who were, until recently, financially excluded or underserved. The year 2015 saw mobile transactions in Rwanda exceed \$1.2 billion (MYICT, 2015).

10.3 The challenge of ICTs

Building on these achievements, three important challenges bear restating. The first challenge is to transform and improve the quality of governance in Rwanda using ICTs. This issue is considered an ICT policy priority in Rwanda, and a strong commitment has been established in the discussed NICI and SRMP policy programmes. Decisions to improve evaluation methods, and systematically develop evidence on implementation and achievement, will clearly help in policy learning and evolution. The UNCTAD mission in April 2016 witnessed many first-

Table 11: ICT and information society indicators in 2001 and 2014

	Rwanda		Tanzania		Uganda	
	2010	2014	2010	2014	2010	2014
Gross enrolment rate in secondary education	30.1	32.6	31.7	33	26.4	26.9
Gross enrolment rate in tertiary education	5.8	6.9	2.1	3.9	3.9	9.1
Adult literacy	65.9	70.5	67.8	70.6	73.2	78.4
Percentage of households with computer	1.3	3.4	2.6	3.8	2.2	5.8
Percentage of households with internet	1.3	3.8	2.1	4.1	1.9	6.2
Internet users per 100 inhabitants		18.0		5.4		19.2
Fixed telephone subscriptions per 100 inhabitants	0.4	0.4	0.4	0.3	1.0	0.8
Fixed broadband subscriptions per 100 inhabitants		0.2		0.2		0.3
Mobile subscriptions per 100 inhabitants	32.7	64.0	46.7	62.8	37.7	52.4
Mobile broadband subscriptions per 100 inhabitants		11.1		3.0		14.7
Cost of one gigabyte of prepaid mobile data (PPP\$)		37.4		36.2		37.3
International internet bandwidth Bit/s per internet user	1895	8517	2652	6081	849	4002

Source: ITU (2015), World Bank

hand narratives of improvements in public services. While implanting a business-like approach in the civil service is a commendable and effective component of implementation, it leaves an important policy lever unnamed. Given Rwanda's development level and context, the Government has been and will continue to be the first mover and early adopter of ICTs. Apart from the telecommunications sector, Rwanda's most resourceful ICT entities are its public agencies and services and these, through their e-governance operations, should become the key motors of the push towards increased technological learning in firms and households. In this regard, policy evaluation at the institutional level should not be constrained to only assessing success as measured against performance benchmarks, but extend to evaluating the level of transformative change affected among partners and beneficiaries. The efforts made by marketing and public relations in transforming positive experiences into accessible narratives that address the benefits of e-governance for Rwandan society may also require strengthening. Its successes will do more to inspire and motivate if they are promoted intensively.

The second challenge is to develop an ICT sector.¹⁰³ All the policy elements discussed in Part I of this STIP review are relevant and need to be mirrored from the national STI strategy onto the sector strategy. The development of working and effective linkages between ICT firms and start-ups, with institutions keen to cooperate on research, should be of primary concern, along with developing absorptive capacities, economic experimentation, and funding and regulatory issues. While Rwanda regularly ranks remarkably well in surveys of its business environment, three areas may need stronger policy support given the pronounced ambition to develop an ICT sector which would evolve into an ICT hub for the EAC.

One of these policy areas is intellectual property (IP). From an international perspective, Rwanda is compliant with international IP standards as a signatory of relevant World Intellectual Property Organization (WIPO) treaties and WTO-TRIPS (World Trade Organization – Agreement on Trade-Related Aspects of Intellectual Property Rights). However, at an operational level, using IP will require increasing institutional capacities, as well as building awareness among firms as to its purpose and practical application. While IP policy and capacity-building often focuses on patents, if policy ambitions aim at developing the ICT sector, due emphasis should be placed on copyright, as well as on the capacity of the national legal system to enforce and judge on non-disclosure provisions commonplace in contracts in technology industries. However, policy should go beyond focusing solely on protecting the rights of IP owners and consider the public interest at large. It should incorporate perspectives on public licences and the public domain, as many internet technologies are either distributed in a way that is relatively unhindered by IP, or else are completely unrestricted. Policies on open and public data standards and interoperability

are provided in SRMP, but are not linked to IP, and thus may be weak if challenged. In addition, data openness is often confused with free public data access, and while these are interrelated, there are important differences. Open data standards mean that the software and file formats that are used to archive and manage public information are provided with their source code and under an appropriate public licence. Such licenses, while "public" in name, are under the purview of IP law and enjoy legal protection from abusive or uncompensated appropriation by private interests.

A second important policy area is government procurement. Even in the most developed economies, many technology and ICT start-ups benefit from government procurement to launch production or to scale-up operations to levels that are competitive internationally and with established firms. Rwandan procurement policy should aim to assist budding ICT firms. While the Public Procurement User Guide of the Rwanda Public Procurement Authority is developed with the aim of ensuring public benefit, care should be taken not to use the provisions given in article 5.8 to discriminate against domestic ICT SMEs: for the financial and physical resources of domestic ICT SMEs, their annual turnover, access to funds and working capital including credit lines from banks, will never match those of large international ICT businesses.

The third policy consideration is the issue of funding ICT start-ups and scaling-up. A sober appreciation is required of the high business failure rates in the ICT sector, especially when moving beyond common services such as mobile telephony and investment in infrastructure. This has implications for funding models. Debt financing (bank loans) at excessive interest rates is not the way forward. Equity finance, where the financier takes a stake in the risk as well as in the outcome of the venture, has substantive advantages because it incentivizes investors to provide support beyond funding through entrepreneurial coaching and assisting in networking and economic discovery. For this to work, a broad range of investors need to be present, including angel investors and venture capital (both private and in public-private partnership), capital markets and private equity.

The third challenge is linking ICT policy and commercial activities with the rest of the national economy. This needs to be a primary focus, as the domestic market represents a large and accessible client base and an opportunity for technological learning for ICT firms. There is a broad agreement that effectively using ICTs can enhance the competitiveness of enterprises or organizations and, by consequence, the entire national economy. However, in a development context, linking ICT with the economic mainstream requires systemic policy support. The level of interaction between ICT entrepreneurs and those of other sectors and institutions needs to be increased so that technology requirements and opportunities are identified and acted upon. Funding innovation needs to prioritize investment in ventures that

bridge ICTs and agriculture, mining, manufacturing and tourism, as well as health, education, and a plethora of public and e-government services. Funding that promotes such linkages should be given priority. Training and education institutions should assess their curricula based on their contribution to facilitating cooperation between the ICT sector and the economic mainstream and government. Most importantly, studies and training in business and entrepreneurial skills should have an important ICT component. Likewise, IT, communications and computer science studies, need to develop competencies and an understanding of entrepreneurship and public service.

The Kigali Innovation City (KIC) project will, by design, provide support for tackling some of these policy challenges. However, not all ICT start-ups will be able to become KIC tenants and support for alternatives providing hosting and interaction with trainers, researchers and academics should be established as a long-term policy. These may be established at Rwanda's university and vocational training institutions across the country. Of importance is the need to mix youth, technologists and entrepreneurs across disciplines, and guide and support them to venture beyond research and into economic experimentation and commercialization.

Nevertheless, there are issues that neither the KIC project nor focused STI policy may be able to address, as their resolution is mostly linked to maintaining current levels of economic growth and national income per capita without negatively affecting income distribution. One such issue is the small market for data services and broadband mobile internet.¹⁰⁴ Despite the high-level of mobile penetration, ownership of smartphones and broadband subscriptions is low, because they are too expensive for most citizens and demand for data-heavy services is still nascent. Another issue is that, even though policy sees ICTs as enablers as well as a commercial sector, mobile service providers are predictably biased towards the business end. They hold that healthy revenues and earnings are central to a burgeoning, well-maintained and technologically current services, while enabling education, health and e-governance are an additional, though important and positive, benefit.

There is as well the matter of nurturing an environment conducive to knowledge creation, creativity and innovation. While this is a challenge for all sectors, the ICT industry relies heavily on the production, management and access to content (e.g. data, creative content, software, media, communications and marketing) around which it develops its services. The ICT sector is in this regard a close neighbour of the creative industries, and linkages between the two sectors should be fluid and supported by cooperation between MYICT and Ministry of Sports and Culture (MINISPOC). Beyond access to sources of content, supporting a vibrant creative industry and cultural and sporting community, with activities and opportunities, is

critical for attracting and inspiring the best young minds to establish themselves in Rwanda, Kigali and at the KIC.

Finally, the ICT sector will enhance its growth perspectives if firms and institutions commit to being open to creativity and innovation. They will need to become at ease with communicating internally, as well as with other STI stakeholders – horizontally, among communities of experts, and informally, outside the confines of firms and institutional hierarchies. Informal communication, knowledge sharing and tacit knowledge transfers at all levels should be encouraged, with the utmost respect for any contractual non-disclosure provisions and due precautions taken to abide by any firm or institutional requirements for discretion or confidentiality. A key issue will be the capability of firms and institutions, particularly those involved in the KIC project, to manage creative and innovative processes and ambitions, and adjust workplace and leadership culture to maximize performance.

To have fluid tacit knowledge exchange and information flows among firms and institutions, the function of information gatekeepers needs to be contained to minimum necessary levels.¹⁰⁵ This would enable better and faster horizontal communication, and would reduce the burden at the highest levels of policymaking or management to act on details that are not meaningful in terms of their seniority and competence. A willingness to innovate and experiment, even at risk of failure, should be encouraged and supported beyond incentives, and at a societal level. One possible path is to encourage students to voluntarily contribute to the Wikipedia encyclopaedic knowledge project in Kinyarwanda. Student seminars, term and research papers on scientific, technical, economic or managerial issues may be considered for contribution towards extra marks. Currently the number of articles hosted on the Kinyarwanda site is a modest 1,799, compared to 31,485 articles in Yoruba, 34,604 for Swahili or 82,778 for Malgasy. This figure should lead policymakers to ask questions about the general understanding of the relationship between creativity and collaboration in Rwanda and what incentives, beyond financial compensation, are valued and can be used to energize content production and, eventually, innovation.¹⁰⁶

10.4 STI and the institutional setting

Transforming the Rwanda economy and setting it on the path of knowledge-based growth, buttressed by pervasive use of ICTs in governance and commerce and by a strong ICT sector, is widely regarded as a national project. Within this policy process, the Ministry of Youth and ICT (MYICT) has an important position, as the carrier of mandates set out in SRMP in cooperation with RDB. MYICT was established in 2012 by combining the youth portfolio from the Ministry of Sports, Youth and Culture and the ICT portfolio from the Ministry in the President's Office in charge of ICT. The aim was to

promote synergies and establish ICTs as catalysts of entrepreneurship and youth employment. The mission and vision of MYICT's is to, "... accelerate socio-economic development, improving productivity of the private sector and developing the growth of ICT [and] fostering ICT development and diffusion in the Rwandan Society and Economy".¹⁰⁷ Guiding principles include a strong role for the private sector, the development of Rwanda into a regional ICT hub, the use of ICTs as enablers of employment, entrepreneurship and education, and the provision of accessible and affordable internet services.

RDB is, as well, an important agency and stakeholder, with one of its five departments dedicated to ICTs. As the principal public investor in ICTs, RDB is charged with an allocated ICT development budget which, as a percentage of GDP, is like those of many developed countries. It sees many innovation opportunities in e-commerce and e-services, mobile technologies, applications development and automation. RDB is financially committed to the KIC project as a future world-class regional centre for ICT firms, and training, educational and research institutions. It promotes Rwanda's competitive advantages in the ICT sector as originating from determined leadership and knowledge economy policies, an inexpensive, young and dynamic workforce, an excellent business environment, and a world class ICT infrastructure, among others.

In July 2017, the RDB handed over part of its ICT portfolio to the newly created Rwanda Information Society Authority (RISA). RISA will be in charge of ICT skills development, creation and innovation of new products and technical work. RISA will be a key agency in promoting the ambitious programme of digitalizing Rwanda. RDB will however keep several ICT-related activities, such as promoting inward investment and marketing ICT products and services abroad.

The private sector stakeholders are represented by the Private Sector Federation (PSF) Chamber of ICT. Formed in 2011, it supports ICT sector development by linking and networking associations, businesses, and entrepreneurs to catalyse and promote ICT and ICT-enabled ventures. The Chamber's objectives include skill development among youth, stimulating

entrepreneurship, promoting investment in the ICT sector, and promoting the export of ICT products and services.

kLab (knowledge Lab) is an ICT innovation hub in Kigali. kLab's mission is, "... to promote, facilitate and support the development of innovative ICT solutions by nurturing a vivid community of entrepreneurs and mentors".¹⁰⁸ It was founded in 2012 through a partnership of public and private organizations. The founding organizations included the Private Sector Federation, the Japan International Cooperation Agency (JICA) and RDB. RDB played a critical role by providing the physical space, power and internet connectivity, while JICA contributed the necessary funding. As an open technology hub, students, graduates, entrepreneurs and innovators are invited to use the space for free to turn their projects into viable businesses. Mentors provide both technical and business advice to tenants and members. kLab organizes and hosts various activities, such as showcases, workshops, hackathons and networking events, to assist in identifying potential investors and sources of funding. Box 5 showcases the work of one of its start-ups – SafeMotos.¹⁰⁹

For human capacity development and higher education, the University of Rwanda College of Science and Technology offers ICT programmes at undergraduate and graduate level at its School of Engineering and School of Information and Communication Technology. TVET centres across Rwanda provide vocational training for ICT-based skills. The TVET Integrated Polytechnic Regional Centre (IPRC) Kigali hosts a Department of Information and Communication Technology at its College of Technology, and is engaging with MYICT in constructing an ICT Innovation Center. RDB, the Private Sector Federation and the Korea International Cooperation Agency are cooperating to provide funding. This ICT Innovation Center will focus on multimedia and mobile applications training. It will also support ICT start-ups and serve as a business incubator. As in other sectors, it is always worthwhile to have joint consideration between training and educational institutions, and firms and institutions as employers, on how the trained and educated youth matches workplace expectations and job requirements. Consultations should result in feedback for adjusting curricula and

Box 5: SafeMotos – ICTs and road safety as a business proposition

SafeMotos was developed by technology entrepreneurs Peter Kariuki and Barrett Nash to accomplish two objectives: to become the Uber of African motorcycle taxis and to reduce the number of preventable road accidents and death. It does so by rewarding safe and responsible driving by logging GPS, speed, acceleration and gyroscope data and analyzing it for driver behaviour, combining this data with customer feedback and providing a booking system that includes driver evaluation. Drivers with at least three years of experience are eligible to join the scheme and are given a smartphone with the SafeMotos app. This improves their earning ability while rewarding safe driving at the same time. SafeMotos has a customer-side app for booking a ride. This is accompanied by a SafeMotos wallet for cashless payment and can be connected to mobile money cash and credit cards.

SafeMotos is an innovative and authentic response to an African and developing country problem. Finding solutions requires deep knowledge of local conditions and an ambition to experiment in possible business models that are locally compatible. For example, as many motorcycle drivers cannot read maps, SafeMotos developed a landmark-based navigation system. However, innovation does not happen in isolation. In Kigali's kLabs, SafeMotos had the opportunity to interact with other entrepreneurs, mentors, coders and developers. Adding to this, Rwanda's continuously improving ICT infrastructure and connectivity can support increasingly ambitious ICT ventures.

intake. Finally, there exists a disparity between students and trainees not being able to afford computers and tablets, while teachers and instructors have dedicated access to IT resources. This imbalance reduces the effectiveness of ICT in course delivery and diminishes the potential of e-learning and distance learning.

International cooperation in human capacity development for ICTs requires strengthening. Recent positive experiences have been encouraging. In 2012, Carnegie Mellon University (CMU) opened their CMU ICT Center of Excellence in Kigali, in partnership with the Government of Rwanda. Its programme is meant to complement Rwanda's ICT strategy and business and environment. It is staffed by full-time CMU faculty and proposes two programmes: a Master of Science in Information Technology, and a Master of Science in Electrical and Computer Engineering. While training and education in ICTs is a priority, capacity-building for using ICTs in other fields is critically required. An important example is the Korea International Cooperation Agency's (KOICA) collaboration with MINEDUC to provide training on the use of ICT in education. A first training session was held in August 2016 and was open to participants from the Rwanda Education Board (REB), the Ministry of Education, TVET centres, University of Rwanda (UR), and the Adventist University of Central Africa. The training will eventually reach more than 100 Rwandan experts.

Due to strong commitment to the development objectives of Vision 2020 and EDPRS 2, the diverse activities of institutional stakeholders are contributing to the implementation of national policy objectives on ICTs. Considering the high importance given to the ICT sector, as well as matching expectations of its impact on the Rwanda economy, it may make sense to consider adopting an innovation system framework that will serve to assist and energize stakeholder cooperation and identify synergies. It would also coordinate assessments and collate evaluations as inputs into a subsequent EDPRS 3 process. SRMP proposes the engagement of several bodies in the strategic implementation: MYICT, the National ICT Steering Committee, a new Board to unite sector and business representatives, and the (to-be created) Rwanda Information Society Agency.

EDPRS 2 deals most explicitly with technology and ICT in its deliberations on Productivity and Youth Employment as Priority Area 2. It sees ICTs as a cross-cutting sector that supports businesses, skills development and public service delivery, and which works towards the Vision 2020 goal of transforming Rwanda into a knowledge-based economy. Market information applications, mobile money and e-payments, and affordable communication, are important for improving business efficiency. Accomplishing this requires a steady flow of young and qualified technical and engineering staff. It also requires strengthening regional cooperation on ICT infrastructure and regulatory issues such as the harmonization of cyber laws. MYICT Sector Profiles for 2014 and 2015 visibly map the noted elements

of EDPRS Priority Area 2 on Technology and ICT, and go further to address areas critical to development, such as agriculture or financial services. What may require greater clarity the way in which progress presented in the ICT sector, and the effect of ICTs on the economy and society, links with policies implemented by MYICT, RDB and other stakeholders. While detailed assessments and evaluation of institutional performance are perhaps too onerous for public consumption, and are certainly conducted appropriately according to each institution, highlighting key operational level policy-outcome linkages would certainly increase overall business confidence and pride in accomplishments in governance.

10.5 A policy framework for STI and ICTs

The guiding framework for STI policy regarding ICTs is the SMART Rwanda Master Plan (SRMP). SRMP sets out policy on how: "... government uses information and technology to deliver better services, create jobs and transform the Rwandan society and economy in a constantly changing environment. Achieving these objectives requires a transformation in our approach to ICT" (SRMP). Its vision statement is, "a prosperous and knowledgeable society through SMART ICT." In terms of coherence with EDPRS 2, the key elements are present in the seven SRMP pillars of health, finance, business and industry, agriculture, education, governance and cities, and these clearly align with EDPRS 2 ICT prerogatives for supporting business, developing ICT skills and improving public service.

SRMP develops a number of additional challenges for policymakers looking beyond current economic realities, path dependencies and historic inheritance. In substance, it is comprehensive. SRMP, in a positive and distinctively Rwandan policy manner, takes the opportunity to review previous NICI policy cycles, and learn and imbed gleaned policy knowledge into the current cycle. It makes a special effort to establish a broader sense of coherence. It goes beyond EPDRS II to consider its relationship with Vision 2020 and the 7-Year Government Program (2010-2017), as well as looking internationally to the SMART Africa Manifesto (2013). SRMP goes into some detail, analysing the ICT realities and policy context. It develops key goals. It moves ahead and considers approaches and methodologies for implementation. SRMP takes risks, as should any innovator and social entrepreneur, and forecasts expected benefits, while proposing a framework for monitoring and evaluation. This completeness also presents an important challenge by raising questions of prioritization and substantive coordination, as well as policy coordination, such as, how will stakeholders be linked up to act and report on the diversity of goals and objectives in the SRMP.

SRMP speaks of seven key deliverables. With respect to NICI it sees five key strategic differences which read as operating principles. The SRMP Vision has three contextual principles (scope, focus and vision) and three targets (prosperity,

knowledgeable society, and SMART ICT). The Rwanda Information Society Agency (RISA) was envisaged by SRMP. RISA has its own set of five strategic principles and 18 objectives, and would be open to taking on new initiatives over time, should these prove worthwhile. The RISA strategy enumerates several benefits that resemble ministry-level policy goals.

SRMP also identifies five key areas of strategy, each with two to five specified goals. It proposes five key policies that need to be considered as anchors of successful SRMP development, namely on broadband, cyber security, private sector development, e-waste and open data. Each of these have their own subset incorporating a mix of objectives, focus areas, goals, goal outputs, strategic intents and approaches. SRMP proposes seven pillars and three enablers.

Developing its strategic planning, SRMP specifies three overarching goals – economic transformation, job creation and productivity growth, and accountable governance – and ten objectives. SRMP concludes by contextualizing the discussion against the structural transformation process where Rwanda faces three important challenges: low productivity, high population density and strained natural resources, and domestic and international financing constraints.

In light of such policy complexity, it seems unavoidable to view the potential for SRMP

success as intimately linked to strengthening the mandate of a future National ICT Steering Committee, and the creation of a very strong and competent RISA. The SRMP proposes that, "... RISA would be accountable for the execution SRMP and to implement a strategy to drive common capabilities, infrastructure and standards across the public sector" (SRMP). This, in return, raises questions about defining relationships between a future RISA and, at the very least, MYICT and RDB, along with their role in SRMP implementation.

Two policy directions may be helpful in assisting with this complexity. The first would be to establish an ICT sector innovation system locus. Its objective would be to develop and energize the linkages and interactions among ICT stakeholders that are needed to make SRMP work. The second would be to advance a very practical business plan for SRMP implementation. It would need a high-level of conceptual homogeneity and a disciplined structure that would evolve from goals to activities and outputs, with each assigned specific responsibilities, resource commitments, and key performance indicators, including time frames. The level of detail would inevitably require the intervention of policymakers with the authority to earmark and commit funding and resources, and assign responsibilities. Aiming at realistic outputs would help involved stakeholders develop a sense of ownership and improve accountability. It would also

Table 10: A policy matrix for ICT and STI

Goals	Investment action	A. Investing in the ICT ecosystem	B. Investing in ICT firms
1. Transform Rwanda into a knowledge-based economy	I	<ul style="list-style-type: none"> • Open and common standards for public data, software interoperability, personal data privacy • Public licences for Government funded software production to promote reuse and knowledge-based development among public institutions • Universal and affordable broadband mobile access • Universal ICT access in education, affordable hardware • Competent computer emergency response teams (CERT) and a cyber-security risk management approach • Open content for education under creative commons type public licence • IT and STEM studies and vocational training • International cooperation in ICT innovation, in R&D and among academics • International participation in information society processes and diplomacy including internet Governance 	<ul style="list-style-type: none"> II • Fair procurement for national ICT SMEs • Local procurement for ICT applications in health and education • Fiscal incentives for the ICT sector • Fiscal incentives and financial support for innovation and R&D in the ICT sector • Mobility of experts and staff between firms and public institutions • Industry-academia linkages to improve R&D and innovation outcomes
2. Develop a world-class ICT sector	III	<ul style="list-style-type: none"> • Pervasive mobile (cashless) payments • Innovation parks, hubs and incubators in Kigali and regionally • ICT extension services • Access to energy • Technology regulations and standards • E-commerce law and regulations • Intellectual property law and regulations • 24/7 online public and business services • Cloud services for public institutions, common infrastructure 	<ul style="list-style-type: none"> IV • Sector innovation system • FDI and technology transfer support • FDI-local firm outsourcing • Commercial matchmaking support • Private and public-private partnership PPP venture capital, angel investors, private equity, public grants, credit guarantees and capital markets • ICT for agriculture, services (tourism, transport) and industry • ICT for green, sustainable industry and services

include communication action and outputs. Periodic reviews would gauge implementation and propose necessary adjustments without waiting for the next policy cycle.

SRMP is clearly asking Rwandan ICT stakeholders to step up their game. However, SRMP has reached such a breadth and complexity that it is demanding on resources and may require a game plan. We can assume that individual SRMP policies are multidimensional and that, as a bare minimum, they can be regrouped according to how they relate to goals and investment. Goals are strategic directions and they will materialize, or not, on the success of implementation of the various ICT policies. Thinking in terms of investment actions helps categorize policies from the perspective of funding intent. Such a matrix can facilitate the assessment of STI policy needs for the ICT sector and help develop perspective on the balance in implementation. This policy matrix is described in chart 10.1. The categorization of policies in the four quadrants is proposed only as an example on how to separate goals. These high-level directions, from actions, are viewed, in this case, from an investment perspective.¹¹⁰

The policy matrix approach can be helpful for taking decisions on overall sector priorities, as well as delineating responsibilities. However, given that in Rwanda ICTs have been singled out as the technology and sector that will have the greatest transformative role in its development, there may be a need to treat all ICT policies as national priorities. Therefore, the value of a policy matrix in this case is to bring clarity in two ways. The first is to match specific policies to investment actions and goals, thereby resolving any potential problems caused by interpreting performance assessments. For example, the results of investment in the support of commercial matchmaking in quadrant (Q) IV will have less to do with the development of a knowledge-based economy when compared to the implementation of the development and distribution of educational content under open and public licences in QI. The second advantage is that it may encourage the work on implementation to move away from the relatively flat structure of the SRMP, and towards a structure that differentiates between:

- Goals: strategic outcomes that cannot be directly "done" because of their strategic level;
- Investment actions: the decision to mobilize financial, material and human resources; and
- Policies: processes that have designated activities, assumptions and indicators, and which may be implemented using a business plan or a logical framework toolkit.

As Rwanda develops, ICT policy focus should naturally move from QI, having activated the policies and appropriated the returns, through QII and QIII, and finally focusing largely on QIV. A casual consideration may conclude that QI is an immediate priority, while policies from QIV look at impact from a long-term perspective. QII and QIII

may be somewhere in between. The policy matrix also allows for a discussion of the importance of STI across the policy quadrants.

As presented, QI focuses mainly on public access to the Internet and to content, human capacity development, and the need to have international exposure and dialogue with ICT stakeholders worldwide. QII proposes policies that may ease the financial strain on ICT start-ups and SMEs, and links them with domestic actors interested in cooperation. The Government and its institutions would consciously take risks with public funds by procuring services from local ICT firms that may not have the track records of international corporations. Fiscal income is reduced, but the core question is whether this made a difference and, if so, how much: did the supported start-ups and SMEs innovate? Did they turn profitable and generate employment? QIII looks at several key regulatory and legal issues and several infrastructural challenges. It is worthwhile highlighting that ICT development as a technology sector and intellectual property regulation tend to advance in parallel. QIV focuses squarely on policies that promote private sector development. The timing of the duration of policy action from QI to QIV may not be easily forecast, as there are strong interdependencies between various policies.

10.6 Conclusions

The Rwandan nation is heavily investing in ICTs, it is confident of returns and has a clear vision of the direction of economic transformation towards a knowledge-based economy. Given the development level of Rwanda, the structure of its economy and the size of the ICT sector, this is a striking and bold decision. Rwanda's self-assurance comes from its ability to govern policy processes and its readiness to evaluate progress, to learn and introduce accumulated wisdom into policy revision and subsequent programme phases. This is particularly true for ICT policy and can be observed in the NICI and SMART Rwanda Master plan policy processes.

There have been many positive developments, particularly in developing ICT infrastructure. SRMP reveals a depth to the understanding of policy and technical issues on ICT. Regarding the road ahead, several key challenges can be singled out. The first is the need to strengthen the involvement of the private sector in general, and not only in the ICT sector, but more broadly in industry and services. While the citizens of Rwanda are the main clients of e-government and online public services, services and industry are the main clients for the national ICT sector. Their involvement needs to be strengthened and this may require greater policy efforts, as mainstream businesses will be more conservative and risk averse than their ICT sector counterparts. Institutional arrangements will need to be adjusted to handle this issue. An important first step would be to more deeply involve MINEACOM and MINECOFIN. The beneficial policy inputs of these ministries can be appreciated, while support

programmes that come under their purview may need to look carefully at ICT needs and requirements. An example of moving in this cross-sector direction is the recently launched National ICT 4 Agriculture Strategy.

Developing the ICT sector will require particular attention to the following: to IP and especially the copyright and non-disclosure aspects, the role of public procurement as the first client, as well as client-mentoring for a young sector and youthful entrepreneurs and experts, and to the problem of finance and scaling up. ICT sector development will succeed only as much as it is successful in linking with other sectors and industries. However, this requires inspiration, creativity and a high-level of interaction and tacit knowledge transfer. Policymakers may need to reflect more broadly on what type of environment will produce, retain and attract the most creative technologists and entrepreneurs.

One answer already exists, for KIC will undoubtedly play an important role in this process. In this regard, policymakers should take care that knowledge transfers generated by KIC grow and develop in depth, that tenants and supporting institutions do not retreat into operational silos and that KIC operations are not assessed and evaluated as a real-estate project. KIC will be, as well, an excellent locus for deepening involvement between academia, the ICT sector, and other sectors and industries. At the same time policymakers will have an excellent opportunity to support the development of evolving linkages and cooperation.

Finally, the success of SRMP is mission critical. It is also a policy vision of great complexity. This presents challenges in implementation and evaluation. If a mid-term review is planned, there may be a chance to consider and evaluate its implementation frameworks and move towards a simpler model that will provide better guidance for the next policy cycle post-2020.

11. Agriculture and STI policy

11.1 Policy background

Agriculture is the dominant economic activity in Rwanda both in terms of value produced and employment. Rwanda is also endowed with particular geo-climatic and land resource characteristics that fundamentally affect this sector. Agricultural policy in Rwanda has multiple objectives that address issues which are both social and economic in nature. Agricultural policy unavoidably engages in common issues of rural development – poverty alleviation and income distribution, the transformation of the informal economy, health, education and gender, etc. – and their overall effect on social stability and national resilience to hardship and crisis. Moving forward from this baseline, policymakers are also tasked with transforming agriculture into an engine of growth, and with developing and commercializing the sector, and with exploring its export potential

beyond the traditional coffee and tea trade. The main policy question is: how to turn agriculture from a subsistence activity to an entrepreneurial activity that innovates using technology?

The response to this challenge in Rwanda can be seen in all the positive developments on the ground. It can also be seen in the commitment and determination of the national leadership to produce positive and real change based on its growing capacity for policy learning from international experience, as well as its own. Strategic problems are dealt with through improvements and adjustments in policy and in implementation, while the *Imihigo* performance contracts are relied upon to produce strong incentives. Local government is charged with providing assistance and extension services and hence plays a key role in operationalizing policy.

The international development context is framed by the Comprehensive Africa Agriculture Development Programme (CAADP) and its 2003 Maputo declaration.¹¹¹ It outlines a set of principles as well as quantitative targets for the performance of the agricultural sector. Countries adopt a common commitment to achieving an annual growth rate of six per cent in agriculture, and to allocate ten per cent of their national budget to the development of the sector. Rwanda committed to its CAADP Compact in 2007 and has been implementing it through its Strategic Plan for Agricultural Transformation in Rwanda (PSTA) programmes. Reporting in 2014, the Ministry of Agriculture indicated success in both criteria (Bizimana, 2014).

The national development policy framework is embodied in Vision 2020. It articulates key priorities for the country's development up to the year 2020. The institutional context for agriculture is established by the development plan made explicit in the Economic Development and Poverty Reduction Strategy (EDPRS), which is currently in its second cycle (2013-2018).¹¹² EDPRS states explicitly that its main objective for agriculture is increasing productivity, in particular regard to limitations for expanding land under cultivation. Such an objective inevitably has STI at its core. As a component of the EDPRS, the Strategic Plan for the Transformation of Agriculture in Rwanda (PSTA) was developed and implemented by the Ministry of Agriculture and is now in its third phase (2013-2018). The ultimate goal of the PSTA, and its responsibility towards EDPRS, is to rapidly increase agricultural output and incomes under sustainable production systems and for all groups of farmers, and to ensure food security for the entire population. To accomplish this, it sets out several lines of action, including production intensification, commercialization and agribusiness development. The PSTA also promotes institutional development to enable cross-cutting and interdisciplinary action.

As discussed in the introduction of this review, the importance of STI in Rwanda's development is established in Vision 2020 as a cross-cutting issue. It specifically highlights the roles of science, technology and ICTs, while identifying innovation as

a key component of human capital development, entrepreneurship and job creation. EDPRS 2 advances the concept of innovation, underlining it as an important principle for programme delivery and noting that its role is to emphasize, "... new ways of thinking, working and delivering because the status quo will not be adequate to achieve Rwanda's ambitious targets" (EDPRS 2). It also proposes that agricultural research, technology, knowledge and skills are key to improving productivity in the sector. However, most mentions of technology are in the context of ICTs or green and sustainable development.

The notion of STI in PSTA 2 is modest. Here, STI is framed as a supporting service for commercializing the sector, and policy aims to, "... strengthen the entities in the sector charged with the development of productive technologies, applied knowledge and imparting this knowledge to farmers" (PSTA 2). In contrast with this understated reference, the majority of the sub-programmes of PSTA 2 unavoidably rely on some soft or hard technologies and innovations to achieve their objectives. This incongruity is highlighted by the detail that only 6.5 per cent of the PSAT 2 budget is allocated to *Sub-program 2.3 Research for transforming agriculture*.

PSTA 3 sees improvements, with Program 2 entirely reformulated to address the area

of research, technology transfer, and professionalization of farmers. Its focus is on using STI to further develop Rwanda's agro-ecological potential, while providing market-oriented research, extension, and advisory services. Improving research-extension linkages, and strengthening inclusive and commercial cooperatives and farmers' organizations, would be matched with enhancing entrepreneurial skills. PSTA 3 programmes have planned expenditure and broad donor support of more than \$1.2 billion (World Bank, 2014). However, budgetary allotments for the STI oriented Program 2 have remained in line with previous allocations in PSTA 2, i.e. about seven per cent of total planned expenditure. Clearly, STI is implicit in other programme lines, so in reality the allocation is much greater. Still, a more explicit discussion of innovation at the farm-as-firm, and industrial agro-food firm level, would introduce entrepreneurial issues. Such issues include the problems of financing innovation and of economic experimentation – i.e. testing the market – and the consequences and readiness of policy to support entrepreneurial risk and deal with failure in poor and fragile rural environments.

The implementation of PSTA 3 relies on the following institutions: the Ministry of Agriculture (MINAGRI), its semi-autonomous implementation

Table 11: World coffee and tea production in 2012 (MT)

Country	Coffee	% of world	Country	Tea	% of world
World	8,826,903		World	4,818,118	
Brazil	3,037,534	34.41	China, mainland	1,700,000	35.28
Viet Nam	1,292,389	14.64	India	1,000,000	20.75
Indonesia	657,200	7.45	Kenya	369,400	7.67
Colombia	464,640	5.26	Sri Lanka	330,000	6.85
India	314,000	3.56	Turkey	225,000	4.67
Peru	303,264	3.44	Viet Nam	216,900	4.50
Honduras	300,000	3.40	Iran (Islamic Republic of)	158,000	3.28
Ethiopia	275,530	3.12	Indonesia	150,100	3.12
Guatemala	248,000	2.81	Argentina	100,000	2.08
Mexico	246,121	2.79	Japan	85,900	1.78
Rwanda (34th)	19,995	0.23	Rwanda (17th)	22,503	0.47
Total top 10 + Rwanda	7,158,673	81.10	Total top 10 + Rwanda	4,357,803	90.45

Source: FAO

Table 12: Crops by area and production in 2015

Crop	Area under cultivation (%)			Production (MT)				MT/Area%
	Season A	B	C	A	B	C	Total Annual	
Tubers and roots	31.3	33.4	55.0	1,319,108	1,336,491	92,226	2,747,824	82,090
Banana	23.0	23.1	0.0	983,989	878,852	0	1,862,841	80,817
Legumes and pulses	23.6	20.4	25.3	275,498	205,251	3,177	483,926	21,852
Maize	12.4	5.2	0.0	295,365	74,775	0	370,139	42,061
Vegetables	0.9	1.1	19.7	129,576	130,597	49,251	309,424	260,173
Other cereals	2.6	10.4	0.0	74,602	166,664	0	241,266	37,118
Fruits	0.6	0.9	0.0	35,568	12,620	0	48,188	64,251
Other crops	5.7	5.5	0.0	412,912	449,903	0	862,815	154,074
<i>...of which coffee</i>								16,936
<i>...of which tea</i>								25,620

Source: NAEB; NIS (2016)

agencies, the Rwanda Agriculture Board (RAB) and the National Agricultural Export Board (NAEB), three Single Project Implementation Units, MINALOC and its offices in 30 districts through their specific District Development Plans. Of note also is the Crop Intensification Program (CIP), ongoing since its launch in September 2007. RAB is specifically designated as the locus for STI in agriculture and will be discussed later in this chapter. The Rwanda Standards Board should also be an increasingly important player in the development of commercial agriculture.

11.2 The challenge of agricultural transformation

Growth in Rwandan agriculture has been based on a combination of yield increases and cultivating new land, both requiring technology and innovation. Increasing the proportion of high-value crops, producing higher-value-added agro-food products, as well as commercialization, are STI-dependent objectives. Nonetheless, policymakers need to address the misguided perception that because agriculture is not a technology sector *per se*, it does not merit a primary consideration by STI policy. The fact that most farmland is on slopes and hillsides means that STI will play a key role through improving soil fertility management and erosion control, and enhancing the sustainability of farming ecosystems. Irrigation will need to advance in order to make better use of available marshland, and to employ farming resources during the relatively unproductive dry season. Interaction with development aid donors is of major importance. Donors typically appreciate the social development aspects of assisting the agricultural sector. However, when policy ambitions evolve towards employing technology and raising productivity in order to commercialize the sector, efforts need to be made so that perceptions and objectives coincide.

Rwanda is densely populated, with 450 persons per km², and has a population growing at a rate of around three per cent. The total population will probably surpass 12 million before 2018 (NIS, 2012). Agriculture produces around one third of the national GDP while providing economic activity for around 80 per cent of the population. Even so, agriculture is rife with under-employment, with only one third of farmers working a full 36-hour week (EDPRS 2). The performance of the agricultural sector is felt throughout the entire economy. A poor annual harvest can have disproportionate consequences on the general economy. For example, during the drought of 2003, GDP growth slowed from eight per cent to two per cent during the same year – a substantial response to a decline in food crop output of four per cent. Natural risks provide some serious disadvantages, especially for uninsurable subsistence farming that produces mainly for personal consumption. Poor harvests, volatile prices and a growing youth population

disinterested in agriculture add to the complexity of the policy challenge.

Coffee, tea, pyrethrum and livestock products are the largest agriculture exports and earn around \$130 million per year for the country. On a global scale, Rwanda is a small coffee and tea producer. Pyrethrum is a natural insecticide and a low-volume but high-value commodity. Livestock production is only five per cent of total agriculture but is as important as coffee and tea for export earnings. Poultry farming is modest but this may increase with new international investments.¹¹³ Table 11 describes Rwanda's international position as a coffee and tea exporter. Table 12¹¹⁴ provides basic data describing agriculture in Rwanda. Horticulture (i.e. fruits, flowers and vegetables) is often cited for its potential, given its intensity – the large physical production volumes that are possible on a given area, compared with Rwanda's major crops. Chart 6 describes the recent growth of the agriculture sector and its main components. Chart 7 describes land use in Rwanda.

Land holdings in Rwanda are small and fragmented, and may be declining due to population growth. This presents policymakers with the most serious obstacle to agricultural and overall economic development. The fundamental challenge is how to transform smallholder agriculture without causing social instability and human strife. An average holding comprises between 0.33 and 0.76 hectares, with the larger holdings often divided into several separate plots. Land ownership is by family, not by individuals. Compounding the problems of smallholdings is inequality in land ownership, whereby 36 per cent of the poorest households own only six per cent of the farm land, with an average of 0.1 hectares per household (World Bank, 2014).

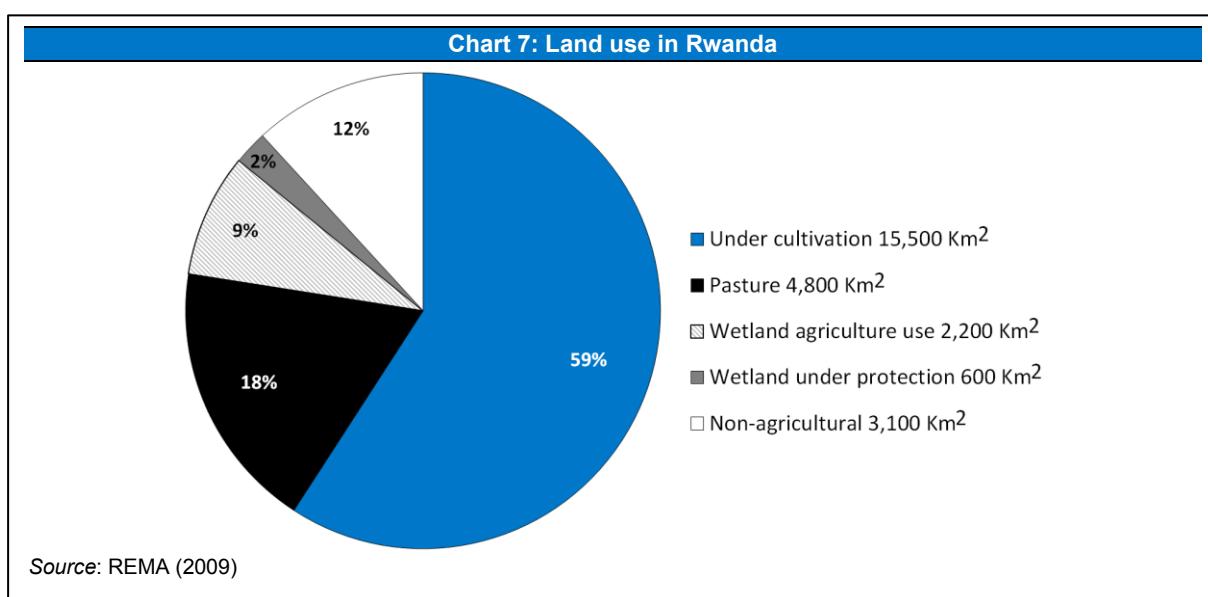
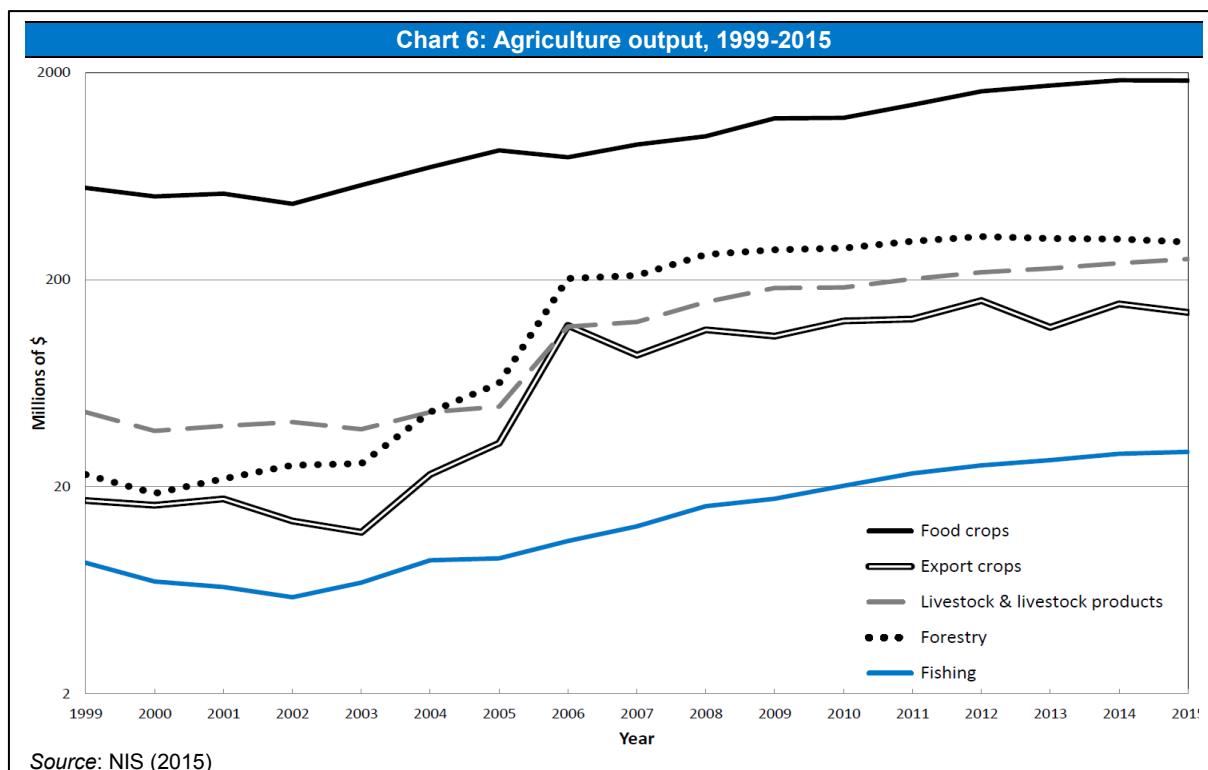
There are unexploited marshlands owned by the state. However, their use is limited by environmental concerns, as well as by the available interest of international investors to venture into rice production – a crop that is seen to be a good fit.

Smallholdings present a serious challenge for advancing basic farm technology, such as increasing fertilizer and pesticide use, and battling soil erosion, particularly when the objective is to improve product quality so that it meets commercial and export standards. Even though Rwanda's arable land and highland equatorial climate are hospitable to a wide range of crops, productivity and yields are below potential, farm earnings are low, and a large proportion of crops are used for personal consumption. Expediting the consolidation and concentration of land ownership is dependent on the development of off-farm jobs. It should be kept in mind that smallholdings and their often-fragmented nature may also serve to diversify the risk of crop failure or market volatility, particularly when financial risk management and insurance are underdeveloped and may be of marginal use in a largely informal sector that produces principally for its own consumption (World Bank, 2015).

While the average size of individual plots will not increase anytime soon there are efforts to overcome difficulties inherent in small scale farming. One solution is to encourage the development of commercial agro-food businesses that would source the bulk of their produce through a network or association of farmers while growing only a small part, or none of the crop themselves. The associated farmers would necessarily receive guidance on various processes and technologies, including synchronized planting and harvesting, and on achieving consistent output quality and quantity. Another possibility is for agro-food businesses to lease and concentrate land from farmers who are then hired with guaranteed minimum revenue equal to what they would earn on their own. Yet another strategy is to liberate arable land by moving

dwellings away from fertile land and into village communities that are provided with better access to infrastructure and services.

Linking agricultural transformation to the Vision 2020 goal of developing Rwanda as a knowledge-based economy is an important challenge. Policymakers have responded by developing an ICT for Rwanda Agriculture (ICT4RAg) Strategy for 2016-2020 (MINAGRI, 2016). Under the purview of the Ministry of Agriculture and Animal Resources (MINAGRI), a taskforce of experts and policymakers from MINAGRI, Ministry of Youth and ICT (MYICT), Rwanda Agricultural Board (RAB), National Agricultural Export Board (NAEB), Rwanda Development Board (RDB) and the Private Sector Federation – ICT Chamber (PSF/ICT), developed a comprehensive policy addressing key STI elements



and ensuring policy ownership. The overall objective of ICT4RAG is to increase agricultural productivity through the use of ICTs. This would be accomplished by developing a database on farmer and farm information, increasing the number of skilled and knowledgeable farmers, spurring job creation in agriculture and peripheral services, improving access to agricultural information, knowledge and markets, and improving access to finance for agriculture. Existing applications, such as the Farm Management and Information System (FMIS) and the eSoko market information system, will be maintained and upgraded with new applications for traceability or managing inputs like fertilizer, seeds or animal feed. ICT4RAG includes guidelines for implementation, monitoring and evaluation. As an interdisciplinary and cross-sector project, ICT4RAG will provide important experience of the challenges of managing an innovation system. The experience and intelligence gathered on assessment should feed back, not only into agricultural and ICT policy domains, but in all policy domains, as a matter of course.

11.3 STI, agriculture and the institutional setting

Rwanda is an agricultural country eager to advance its technology capacities and willing to embrace change. To achieve this requires an improvement in linkages among businesses and with other institutions. Research activities and STI policies need to be relevant to the entire value chain, without forgetting poor subsistence farming communities, but with a special focus on the diversification of production and potential export sectors. The main institution on the STI side of policy is the RAB.

RAB was established in 2010 by uniting three institutions that until then had been dealing separately with animal extension, agricultural extension and research work. The goal was to transform its work programme in order to help turn Rwandan farming into a knowledge-based, technology-driven and market-oriented industry. RAB is a semi-autonomous implementation agency of MINAGRI. It is responsible for the implementation of PSTA 3 activities, relating to soil conservation and land husbandry, research, extension, farmer and cooperative training, and input provision. It oversees Rwanda's irrigation infrastructure and post-harvest mechanization and works on the development and expansion of food crop and livestock value chains. RAB defines its vision and mission as working towards improved food security and livelihoods by transforming agriculture from subsistence into modern farming through research and extension in a sustainable manner.

From an STI standpoint, and in particular from an innovation system perspective, there are three apparent issues. The first is the question of funding. If the five-year period for the PSTA 3 is budgeted at around \$1.2 billion, there may be reason to review the workability of the allotment for RAB's annual

development budget (i.e. costs not associated with salaries or operational expenses) of \$6 million in terms of its objectives. A second issue is related to the publicly available RAB annual report of 2012-2013. The report is packed with information on various research and extension activities. However, there are no explicit linkages to PSTA 3 programmes. This is not to say that they do not exist. In fact, on closer reading, many of the reported accomplishments seem tied to selected PSTA objectives. The lack of reporting on explicit linkages between RAB activities and PSTA and EDPRS objectives, however, indicates that the sector innovation system may be at risk of underperforming and that stronger attention from policymakers may be warranted. In addition, while the RAB annual report referenced CIP as a policy source, PSTA 3 notes CIP only in passing. A third issue is that activities relating to the involvement of other institutional stakeholders, namely private sector agro-food business and academic and training institutions, seem to be at a very modest level or non-existent. This again raises the question of whether linkages are weak and is an indication that the sector innovation system is in need of greater support. Raising awareness about linkages and cooperation as core innovation system issues may require support through strengthened capacity-building at the policy level. At the international level, the programme of interaction with FAO or WFP was modest or non-existent.

The UNCTAD mission understands that these indications of underdeveloped linkages do not entirely square with evolving inter-institutional arrangements, which have the Director General of RAB sit on the Board of the Ministry of Education, while NIRDA delegates a representative to sit on the RAB Board. These arrangements work towards improving inter-institutional cooperation and ensuring cohesive delivery. However, an insufficient level of interaction with other stakeholders, such as firms and academia, leads to concerns about the clarity and purposefulness of the strategic direction of RAB's R&D activities, as well as its ability to move technology out of the lab and into the field: to convert science and technology into innovation. Technical research and experimentation on its own will fall short in affecting real change in the sector unless it is complemented with research on post-harvest activities and, furthermore, by contextualizing all research against an examination of the socio-economic situation in rural communities.

Cooperation with policy and academic institutions requires strengthening. It is not only a matter of awareness or political will, nor is it a one-sided issue for RAB to deal with. Academic institutions largely focus on teaching and basic training. Higher learning and research requires greater commitment, as well as more sophisticated equipment and facilities. Without these capacities, it is difficult for policy and academic institutions to find common ground for cooperation.

International academic cooperation is nascent. Recently, Michigan State University and the University of Rwanda launched a Master of Science

degree programme in agribusiness for delivery in Kigali. The degree programme prioritizes accessibility to women and midcareer professionals. It incorporates on-the-job learning and requires students to take on internships in the agro-food sector to prepare for leadership and entrepreneurial roles and responsibilities. The Jomo Kenyatta University of Agriculture and Technology has several cooperative linkages, including with the University of Mogadishu, Kaduna State University (Nigeria) and other academic institutions in China and the USA, and would benefit from strengthened cooperative activities with the Kigali school. Improving the relevancy of academic studies in agriculture for the real-world problems in the sector is important for the better alignment of human capital with employment prospects. Discussions during the UNCTAD mission suggested that the TVET schools were working well and graduates became quickly operational in the sector. A skills gap does exist, but this is a general development problem and not unique to agriculture or to Rwanda.

11.4 Framing the policy issue for STI

Many challenges for the agricultural sector in Rwanda have a technological dimension. In practice, technical solutions will become innovations – a new process, product or service that has commercial or social value. However, two specific issues related to agriculture require policy attention. The first is the understanding of the additional risk assumed by an innovator who is a first-mover. First-movers are important as they contribute to economic diversification. However, they take on the full risks of economic experimentation. This is problematic in the agriculture sector where farmers are poor and their livelihoods are fragile and thus not fully equipped to take on innovation and entrepreneurial risk. Lacking special policy support, first-movers will hesitate, while local farmer-entrepreneurs may give the impression as deficient in energy and dynamism or to be ‘playing it safe’. The second issue is accepting that innovation capability is strongly related to knowledge appropriation and skills development as a long-term and continuous process.

Policy formulation often starts with examining achievements to date, future economic potential across crops and sectors, and current conditions of supply. The baseline is: what can Rwandan agriculture produce? This is fair, if somewhat open-ended. The question, as posed, challenges the policy response to engage in a level of breadth and complexity, especially with regard to STI, that may demand resources that the nation is unable to provide. Clearly, development assistance, debt and FDI could fill resource gaps and play an important role here. However, certain sources of external finance will have an unavoidably uneven impact on rural livelihoods. Therefore, it may be more appropriate to frame policy options in a matrix that can assist in developing priorities, rather than

generating lists of policy objectives with corresponding financing and resource requirements.

By definition, development policy is multidimensional, so for the sake of simplicity we can use as an example a two-by-two matrix to consolidate policy perspectives. Firstly, by demarcating policies that address potential commercial demand or target markets – domestically and for export – a more balanced reflection with greater clarity can be provided. A second policy matrix component is the delineation between two desired outcomes: the impact on social development and poverty alleviation, and the endorsement of commercialization. Such a framework may facilitate defining STI needs in the sector and their balance in implementation. This example of a policy matrix is described in chart 11.3. This approach guides policy in taking decisions on overall sector priorities: a casual consideration may conclude that quadrant (Q) I is an immediate priority, while QIV is a long-term and strategic issue. QII and QIII may be somewhere in between. The policy matrix also allows for a discussion of the importance of STI across the policy quadrants.

QI brings our attention to several STI related issues. The first is that increasing off-farm employment will be relate to innovation of some kind, and therefore to the diversification of rural economies, or to providing rural populations with better access to urban job opportunities. As not everyone can have economically feasible access to the Kigali job market, the Ministry of Infrastructure’s project on the development of secondary cities becomes a critical factor. Outside the discussion of specific PSTA programmes, off-farm employment is given due consideration in PSTA 3 as a strategic condition for the success of agricultural policy and its broader social impact. However, there is no explicit linkage to the secondary cities project, and off-farm job creation is considered in areas which are still related to or downstream from agriculture. A second issue highlighted by the matrix is the need of strong policy support for four basic agricultural technologies: fertilizer use, improved seed stock, irrigation and control of soil erosion. Finally, extension services need to be relevant to the smallholding farmers who consume a significant portion of their crop. When we review PSTA 3 we find that Program 1 covers these concerns. However, Program 2 on technology has modest implications for QI and this issue may be worth revisiting. Programs 3 and 4 seem peripheral for QI, even if they include the improvement of rural infrastructure and food security as explicit goals. Overall, it is no surprise that, for QI, only a few of the PSTA 3 Program Key Results indicators are considered relevant indicators of success.

QII is largely absent as a policy direction. STI measures for establishing export-level phytosanitary and hygiene standards, advancing production to achieve these, and building capacity for testing and certification, will all be trickle-down benefits from policies directed towards QIV. This may be a deliberate decision on priorities by

policymakers, while the matrix approach only highlights this peculiarity.

QIII engages the full scope of STI policy and is broadly supported by PSTA 3, strategically and as a matter of programme activities, especially Program 2 and 3. QIII highlights the importance of non-technological innovation. One of these is innovation in finance. If farmers are to scale-up by reducing the diversity of their production, or even by mono-cropping, the availability of affordable and locally appropriate agricultural insurance, credit and credit guarantees, will be a key incentive. However, mere availability is insufficient – developing awareness and user knowledge among farmers, as well as trust-building, will be important. Less prominent in PSTA 3 is the idea that local demand will stimulate commercial production, but for this to happen commercial consumption patterns and preferences need to be examined, and a corresponding plan strategized. Simply relying on a supply push is half a strategy. Most discussions of consumption in PSTA address improving nutrition and relate to poverty and health issues. This is necessary but it is not fully relevant to developing commercial agriculture, which must necessarily respond to the an ever-growing and increasingly affluent consumer market. National campaigns aimed at changing consumption patterns may not be hard science and technology, but they are, nevertheless, key facilitators of innovation. STI aimed at increasing output during the dry season (season C in table 11.1) is critical for success in QIII as it produces only about two per cent of Rwanda's physical agriculture output, and as such provides a broad scope for innovation.

QIV is perhaps the most demanding policy quadrant in terms of STI. Export orientation has specific requirements. The ability to produce consistent volumes of narrowly specified products

that can be delivered at regular, predetermined intervals and volumes is particularly critical. This often means moving towards industrialized agriculture that uses intensive technology. The key strategic question is: given the structure of land holdings and the nature of Rwandan farming, what prospective products can fulfil these requirements? Regarding perishable products, which include a significant part of horticulture, the near-term strategy may be better advised to focus on QIII, and import substitutions, while framing for QIV in the medium- to long-term.

A focus for STI then could be products that require a degree of processing, homogenizing raw inputs to a degree where individual lots will average out into a general and controllable quality, or can be categorized according to different specifications, types and classes. The best evidence for the potential of this approach is in the success of the country's coffee, tea and pyrethrum businesses. Specific technologies will then be directed at the physical manipulation of raw agricultural inputs, thermal treatment, chemical treatment, metabolic processes, and preservation, canning or other packaging.

The innovation challenge will be to identify products that Rwanda can make internationally competitive, as well as presenting opportunities to move up the value chain in the food industry. The UNCTAD mission found that the packaging was an important issue due to the legislated limitations on the use of plastic. Discussions revealed, however, that the commonly sought solution was a 'work-around', such as temporary import-for-export of packing materials, rather than innovation in sustainable packaging. Packaging is doubly crucial in light of Rwanda's underdeveloped transport links with EAC neighbours, and its land-locked situation and difficulties in accessing major ports. Finally,

Table 13: A policy matrix for agriculture and STI

Objective	Target market	Domestic consumption	Export
Address social development needs, contribute to poverty alleviation		I <ul style="list-style-type: none"> • Development of off-farm employment, secondary cities project • Productivity increase in staple crops and livestock: fertilizer and seed stock, irrigation • Soil erosion: terracing and irrigation • Extension and STI needs of smallholding agriculture 	II <ul style="list-style-type: none"> • Fair trade marketing • Geographic location certification, AOC • Export level phytosanitary regulations, control and certification
Increase commercial production		III <ul style="list-style-type: none"> • Enhanced use of ICTs • Finance, guarantees and insurance • Development, change of national preferences and consumption patterns • Restructuring or reorganizing smallholdings to scale for STI • Irrigation to increase output during dry season • Commercial horticulture, farming, poultry • Logistical infrastructure for commercial farming • Agro-food industry development • Extension and STI focus on farmer entrepreneurs 	IV <ul style="list-style-type: none"> • Wetland development and irrigation • Restructuring or reorganizing smallholdings to scale for STI • Enhanced marketing, geographic location certification, AOC • Move up value chain with <ul style="list-style-type: none"> ◦ Food commodities which can be homogenized ◦ High value agriculture products • Food processing industry • Traceability and tracking • Packing materials • Export level phytosanitary regulations, control and certification • Deep cooperation with RAB research and academic institutions • Commercial investors and FDI

phytosanitary standards and traceability are unavoidable STI issues for the developing and exporting food sector. The Rwanda Standards Board may have an important and enhanced role to play in this context.

11.5 Conclusions

Productivity growth, improved earnings and improvements in income distribution are rarely symmetrical processes; not least in the agriculture sector. The application of technology and success in innovation for commercial production will create a certain disparity among farmers. Land access and use policies, particularly for land under government management, will be a differentiating factor. Government support for exportable commercial agriculture should not result in the risks of monocropping being shifted to poor farmers who agree to reduce farming for their own consumption. Technology and innovation bring their own specific problems. For any given technology, an important question is: how does it scale? Is it scale-neutral? Does it travel well from the lab to the testing ground, and then into the real economy where practitioners are not agronomists working on government research budgets? Does scaling up require continuously increasing investment and what will the source of revenue be to sustain the technology? Rwanda has seen remarkable success in its agriculture. However, policymakers are as ambitious as the geophysical conditions are favourable. The situation presents both challenges as well as opportunities. The first problem is that the linkages between the policy elements and supporting institutions seem to be largely implied rather than explicit. This does not necessarily mean that the linkages are dysfunctional or sub-optimal.¹¹⁵ However, a more explicit elucidation of linkages would increase policy resilience and strengthen cooperation among institutions. This is particularly important when assessing how the PSTA Program works, and especially Program 2 and its implementation by RAB, which fold back into PSTA 3 key indicators. The second is that STI policy is closely tied to the specific socio-economic and environmental realities, and therefore care must be taken that innovation must be locally relevant, even if it is to produce a world-class export product. A third challenge is that of prioritization and structure. The UNCTAD mission

understood that many policy goals had similar or equal levels of importance and priority. That *everything is important* in a development context is an unavoidable truth. However, policy resources are limited and some differentiation by scope or purpose may be considered useful, especially when taking up the issue of innovation – an endeavour that is inherently risky and which requires failure to generate success. Finally, and mainly due to the small land hold problem, it is unlikely that Rwanda will be able to apply comparable technologies, and compete in the international perishables market, on terms and conditions of EAC producers that are based on large land holds and large-scale inputs, regardless of FDI. Scaling is a key challenge and each technology under research and testing should be explored on this issue.

More generally, soft innovation in policy and practice will be also important. Redefining consumer preferences and expectations, in concert with the development of commercial agriculture, will be important, as developing products for export only, without a domestic consumer base, is doubly and unnecessarily risky. For example, while coffee is a major export, annual coffee consumption per capita is about 35 grams,¹¹⁶ compared to 5.8 kg for Brazil or 1.8 kg for Colombia. There is no need to repeat this kind of outcome in other agricultural sectors and products. Rwanda is well-positioned to strengthen its innovation in agriculture, even with several issues that may need closer consideration. Policymakers are generally well aware of the need for innovation. PSTA 3 bears witness to this, specifying as a particular Program Key Result the number of "... new technologies developed, released and adopted by farmers, ... consistent with Rwanda's competitive advantage and coming from either global or local markets" (PSTA).

12. Industry transformation and STI

12.1 Policy background

Rwanda's development goal is succinctly expressed in Vision 2020: "... [to become a] middle-income nation in which Rwandans are healthier, educated and generally more prosperous." The primary strategy for achieving this goal is economic transformation. Transformation can be measured in many ways and the change in the

Box 6: Fablabs - the fourth industrial revolution in Rwanda?

President Paul Kagame launched FabLabs in Kigali on 12 May 2016. FabLabs are a global network of local technical facilities that enable innovation by providing individuals tools for design and prototyping. There are more than a thousand FabLabs around the world. FabLab members use the facilities to turn innovative ideas into products, specifically in hardware and electronics. FabLabs provide a platform for capacity-building and integration of hardware skills with software knowledge. Digitally enabled design tools are at the heart of FabLab, with Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), 3D printing, Computer Numerical Control Machines, Virtual Reality and Augmented Reality presenting the main toolkit.

FabLabs was established through the cooperation of the PSF ICT Chamber with RDB, Japan International Cooperation Agency, MINEDUC, SolidWorks Corporation, MIT-CBA, and Gasabo3D, and following on policy learning from experience with ICT incubator kLabs. FabLab has already registered several innovative projects. The Red Cross and United Nations are using FabLab facilities to design spare parts and elements of drones delivering supplies to isolated refugees. Sustainable Health Enterprises is prototyping sanitary products, while individual researchers are exploring the production of smart-farming sensors that detect whether crops need water, and the design of locks for a food delivery service.

relative size of industry and its contribution to economic growth is one of them. Between 2006 and 2015 industrial output grew at an average yearly rate of 9.3 per cent and its share of GDP grew from 12 per cent to 14 per cent during this period. This was slightly faster than the 7.7 per cent average growth in the entire economy, but was not sufficient in having a major transformative effect on the economy.¹¹⁷

Industrialization is a difficult process for many developing countries as it requires long-term perspectives on finance, STI and governance. Both local and international factors matter. Sluggish industrialization is but one aspect of the general lack of rapid convergence in economic growth and development between developed and many developing countries. Therefore, a lack of more notable progress is unfortunate but not unusual. By comparison, agriculture can be a more clear-cut development proposition: there is a certain endowment of arable land and a large part of the national calorie consumption will be produced locally as commodity grains and cereals. Services may also have a modest advantage over industry, as the relationship between their capital and operating expenditures tends to favour the latter,

therefore making access to finance easier. The difficulties of industrialization are compounded by the dynamism of the global economy. The processes of globalization, financialization and the fourth industrial revolution should be considered during policy formulation. Each has an important STI element. Box 6 gives an example of one element of the fourth industrial revolution entering into Rwanda's industrial activity. Box 7¹¹⁸ gives a brief overview of global developments and potential impact on Rwanda.

Taking a holistic approach, it is advisable that any consideration of STI policy and the development of industry in Rwanda should address local development circumstances, as well as the global context. Vision 2020 is keenly aware of the need to match national and global perspectives and proposes that: "... *industry and service sector development cannot be realized without a competitive stock of skills, infrastructure and financial services. ... The issue, however, is ... identifying Rwanda's comparative advantage and concentrating strategies towards it.*"

EDPRS 2 discusses industry as a key element in the thematic area of economic transformation, while acknowledging that the performance of industry in

Box 7: Globalization, financialization and the fourth industrial revolution

Industry and manufacturing has experienced an enormous transformation in the last five decades. The first game changer was the *globalization* of the world economy.¹ The main drivers behind globalization have been large firms in industry, finance and services. The main enablers are open national economic policies, multilateral trade, finance and IPR institutions and their regimes, and the development of technologies and capacities in transport, logistics and ICTs. Global growth in recent decades has been linked to globalization and several large developing countries have become important manufacturing nations. However, the effects have not been evenly distributed, nor has the danger of economic marginalization, particularly for Least Developed Countries (LDCs), dissipated. Technology, finance and trade erode traditional comparative advantages and countries without strong development and STI policies are unable to develop new competitive advantages.

Globalization occurs in an increasingly financialized world economy where returns (and losses) on investment are increasingly generated in finance rather than in industry (Krippner, 2005; UNCTAD, 2015). Financialization has several facets. The first is a decreasing output of industry relative to financial services. The second is that investors prefer to pursue financial returns and have a limited interest in firms and entrepreneurs who compete through technology development and product innovation. Finally, the experience and tools the financial sector uses to deal with risk do not easily map against uncertainties encountered in innovation. This results in an undersupply of finance for STI from the mainstream financial services sector.

The third game changer is currently evolving and is sometimes called the *fourth industrial revolution* (Schwab, 2015). It manifests itself as acceleration in automation and data exchange among production systems, smart production that uses complex feedback and control systems linked to detailed models of their operational environment, an increased responsiveness to customization and a decrease in size of necessary economies of scale to achieve feasibility, and a generalized emergence of an *Internet of Things*.¹ While equally, if not more, technologically intense than globalization, the effects may be different. Initial consequences will be labour-saving and may liberate human capacity to be developed and employed in more productive services or industries or at higher ends of the value chain. However, technological progress will eventually produce an erosion of labour-cost advantages in low-wage countries as a competitive factor. This will result in the re-localization of industries in search of a better over-all mix of competitive advantages beyond just low wages.

The main long-term effect may be a reduction of international trade and the reduced importance of scale in production. On-site, small-run and customized production, at a price that discourages high volume production and trade, will be supported by a second STI intense development: increasingly affordable and locally produced sustainable energy. A third development is the pervasiveness of human competency, a phenomenon that is the result of the deployment of massive ICTs. Competencies and tacit knowledge become increasingly easier to transfer, as content, from academic to practical know-how, goes online. This is partly due to traditional knowledge stakeholders opening-up their knowledge vaults on the internet, and is spurred on by the growth of a culture of open access, open innovation and knowledge-sharing enabled by social media and content platforms.

There are five implications for industry and STI policy formulation in Rwanda. The first is that existing competitive and comparative advantages¹ need to be secured and new ones developed. The second is that traditional bank finance should not be expected to fund innovative ventures, and alternative funding options¹ should be considered as primary sources. The third implication is that STI and industrial policy will put pressure on the labour market. Sectors with the capacity to produce off-farm employment opportunities will require support. Fourth, domestic and regional markets will need to become a key consideration for policy, while a focus on exports to developed regions will become increasingly riskier. Finally, the winners in this transformation process will be firms and entrepreneurs that have taken full advantage of digital technologies to maximize their technological competencies.

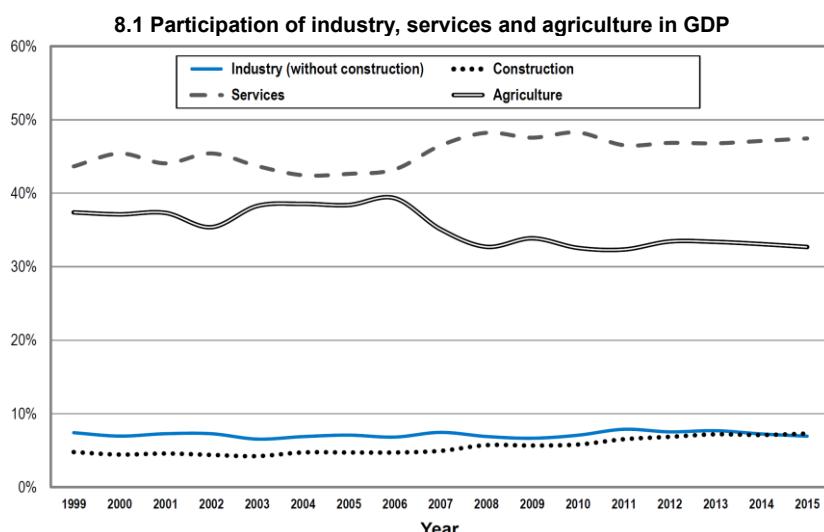
the EDPRS 1 period was limited. It speaks of the need to have stronger relationships between MININFRA, MINEACOM, NIRDA, the Rwanda Housing Authority,¹¹⁹ and other industry stakeholders, and in the context of a *green economy* approach to economic transformation, whereby higher regulatory standards aimed at environmental protection stimulate innovation. EDPRS 2 considers industry in the context of the thematic area of youth employment and productivity, especially through its interaction with digital technologies and the ICT sector. The education, skills development and tacit knowledge transfer element is well noted and the role of TVET is emphasized. EDPRS 2 plans for the development of four industrial zones across the country.

The Rwanda Industrial Master Plan 2009-2020 (RIMP) focuses on four key inputs: energy, transport, water and ICTs. Strategic support is provided to create a good business environment, enable export, and develop the required human capacities. This would in turn stimulate industry to

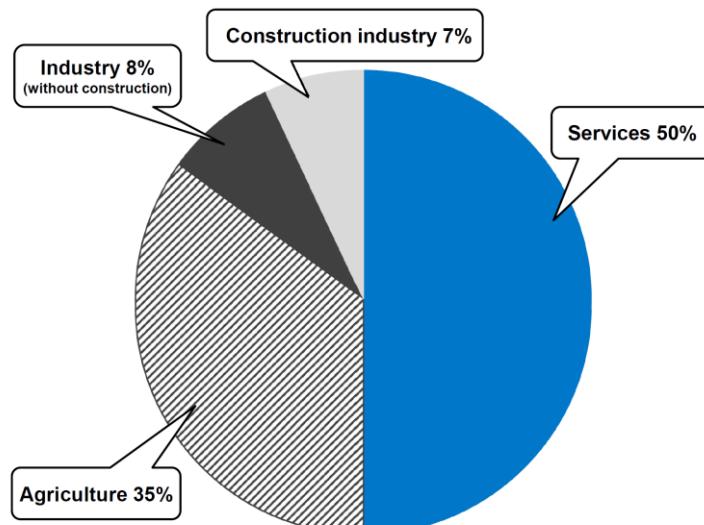
grow, move up the value chain, attract FDI, diversify and achieve all this in an environmentally sustainable manner. The overall impact would be growth in GDP, economic transformation from an agricultural economy to industry, job creation and poverty alleviation. The designated target is set at \$900 per capita GDP by 2020. Extrapolating existing data, this would assume a yearly GDP growth of 5.5 per cent expressed in US\$, or 8.25 per cent in RWF. The target share of industry in GDP for 2020 is set at 26 per cent.

RIMP is succeeded by the National Industrial Policy of 2011 (NIP). NIP sets out goals in terms of industry participation in GDP, investment and employment. It proposes three objectives: increasing production for domestic consumption, increasing exports, and developing an enabling business environment. NIP points out several important problems. One is inadequate human capacities at the technician level, while citing that enrolment in TVET schools is low and insufficient for industrialization. The problem of insufficient

Chart 8: Industry, agriculture and services in the economy of Rwanda 1999-2015



8.2 Share of industry, services and agriculture in GDP, 2015



Source: NISR, Annual GDP National Budget Accounts

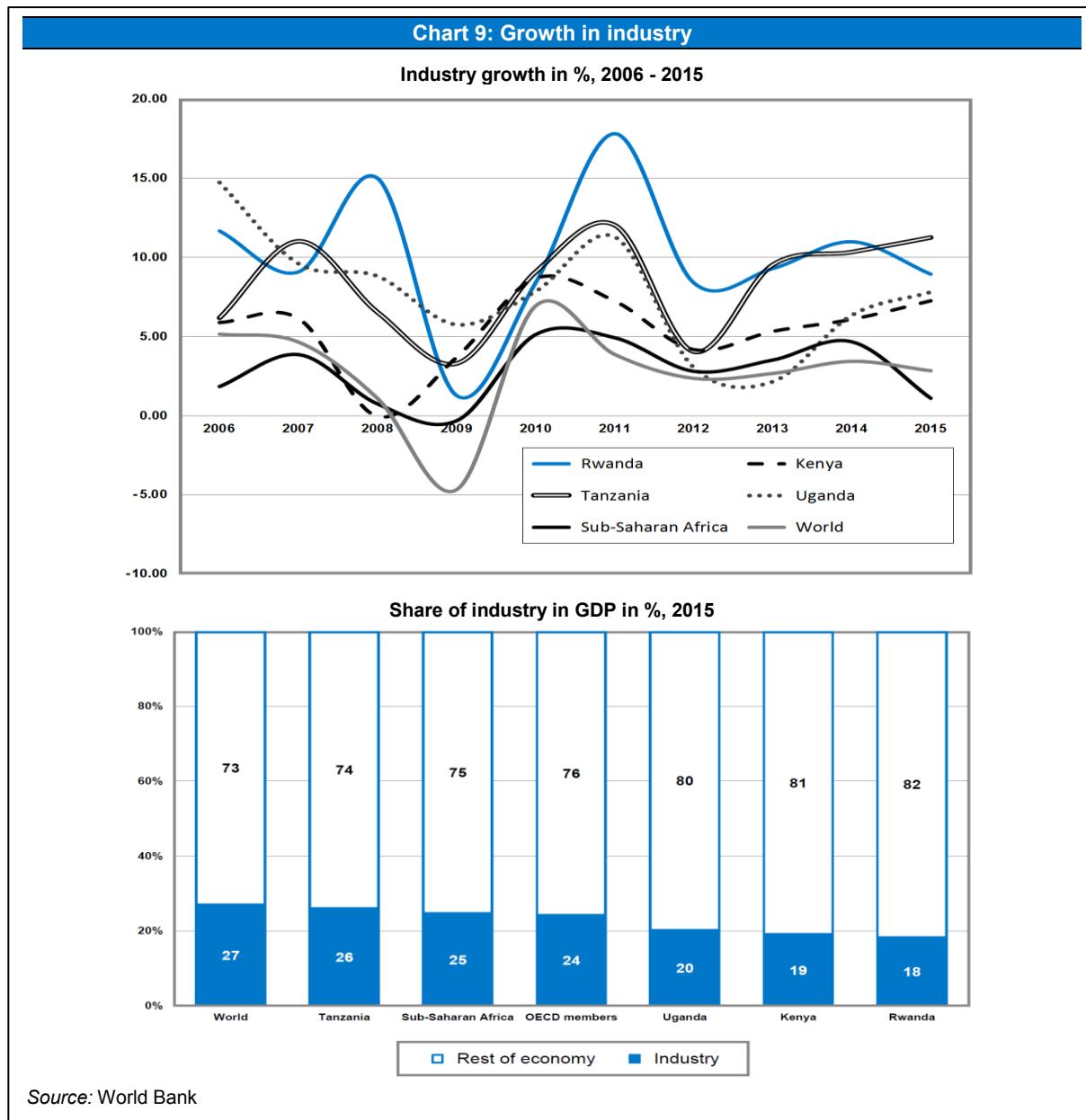
financial resources is noted as well. Issues in trade and trade facilitation are highlighted, including the excessive cost of international transport, regulations in importing markets and the perennial problem of plastic packaging, which under Rwandan regulations is severely restricted. STI considerations are linked to the analysis as well as to policy formulation. NIP responds by proposing ten critical sectors as policy priorities and staggers them per the term during which first results would appear, from short- to medium- to long-term: agro-processing, ICTs, high-end tourism, textiles and leather, mineral processing, construction materials, pharmaceuticals, chemical products, building materials, and bio plastics. NIP concludes with a policy matrix that will guide implementation.

12.2 Progress and achievements

Despite progress in many social and economic development areas, the growth in industry and services, with a complementary decline in the

participation of agriculture, has been modest. Between 1999 and 2015, the contribution of agriculture to GDP was reduced by about four per cent, from 37 per cent to 33 per cent. This was complemented by a two per cent growth in the share of industry, mainly in the construction sector, amounting to 14 per cent of GDP in 2015. The rest of the economy is represented by services whose participation grew by two per cent as well, and represent 44 per cent of GDP in 2015. Chart 8 describes these changes.

International comparison can be useful to gauge policy directions against similar global contexts. Industrial growth at the national level is affected by global economic conditions through many different routes besides a change in demand for industrial exports. Rwanda is a case in point: compared to several nearby countries it has the fastest growth of industry as well as the most volatile, accompanied by a comparably weaker export sector. Chart 9 compares industrial performance in Rwanda with several countries and regions.



A critical issue for Rwandan development has been an insufficient time horizon to complete Return on Investment (ROI) cycles in industry. These tend to be longer than those in services and agriculture and therefore require a higher level of confidence among investors in the institutions of government. Instability is ruinous for industry and today, only one enterprise founded during the colonial period is still active – the Sotiru wheat mills and processor (Gathani, 2013). Conditions for economic growth and industrial development include political and macroeconomic stability, well-functioning institutions and the rule of law. Foreign and domestic investment is highly sensitive to these factors, while social and economic instability is particularly harsh on the poor (Kniivilä, 2007). Owing to purposeful government policy that understands security as an economic development and business facilitation element, Rwanda is now experiencing a prolonged period of peace and stability, and confidence is returning. In addition to this foundational framework condition, the UNCTAD mission in April 2016 noted an acute awareness that linkages between industry growth and other framework conditions, such as energy infrastructure development, human capital development, access to finance and an enabling environment for business, are inseparable at the policy level and in practice. The national economy will need to move forward in its entirety, even if certain sectors, such as ICTs, may have a stronger transformative effect.

The structure of Rwanda's industry is presented in table 14. The largest sector is the construction industry. Currently, the fastest growing sector is mining and quarrying, which grew 155 per cent during the period 2010-2015, at an average annual rate of 28 per cent. It is followed by the electricity power sector growing at 19 per cent. The manufacture of non-metallic mineral products, metal products, machinery and equipment, furniture and other manufacturing, and the construction industry, grew at similarly fast rates, all above 17 per cent. Sectors which have a resource base in agriculture grew at half the rate of the fastest growing ones. This may be indicative of problems in

agriculture and how it links up with other sectors and industries as an element in a value chain.¹²⁰ An analysis of value chains from agricultural production to agro-industry final products, mapped against the structure and conditions in the agro-industry and food sector, may be warranted.

12.3 The challenge of industrialization

The challenge of industrialization in Rwanda is about establishing the entirety of the framework conditions and linking up the various responsible institutions and their policies with a high-level of coherence. These have been mentioned here and have been discussed at greater length in Part I of this STIP Review. Several key issues are worth adding to that discussion.

Rwanda's development begins, like many other countries, with a combination of an underemployed work force and national resources, which in this case is arable land and its output and minerals. Comparative advantages will be assessed as a commercial proposition and financial resources can be used to employ the underemployed to exploit the natural endowments at hand. Industrialization is a process that enhances and creates comparative and competitive advantages. It starts when the processes of human capital development, and technological upgrading of firms, begin to accelerate, guided by development goals and policies, such as those expressed in Vision 2020 and EDPRS. The capacity to deploy technology with commercial outcomes is a function of the level of human capital development and is usually expressed as the education and skill level of the national workforce. This critical link, between industrial capacity development and education, needs to be managed at an institutional level to ensure progress towards a common goal. Innovation, particularly in industry where financial stakes are high, will suffer from institutional coordination failures in countries where training and education capacities are limited: the human capacity that is developed needs to count towards established industrial development priorities.

Table 14: Structure of industry in Rwanda

	2010	2011	2012	2013	2014	2015	% of industry in 2015	Average yearly growth %
Construction	193	251	304	350	383	426	51.3	17.4
Beverages and tobacco	91	99	115	127	128	135	16.2	8.3
Mining and quarrying	33	74	70	89	96	84	10.1	28.3
Food	42	50	55	59	60	62	7.5	8.3
Electricity	10	11	15	17	19	23	2.8	18.5
Wood and paper; printing	14	14	16	17	18	21	2.5	8.6
Water and waste management	12	14	15	15	16	17	2.0	7.3
Non-metallic mineral products	7	9	10	11	13	16	1.9	18.2
Metal products, machinery and equipment	6	9	11	10	12	13	1.6	18.3
Furniture and other manufacturing	6	8	9	10	10	13	1.6	17.4
Chemicals, rubber and plastic products	7	9	10	10	10	11	1.3	9.9
Textiles, clothing and leather goods	7	8	9	9	10	10	1.2	7.6

Source: NIS

Therefore, the interaction between, as a minimum, MINEACOM, PSF and MINEDUC, is mission-critical and institutional goals and policies will require a high-level of coherence.

A second challenge concerns the source of technological upgrading. FDI is a major source and its advantages and necessary conditions for deployment have been discussed in part I of this STIP Review, and at length in economic policy literature. One important advantage of FDI is that it can also be a source of finance. Other positive effects of FDI depend on how it will link to other firms in its environment. Sometimes these will be large firms with comparable capacities and competencies. However, candidates for cooperation are often SMEs acting as suppliers or providers of services. In the case of Rwanda, SMEs would require strong support to be able interact with a foreign investor. Policy support for SMEs should therefore focus on developing entrepreneurial and technical skills that would enable interaction with firms established as a result of FDI.

Technological upgrading can also occur because of R&D and applied research activities. So far, annual R&D levels in Rwanda have been too modest (0.4 per cent of GDP according to UNESCO, 2015) to expect a significant impact. However, there is an eagerness to improve the situation. This eagerness is manifested by several projects underway to establish research and innovation labs, and centres of excellence, in biomedical and digital technology fields. Here, there are two issues of concern for industrial policy. The first is to establish a process that would define the industrial and innovation outcome in each specific area of research: what will the line of research affect in terms of new products or improved production technologies? The second is to establish that R&D outcomes are in a field that already has some industrial activity, or that is in a technologically proximate industry so that competencies can be easily transferred and financiers can rely on their experience to judge the risk-return context. Developing a knowledge base in a field that is not related to existing industry, nor in a nearby sector with established comparative advantages, exposes policy to a high risk of coordination failure (Haussman, 2010).

A third challenge relates to trade facilitation and trade services issues. One of these is the issue of Rwanda being underserved by overpriced transport services due to its landlocked position. The solutions are large and complex. They are also somewhat outside the domain of national economic policy. The current project is estimated to cost Rwanda around \$800 million and would build a railway to Isaka in central Tanzania, while the railway from Isaka to Dar es Salaam port would be rehabilitated. A second issue is the problem of the restrictions on plastic use, in order to safeguard the environment from plastic pollution, and the impact on packaging has already been discussed in this review. Suffice to say that this may be a prime opportunity to research biodegradable packaging options and consider becoming a first-mover in the EAC. The response has been low-tech and

Rwandan packaging producers have switched to paper, but this is of little use for would-be exporters who need to deliver products to international standards, packaging included.¹²¹ A third issue is the need to strengthen non-technological competencies that are related to entrepreneurship and innovation, such as management, operations research, marketing and promotional skills and outlooks. The key issue is to have a shared exposure to these skills and concepts among researchers, engineers and academics in sciences. Equally, knowledge of industrial technologies and processes would benefit entrepreneurs and managers.

12.4 STI, industry and the institutional setting

MINEACOM is the main institution handling industrial development and STI concerns. It promotes its vision as, "... achieve(ing) accelerated and sustained economic growth led by a dynamic and competitive private sector".¹²² It proposes to do this by supporting the development of competitive private sector industries, while ensuring a level playing field for firms, entrepreneurs, and for consumer protection. Its objectives are to increase the share of services and industry in GDP, to support job creation, to promote regional and global trade integration in order to address trade deficits, and to build human capacity to deliver on all of the above. MINEACOM has three affiliated agencies: RSB, the Rwanda Cooperative Agency (RCA) and NIRDA. RSB has been discussed in chapter 6 of this review. The role of RSB is to develop, award and enforce standards on Rwandan products. The mandate of RCA is to promote, register and regulate cooperatives. There are several other institutions that are critical for industrial policy which have already been discussed in the review, including educational, academic and TVET institutions, as well as BDF, which is active in financing private firms, including SMEs and start-ups.

NIRDA's activities are also discussed in chapter 6 and its role will only be briefly noted here. NIRDA declares its mission as one of implementing NIP, carrying out R&D, training entrepreneurs, establishing international research partnerships, facilitating growth of SMEs, including improving products and entering new markets, and providing prototype and reverse engineering services. R&D at NIRDA is conducted in four divisions: Pharmaceutical and Chemical Industries, Agro-processing and Biotechnology, Cleaner and Environmental Management, and Processing Engineering, Manufacturing and High-Tech. There are 114 researchers employed who are involved in projects for agriculture, the pharmaceutical sector, cosmetics and chemical industries.

MINEACOM also handles intellectual property policy. Its main focus so far has been in harmonizing Rwanda's IP regime with international standards in order to support unimpeded trade, finance and investment with international partners. An IP environment compatible with international

standards is often seen as a fundamental requirement for attracting FDI. The current IP regime in Rwanda is based on Law N° 31/2009 of 26/10/2009 on Intellectual Property, the establishment of a Rwandan Society of Authors, membership in the Africa Regional Intellectual Property Organization and ascension to the Madrid Agreement, The Hague Agreement and the Patent Cooperation Treaty. The primary objective of Rwanda's IP law is seen as: "... contribut(ing) to the promotion of technological innovation and to the transfer and dissemination of technology, to the mutual advantage of producers and users of technological knowledge".¹²³

The Kigali Special Economic Zone (KSEZ) is a part of Rwanda's Special Economic Zone. It is designed to address several issues, such as access to land, energy, transport linkages, bureaucracy and skill availability. KSEZ includes an Export Processing Zone where a firm can import machinery, equipment and material for the manufacture of export goods without payment of import duties. KSEZ is being developed in two phases. Six provincial industrial parks are planned in an effort to replicate the initial success of KSEZ. The KIC project has been discussed in chapters 6 and 10 of this review. The discussions of policy issues for KIC as an innovation and industrial park in box 6.2 equally apply to the KSEZ project.

12.5 A policy framework for industry and STI

The National Industrial Policy of 2011 contains Rwanda's strategic goals for industry and defines the role of STI in achieving them. NIP is established and implemented by MINEACOM. The discussion of STI is developed in NIP part 4.3.8 *Technology, Research and Innovation*. It provides a clear perspective on the issues and should be noted by all line ministries and public bodies, and considered as a guiding framework for their own STI policy development.

In its discussion, NIP explains that STI should be viewed in the context of a global and open economy and that the key concepts are technological capacity and the production of more value-added goods and services. It develops several broad principles. One is that practical innovation should be the priority for Rwanda. STI should also be relevant for all sectors and programmes – private, public, rural, urban, infrastructure, education or energy. NIP explains that STI requires diverse levels of competencies, from sophisticated scientists to engineers, and technical and vocational workers. It stresses that STI is about, "... getting knowledge out of the laboratory and into the market" (NIP, 2011), and acknowledges the important role of marketing, management, and entrepreneurship. NIP claims that public-private partnerships are the key operating mode for Rwanda and therefore research projects must conform to private sector needs. It recognizes the advantages of technological leapfrogging and being a "latecomer", provided the

commitment to develop technological receptiveness is firm. Finally, NIP declares that STI must reach out, beyond high-tech, and address all sectors and activities that require scientific, engineering, and technical knowledge and inputs.

NIP implementation is based on a five-year Policy Matrix which contains policy areas coherent with the NIP discussion, policy actions, performance indicators, responsible agencies, timeframes and budget indications. In terms of its STI policy actions, the main consideration has been the establishment and activation of NIRDA as the linking agency in charge of: "...facilitat(ing) the transfer of innovative technologies, to carry out industrial research and to stimulate national and international partnerships ... (and) enable(ing) partnerships between Rwandan firms and international firms and institutions in providing technological solutions" (NIP, 2011).

MINEACOM has developed a second policy vehicle in its Rwanda Private Sector Development Strategy 2013-18 (PSDS) and focuses on STI in Program 5 on Skills and Innovation. It reports that firms are increasingly faced with an inadequately educated workforce. On the other hand, on-the-job training and specific vocational training might be the best way to address any skills deficits. Therefore, only greater private sector involvement in training will resolve this issue. This requires strengthened cooperation between RDB, PSF, WDA, as well as TVET and higher educational institutions. For training and skill transfers that are not available in Rwanda an accreditation scheme of providers will be developed. An expansion of the programme of private sector internships and apprenticeships is foreseen. In its discussion of coordination and market failure, PSDS notes that firms need to acquire the capability to innovate new technology or business models, to alter market outcomes. PSDS explains how its policy actions are coherent with EDPRS 2 and proposes a logical framework for policy implementation and evaluation.

The MINEACOM annual report 2014/2015 describes developments on the ground and highlights key projects that are evolving as a result of NIP. Almost all developments will have an implied innovation component, in particular the reporting on flagship projects, industrial parks and CPCs. However, the report does not report along areas of intervention and policy actions, as set in NIP. There is also no direct reporting on progress on the ten selected clusters defined in NIP and the application of a cluster progression ladder. While the annual report is clear, and successfully outlines actions and accomplishments, by not aligning its reporting to the NIP it may forfeit opportunities for policy learning in the evolution of new or revised NIP.

12.6 Conclusions

The relationship between industrial policy and STI is indisputable. This fact underscores the discussion in chapter 8, which finds that investments in human capacity-building and the development of funding mechanisms are not

translating yet, or at least not strongly enough, into innovation indicators such as the Global Innovation Index (GII, 2016; World Bank, 2016). This review suggests that such indicators may fail to absorb what innovation really means in a developing, but still low-income, country and that they are best used to gauge in-country progress year-on-year, rather than as an absolute measure or comparator with other countries. Still, the GII hints at sluggish innovation, and the slow transformational impact of industrial growth on the Rwandan economy validates this concern.

There is also an underappreciation of global economic trends, and a hesitance to relate domestic policy beyond accepting the unrelenting increase in competitiveness in the world economy. Factors such as globalization, the fourth industrial revolution and financialization, can and will affect Rwanda's industrial development trajectory, directly or indirectly, and should be considered during policy formulation.

At the industrial policy level, the UNCTAD mission found that there is an evolved level of understanding of innovation and how it relates to commerce and entrepreneurship on the one side, and to science, R&D and applied research on the other. However, there is some uncertainty about whether such an understanding is fully shared with established funding mechanisms. A general impression is that the commercialization end of innovation – the part that carries the bulk of the risk and uncertainty of the process – is left to explore funding from banks. These are typically in the form of commercial credit lines, which require security and charge interest rates starting at 11 per cent and can go above 17 per cent. Such rates demand an immediate and high-level of profitability from applicants, severely reducing enterprise capacity

for capital accumulation and consequently for investment in knowledge and technology acquisition. Such funding mechanisms may be suitable for trade and business propositions, where turnover is quick while capital investment is small, but are unsuitable for industry and especially when innovation is a key component in the venture.

Another important concern is the relationship between established and planned research areas and institutions and how these will relate to the needs of innovation in industry. Given Rwanda's limited resources, any science and R&D programmes that do not have clear innovation outcomes, either commercially or through the provision of public services, may potentially crowd out more useful R&D activities. R&D that is not in concert with specific industry and economic development goals may not find its expression in a process, product or service. It follows that it will also not be able to contribute to generating a return for its financers, which would be the entirety of Rwandan society in the case of public R&D funding.

NIP is keenly aware of these issues and MINEACOM has set up NIRDA to operationalize some of these concerns. However, the job is much greater than establishing a responsible agency. The need to develop better coordination and coherence between policy and action among a broad spectrum of stakeholders should be a key concern. One policy option is to develop an industry innovation system coordination framework. At this point, a better proposal may be to ensure that industrial policy and innovation needs become the cornerstone of a national system of innovation. The rationale is that much, if not all, of the top-level STI concerns will perfectly map from an industry sector innovation system to the national one.

Part III: Conclusions and recommendations

13. Conclusions and recommendations

13.1 Conclusions

Rwanda has made remarkable progress in the last twenty years. Nevertheless, there is no letting up and policy ambitions and development aspirations are at a high point. Becoming a knowledge-based economy is the target, and the means will be to provide a high-level of public service and to develop a receptive and world-class business environment. Technology, and in particular ICTs, are central to this strategy and therefore STI policy becomes a key factor.

Innovation is happening in Rwanda and new and improved products and services are appearing daily, from both the public and private sectors. Policymakers are keenly aware of innovation as an enabler of economic growth. The idea that development requires knowledge and technology comes naturally to Rwanda's policymakers, entrepreneurs and youth. The conviction is there, the test is in the details of implementation.

13.1.1 Macro-level policy challenges

Three important challenges need be faced in developing and implementing STI policy. A primary challenge is developing a national system of innovation. This depends on adjusting policy habits towards greater involvement in cooperation across policy domains, and the development of linkages among public institutions and with firms, industries, educational and academic organizations, and the general public. Evolving a broad consensus on the meaning and role of innovation in STI policy and in economic development is another important challenge. It is critical for enabling cooperation and coordination between various sectoral and thematic policies and their institutions. It is critical also for developing assessments and evaluations of policy outcomes that can be used in policy learning and for improving performance in subsequent policy cycles. A third challenge is getting the right balance in policy so that it addresses both job creation and skills development, development in rural and urban societies, technology supply and technology demand, and digital industries and mainstream and traditional sectors and industries.

Rwanda's policy response to its development and STI challenges is impressive. Between Vision 2020, PRSP (2002-2007), the 7-Year Government Plan (2010-2017), EDPRS 1 (2008-2012) and EDPRS 2 (2013-2018), as well as sector plans per industry, public service and national resource, policymakers have demonstrated an ability and willingness to think forward, and to develop and implement policy. In addition, policymakers have demonstrated a particular capacity for policy learning and do not miss opportunities to evaluate the outcomes, and introduce wisdom gained in ensuing policy cycles. There is a prominent level of coherence in high-

level policy, unified behind Vision 2020 goals of Rwanda developing into a middle-income developing country, and a services-oriented and knowledge-based economy by 2020. This coherence needs to be assessed, not only as a matter of intent, but also in STI policy outcomes described with appropriate data. Implementing evidence-based policy management should be a growing locus for cooperation between STI policymakers and the National Institute of Statistics.

A key factor in implementing Vision 2020, development and STI policies and targets, is the system of *Imihigo* performance contracts. It was introduced in policy implementation after evaluations of development policies in the late '90s concluded that there had been an insufficient impact on poverty reduction. *Imihigo* is an example of the capacity of Rwandan policymakers to identify systemic weaknesses and use these as inputs in a learning process – a strong indication of the Rwandan potential to innovate. However, *Imihigo* may need to be adjusted in order to serve better in the context of innovation, where policy outcomes are inherently riskier and more uncertain. It might be worth considering if differentiating the merit awarded to specific *Imihigo* commitments can be associated with their innovation potential.

Beyond the problems generated by Rwanda's modest natural resource endowments and landlocked geography, development policy has to deal with five major difficulties. The first is a strong population growth that annuls a large part of national per capita GDP growth. The second is job creation: every year about 200,000 people enter the job market looking for off-farm employment. The third is its trade deficit. The fourth is a strong reliance on ODA. While necessary at the moment for the launch of important development projects, large ODA support is not compatible with medium-term aspirations to become a middle-income developing country. Finally, Rwanda is a populous country, but only a minor part of its population functions in the formal and monetized economy and can be considered a consumer base for innovative commercial products and services. STI has a role to play in the resolution of these problems, but success will depend on the ability of STI policy to link and coordinate with other policy domains and maintain its coherence with Vision 2020 and its successor.

13.1.2 Directions in implementation

There are ten factors that will affect the ability of Rwanda to take advantage of STI.

The first factor is the development of policy and actions supporting the strengthening of a Rwandan national system of innovation. These should necessarily be established at the highest level of leadership and have decision-making authority rather than be tasked with providing guidance. Progress on this issue will indicate that STI has

become a mainstream development concern in Rwanda.

The second factor is investment in human capacity development relevant for the knowledge economy. This necessarily means establishing strong links between education and training institutions, and proposed or functional centres of excellence (e.g. KLab, KIC, eHealth and Biomedical Engineering, SMART Rwanda Innovation Growth Centre, etc.) with support and funding from NCST through NRIF.

A third factor is aligning the demands of industry in terms of labour and job skills with the output of schools, universities and vocational training institutions. This will not only require revisions in degree programmes and changes in teaching and learning methods, but may entail revisiting the enrolment intake in universities and training institutions and revising downwards for degrees and qualifications that have poor employment results. Technology transfer and innovation require new skills and knowledge, but industry often has to rely on contracting foreign technical experts. This is not only a matter of adjusting curricula but of establishing closer cooperation in terms of joint research and internship programmes, nationally and internationally.

A fourth factor is the development of absorptive capacities in mainstream services, sectors and industries, and using high-tech innovation loci, such as the ICT industry, innovation hubs and centres of excellence, to leverage the development of technological receptiveness throughout the entire economy.

A fifth factor is increasing the currently low penetration of broadband internet usage. Rwanda is connected to the Internet backbone with adequate bandwidth, has built an impressive optic fibre infrastructure, and has put in place a 4G LTE mobile broadband infrastructure. The challenge is to use this infrastructure to create economic value and improve public service.

A sixth factor is addressing the mismatch between evaluations of the business environment: it is rated highly, while the innovation climate is varied. Overall however, innovation is within EAC averages, while innovation efficiency is relatively lower, according to GII indicators. This suggests that investments made in education and ICT infrastructure may not have the desired impact. This is a serious issue that deserves deeper consideration than this STIP Review allows.

A seventh factor is energizing the business community. Outside ICTs, the business culture is conservative and concedes that incentives for investment, let alone technological upgrading, are insufficient, because outcomes are uncertain. This particular issue needs more profound consideration, particularly if the development of Rwanda depends on developing 200,000 off-farm productive jobs every year to match population growth. It is inconceivable that the Government can act as an employer of last resort on this scale, or that those entering the workforce will have sufficient

entrepreneurial skills and ambitions to remedy this situation.

The eighth factor is consolidating the innovation funding and financing ecosystem. There are several funding agencies, all with slightly different funding capacities, and looking for different but more-or-less overlapping deals. Internally, the funding agencies may be clear about their objectives and targets. Externally, developing a perspective on what is the best source for one's particular business proposition may be less straightforward. Improved clarity on the possibilities of funding the innovation end of the STI spectrum, including commercialization and scaling-up, is needed. Angel investors, venture capital and PPP funding mechanisms will need to work with existing government-supported funding agencies. A coordination mechanism and a single-entry point to advise and guide entrepreneurs should be considered.

The ninth factor is the development of technological research services. RSB needs to be brought into the centre of STI policy implementation, and explicitly associated with ongoing and planned projects and programmes. Raising awareness among firms and entrepreneurs about the need for certification and independent third-party technical verification, and its role in increasing consumer confidence and demand for local produce, is critical, both for expanding domestic production as well as for increasing exports and decreasing the trade deficit.

The tenth and final factor is achieving a critical mass of R&D programmes and projects that will tip Rwanda's development into a knowledge economy trajectory. R&D must squarely aim at contributing to solving the problems and challenges in production, in the real economy. Rwanda's continued progress and participation in regional integration and EAC processes will stimulate its industries and sectors to increase R&D activities and invest in their innovation performance as its firms and entrepreneurs are challenged by larger and more competitive markets. While the quality and the purpose of R&D programmes are important, excessively severe scrutiny of proposals, stemming from the prerogative that public money must be effectively spent and R&D projects must achieve notable results, eventually leads to reduced research activity. On the other hand, limited resources are a fact of life in Rwanda and in the development context more generally. Science and R&D programmes have an important secondary effect on human capacity development. They should be managed towards achieving effectiveness by linking them with specific innovation interests and targets, preferably in industry.

13.2 Recommendations

The strong engagement of the national leadership in the science and technology development of the country, aimed at making innovation the backbone of the overall process of economic and social

progress, is exemplary. Policy efforts and implementation need to be further strengthened to ensure that the progress made is sustained, and to validate ambitious investments and plans, and to generate a measurable impact.

Recommendations are presented as amenable to immediate implementation, as a matter of long-term strategy, addressing specific sector issues in energy, ICTs, agriculture and industry. In view of this, the UNCTAD STI Policy Review recommends the following policy actions.

13.2.1 As a matter of long-term strategy:

1. Improving the *integration of STI in the overall development strategy* of the country, notably in promoting innovation and change in the established economic sectors, including and beyond the current policy focus on high technologies and related R&D;
2. The establishment of a mechanism for better and *greater involvement of all concerned frontline ministries* in STI policy design and implementation processes, with appropriate oversight of their engagement at the highest level of governance: the design of a National STI strategy and its implementation, and the creation of a *high-level Innovation Council* with key ministers as members; review international best practice and develop an innovation governance model suited to Rwanda's development ambitions;
3. The *development of STI policy evidence* at macro and firm level and using examples from international best practice such as the OECD Oslo and Frascati manuals, the EU Innovation scoreboard and UNESCO Institute for Statistics science and technology surveys;
4. The *coordinated mobilization of public and private STI stakeholders*, including academia and training institutions, firms, government authorities, citizens, representatives of environmental concerns, and senior level politicians and high-level Innovation Council members, to contribute to formulating and implementing STI and economic development priorities;
5. Ensuring *policy coherence at operational and implementation levels* across different line ministries, as well as private and public STI stakeholders, including through annual reporting;
6. Coordinating and *supporting linkages between universities and TVET, and innovation centres* and centres of excellence with support from NCST and NRIF and with the guidance of high-level Innovation Council;
7. Sector policies and related projects and programmes designed to support implementation should include analysis of their potential for:
 - a. Scaling-up in outreach and scope;
 - b. Replicability in other sectors and localities in Rwanda, and in the EAC region; and
 - c. Their impact on overall human capacity and, more generally, technological receptiveness and absorptive capacity development.
8. The development of an innovation-centred plan for *reducing reliance on ODA*;
9. Supporting *EAC integration processes to enlarge the consumer base* and increase the competitiveness of firms, improve access to energy and transport services, increase knowledge production and exchange, and foster human capacity development;
10. The development of *specific innovation programmes* in selected areas of importance for the economy and Rwandan society as a whole, such as agro-food, medical technologies and ICTs;
11. An increase in the promotion and enhanced support for *innovation in public service* within public authorities and ministries that are front-line STI stakeholders;
12. The increase and improved *provision of finance* to assist the *diffusion of technology and innovation* in the economy as a whole, including improved facilitation for *STI oriented business creation and development*, such as extension services in agriculture, innovation workshops in TVET, entrepreneurship support schemes in employment offices, etc.;
13. An *increase in funding of R&D*, combined with a systemic linking of R&D programmes with problems and needs in firms and industries through imposing requirements such as joint submission of funding proposals by partnerships composed of both firms and research institutions;
14. The development of *biodegradable packaging technologies and solutions* for agriculture and agro-food sectors, industry and trade services and logistics, and establishing Rwanda as a regional leader in this domain;
15. The development and strengthening of *long-term partnerships with foreign and international STI counterparts*; the establishment of a nationwide programme to raise the overall technological level and technology *absorptive capacity* of the business sector through efficient linkages with foreign firms for the *transfer of technology, management and soft skills, and quality control in production*.

13.2.2 For immediate implementation:

1. An increase of assigned staff in charge of innovation policy implementation in relevant government agencies, along with strong and permanent support for continued development of their competencies in STI and innovation system policy and practice;
2. An increase in the involvement of academia and business sectors and industries in policy formulation and implementation and a systematic involvement of senior level representatives in relevant policy making bodies at both the overall STI policy and at the sector level;
3. A strengthened innovation orientation of *Imihigo*, whereby innovative and innovation-supporting commitments are given special merit and *rewarding innovative approaches and learning achievements* in the performance commitments and evaluations of the public civil servants and policymakers;
4. The establishment of a *single-entry point or advisory service for funding for start-ups* and firms in need of finance, regardless of size, sector or innovation ambitions;
5. The use of the newly established Rwanda National Research and Innovation Fund to respond to the diversified challenges and opportunities existing in the economy as a whole, and particularly to stimulate R&D activity in the productive sectors through *collaboration between firms, universities and public entities*;
6. The use of matching funds, where private funding is matched with public funds, to establish public support for firms willing to invest in R&D;
7. Scale up the involvement of RSB in all relevant innovation projects and programmes, such as the Made-in-Rwanda campaign as well as through systematic checking of standards, quality control, export certifications, etc.;
8. Extending and supporting the work of *professional student traineeship programmes* such as IAESTE and AIESEC;
9. A feasibility study for a *digital national job market* platform;
10. The strengthening of support mechanisms, such as technology transfer centres and business incubators at universities and business associations, for the *identification of technology needs* in the productive sector;
11. The strengthening of support mechanisms for the identification and remedy of *soft technology deficiencies in firms and industries* (marketing, logistics, etc.);
12. Strengthening funding support for innovative firms and entrepreneurs within the *Made in Rwanda* campaign and reinforcing its *linkages to relevant institutions such as the RSB*;
13. Strengthening the support for innovative firms and entrepreneurs with plans to *increase e-commerce activities*, starting with an assessment of the legal and overall environment to establish a joint e-commerce support team between, for example, MINEACOM and PSF;
14. A review of *education structures, initiatives and reforms* at all levels – from university down to preschool – to ensure that ongoing national human capital development is conducted with *anticipation of growing knowledge and innovation needs*;
15. Establishing *financial support schemes for students* (grants, subsidies and zero interest loans) to purchase IT equipment;
16. Increase *public relations activities and media coverage* to highlight successful innovations and entrepreneurs, and stimulate an increase in deal flow.

13.2.3 As a matter of sector policy:

Energy

1. The revision and adjustment of incentive structures for biomass, on both user and producer sides, including investment in developing awareness of health impacts and the need to adjust practices in households;
2. The strategic development and geographic placement of power generation capacities to facilitate access for industry and to incentivize the build-out of the electrical grid;
3. Continued research on the implantation of biomass digesters and solar energy sources, particularly for off-grid installations;
4. Increasing R&D funding for energy and strengthening of courses and programmes on energy engineering and technical training, taking into account how development policy sees power generation expanding more than five-fold by 2025, with an appropriate extension of the electrical grid;
5. The coherence of RURA activities and reporting vis-à-vis REP and EDPRS 2 policy goals needs to be reviewed, and the potential for establishing better linkages with other institutions such as RSB, academic and research institutions, and private sector firms and organizations, such as the EPD, should be explored;
6. Linkages between energy and ICT policy development and implementation need to be reviewed and strengthened; energy policy development and implementation

- needs to be coherent with other policies, and regular interaction and consultations between REG, RURA, MININFRA, MINEACOM, MINAGRI, MINIRENA, REMA, RDB and the NCST may be advisable;
7. The relationship between the Energy Development Fund and the Renewable Energy Fund may require review and clarification, particularly regarding how their goals will combine to solve problems and exploit synergies;
 8. Implementation strategy may be reviewed to develop clarity regarding which goals can be accomplished by which strategies using a policy matrix or similar policy tool; the development of action plans may benefit from using a business plan or logical framework approach;
- ICTs**
9. Establish an ICT sector system of innovation coordination and support mechanisms in the form of a council of industry and government leaders and key stakeholders;
 10. Enlarge the scope of evaluation of policy performance of e-governance to include transformative effects on partners and beneficiaries;
 11. Improve the capacity for handling intellectual property, in particular regarding enforcing copyright and non-disclosure agreements; develop an understanding of public and open licences and the public domain, the knowledge and technologies they avail and their use in content development and protection, including for public data, open data standards and software;
 12. Use procurement to stimulate the development of local start-ups and SME;
 13. Develop funding sources and a mechanism that can accept high-levels of failure typical in the ICT sector;
 14. Explore linking ICT to other sectors and industries through KIC and by developing incubators and innovation centres within academic and research institutions and facilities; increase outreach to MINEACOM and MINECOFIN, appreciate their policy concerns and explore programmes under their purview that may have substantial ICT elements;
 15. Improve linkages between the ICT sector and the creative economy, supported by closer cooperation between MYICT and MINISPOC;
 16. Improve informal knowledge sharing and tacit knowledge flows by reducing the role of information gatekeepers in firms and institutions, and encouraging horizontal communication, as well as supporting a culture of collaboration on open content and open innovation projects;
17. Review implementation plans for SMART Rwanda aimed at identifying its capacity to act as a business plan or project programme with a logical framework structure;
- Agriculture**
18. Ensure that EDPRS 3 considers the relationship between agriculture and technology, and the importance of innovation for moving towards a commercialized agriculture sector, with an increasing presence of agro-food firms moving the entire sector up the value chain;
 19. Ensure that PSTA 4 considers innovation at the farm-as-firm and industrial agro-food firm level, and includes a consideration of entrepreneurial issues, problems of financing innovation, and of economic experimentation, and the readiness of policy to support entrepreneurial risk, and deal with failure in poor and fragile rural environments;
 20. Commit policy and R&D efforts on developing productive activities for Season C;
 21. Develop a strategic orientation for producing several select agro-industry commodities that are not easily perishable and can tolerate transport from existing or potential resource bases;
 22. Use ICT4RAg process and outcome as a model to extend linkages to energy and tourism sectors;
 23. Increase funding to RAB to improve R&D and increase extension services;
 24. Guide RAB reporting to consider aligning to PSTA 3 programmes and EDPRS 2 objectives;
 25. Based on established inter-institutional cooperation with MINEDUC and NIRDA, deepen interaction with other stakeholders, including agro-food and related firms, and academic and training institutions;
 26. Increase funding for projects and programmes that develop off-farm jobs and employment; evolve the understanding that off-farm may or may not be related to agriculture; link off-farm job creation to the second cities project;
 27. Reducing crop diversity and moving to mono-cropping in order to promote commercialization and agro-food industry development increases performance risk for farmers and must be compensated with insurance, credit guarantees and social safety nets;
 28. National campaigns should aim at changing consumption habits to align with competitive advantages in exports;

- high-quality coffee and tea should become Rwanda's national beverages;
29. Strengthen marketing and promotion skills, use of denominations of origin and trademarks to promote and differentiate high-quality agro-food products in export to the EAC and globally;

Industry

30. Policy development should go beyond strictly local issues and consider the effect of global developments, such as globalization, financialization, and the fourth industrial revolution, as well as the effects of EAC regional integration processes;
31. The industrial system of innovation should be fully morphed into the national system of innovation from the perspective of policy goals and targets, as well as regarding operational issues;
32. As STI puts pressure on the labour market through higher productivity and capital intensification, industrial policy may need to coordinate with other policy areas to stimulate off-farm job creation;
33. Policies ensuring macroeconomic and social stability should be considered as functional elements of industrial policy, given the longer periods needed to cease returns on investment in industry and the higher levels of commitment to capital investment compared with the services sector;
34. Analyses of agricultural value chains are needed in order to assess the problem of underperforming linkages between farming and agro-industry, and proposal of policy remedies;
35. Human capacity development at all levels should be validated against industrial development priorities;
36. When there are reasonable prospects for FDI to establish production, relevant local firms and SMEs should engage in a targeted and applicable upgrade of their technological and learning capacities;
37. R&D efforts should focus on real industrial concerns, while new areas of research should be in fields that are proximate to existing industrial activity that has an established comparative and competitive advantage;
38. The problem of plastic use restriction and the development of acceptable (biodegradable) packaging should be tackled as a primary innovation challenge and opportunity;
39. Technological upgrading in industry should be matched with the development of soft skills in management, operations research, marketing, etc.;
40. The revision of the NIP should include a provision that all stakeholders under the purview of industrial policy should evaluate and report on their performance according to established goals and policy priorities.

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Annex

Table A: Rwanda in the Global Competitiveness Index

Items	Rank (140 countries)	Score (1-7, 7 is best)
Institutions	17	5.4
Infrastructure	97	3.2
Macro-Economic Environment	92	4.4
Health and Primary Education	88	5.4
Higher Education and Training	120	3.1
Goods Market Efficiency	44	4.6
Labour Market Efficiency	8	5.2
Financial Market Development	28	4.5
Technological Readiness (+)	103	3.1
Market Size	126	2.5
Business Sophistication	69	3.9
Innovation (++)	46	3.6
Technological adoption	44	5.0
ICT use	130	1.2
Capacity for innovation	62	4.0
Quality of scientific research inst.	68	3.8
Company spending on R&D	65	3.3
University/Institutional collaboration in R&D	64	3.7
Government procurement of advanced technology	6	4.6
Availability of scientific and engineers	71	4.0
Patent Cooperation Treaty patent applications	119	0.0

Source: WEF, 2015

Table B: Rwanda and the Global Innovation Index

Items	Rank (143 countries)	Score (1-100; 100 is best)
GII - Global Innovation Index	94	30.1
Institutions	61	63.2
Human resources and research	99	21.9
Infrastructure	98	29.9
Market sophistication	26	58.4
Business sophistication	45	38.3
Knowledge and technology outputs	125	14.1
Creative outputs	115	21.6

Source: Cornell University, INSEAD and WIPO, 2015

Endnotes

- ¹ World Bank, World Development Indicators, average for 2003-2015, accessed on 08.10.2016; <http://data.worldbank.org>.
- ² See: www.rw.undp.org/content/rwanda/en/home/ourwork/povertyreduction/in_depth.html
- ³ 4G LTE is one of several competing 4G standards for wireless mobile telephony and data services.
- ⁴ This is in contrast with the UNCTAD's mission impression, which regularly asks the question, "What does innovation mean to you?" to all partners in discussion. Most of them had a broad perspective of innovation, focusing on practical outcomes.
- ⁵ At the time of writing a National Council of Science and Technology has had a first meeting. The Council is a council of experts and serves in an advisory role.
- ⁶ This is a rough approximation based on the latest estimates of build costs by the US Energy Information Administration (2016).
- ⁷ This means that many people will have two or more mobile contracts.
- ⁸ 4G LTE is one of several competing 4G standards for wireless mobile telephony and data services.
- ⁹ The ICT sector refers to firms and institutions producing equipment and services related to broadcasting, computing and telecommunications.
- ¹⁰ For example, UNESCO (2015) or GKI (2013 and 2014).
- ¹¹ UNESCO researchers in R&D (per million people), latest data is for 2009 and 2010.
- ¹² See table A in the Annex.
- ¹³ See: <https://www.fitchratings.com/site/pr/1005281>
- ¹⁴ See: www.rw.undp.org/content/rwanda/en/home/ourwork/povertyreduction/in_depth.html
- ¹⁵ See: <http://www.who.int/bulletin/volumes/86/11/08-021108/en/>
- ¹⁶ See: <http://hdr.undp.org/en/indicators/137506#>
- ¹⁷ See: <http://www.minagri.gov.rw/index.php?id=28>
- ¹⁸ If we exclude countries with very small territories or those that are essentially cities, Rwanda is the fifth most densely populated nation on earth behind Bangladesh, Lebanon, Republic of Korea and the Netherlands.
- ¹⁹ The Ministry of Finance and Economic Planning, Macro Framework Public Data Set, June 2016. See: http://www.minecofin.gov.rw/fileadmin/templates/documents/Data_Reports/Updated_MacroFramework_Public_Dataset-June_2016.xlsx
- ²⁰ This, however, is not a hard-and-fast rule as some countries, while not particularly innovative, will trade a high percentage of their GDP due to a large tourism or commodities export sector. Others will trade less because of their large domestic markets.
- ²¹ See: www.tradingeconomics.com/commodity/coffee; www.indexmundi.com/commodities/?commodity=tea
- ²² See: <http://www.newtimes.co.rw/section/article/2015-03-15/186915/>
- ²³ This is due to a low level of income, as well as to a low level of interaction with the formal and monetized economy of a rural population that lives off subsistence agriculture. By the same token the EAC, with its population of about 100 million, represents a market of perhaps 30 million consumers. However, these are static perspectives that may be out of date in a decade.
- ²⁴ In the development of innovation systems theory, policy research established two lines of enquiry (Godin, 2007). The first led to descriptive research on national institutions, including institutional rules and behaviours, and the organization and functioning of national innovation systems. The second line of enquiry was concerned with how knowledge is created and transferred and gave rise to the concept of the knowledge economy. It focused on the capability of an innovation system "*to ensure timely access by innovators to the relevant stocks of knowledge*" (David and Foray, 1995).
- ²⁵ The latest data available is from the period 2009-2014 and from various sources, but mainly World Bank, and therefore should be no presumption of accuracy.
- ²⁶ Secure servers are servers that use encryption technology in internet transactions.
- ²⁷ The GII gathers data from more than 30 sources, covering a large spectrum of innovation drivers and results. The GII is positively biased towards official data and underweight on qualitative assessments, with only five survey questions included in GII 2016.
- ²⁸ The Bloomberg Innovation Index and the Boston Consulting Group International Innovation Index are similar ranking exercises. However, they do not include Rwanda in their analysis.
- ²⁹ The two-letter country codes in chart 2 are defined in ISO 3166-1 and are part of the ISO 3166 standard published by the International Organization for Standardization.
- ³⁰ See: rru.worldbank.org/BESnapshots/Rwanda/default.aspx
- ³¹ This is in contrast with the UNCTAD's mission impression, which regularly asks the question, "what does innovation mean to you?" to all partners in discussion. Most of them had a broad perspective of innovation, focusing on practical outcomes.
- ³² An invention is the practical outcome of the application of knowledge and ideas that are the results of experience, scientific enquiry and technological research and development. These may be new globally or perhaps only locally.
- ³³ These SDGs are: 6. Clean Water and Sanitation; 7. Affordable and Clean Energy; 11. Sustainable Cities and Communities; 13. Climate Action. Relevant as well are: SDGs 14. Life Below Water and 15. Life on Land.
- ³⁴ 'Structured' here means the establishment of coordinating bodies or mandating *national system of innovation* functions to existing public institutions.
- ³⁵ *Uberization* means the conversion of existing jobs and services into discrete tasks that can be requested on-demand, often using an online or mobile application. The *gig economy* represents an economy in which there are few permanent employees and most jobs are performed by temporary or freelance workers. Source: <https://www.collinsdictionary.com>
- ³⁶ The ILO (2014) describes the informal economy as: "... economic activities by workers and economic units that are – in law or in practice – not covered or insufficiently covered by formal arrangements. Their activities are not included in the law. ... As the large majority of workers in the informal economy and their families do not benefit from social protection, they are particularly vulnerable to various risks and contingencies."
- ³⁷ This category excludes mining, power generation, water management and construction.
- ³⁸ Data is from the Ministry of Finance and Economic Planning Updated Macro-Framework Public Dataset of June 2016.
- ³⁹ See: www.doingbusiness.org/data/exploretopics/entrepreneurship
- ⁴⁰ A small and medium enterprise is defined according to the following criteria: smaller than 100 jobs, less than 25 million RWF turnover, or with equity less than 75 million RWF.

⁴¹ Law N° 57/2008 of 10/09/2008 Relating to the Prohibition of Manufacturing, Importation, Use and Sale of Polythene Bags in Rwanda.

⁴² The breakdown of BDF's activities, since its creation, appears as follows: Guarantees: 4,908 firms have benefited from them, for a cumulated amount of RWF 46 billion ; Grants: 12,982 beneficiary firms for a cumulated amount of RWF 7 billion; Refinancing: 65 firms for a cumulated RWF 28 billion; and Venture funds: 22 firms for a cumulated RWF 3 billion.

⁴³ Figures provided by BDF during discussion with UNCTAD mission on 26 April 2015.

⁴⁴ Rwanda Stock Exchange Annual Report 2015.

⁴⁵ Figures given during interview with kLab in Kigali, April 2016.

⁴⁶ See: <https://www.globalinnovationindex.org/>

⁴⁷ See: <http://www.bloomberg.com/graphics/2015-innovative-countries/>

⁴⁸ See: <http://www.statsamerica.org/innovation/>

⁴⁹ See: http://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards/index_en.htm

50 See: <http://tinyurl.com/oecd-frascati> and <http://tinyurl.com/oecd-oslo>

⁵¹ This information was provided by BDF which has, until the UNCTAD mission in April 2016, coached over 10,000 firms and entrepreneurs.

⁵² See: <http://tinyurl.com/youth-jobs-rwanda>

⁵³ MINECOFIN, 2015-2016 Original Finance Law, ANNEX II-6 Budget by Budget Agency; <https://tinyurl.com/rwagovbudget>

⁵⁴ The other half is spent on staff salaries.

⁵⁵ One particularly disturbing story told of some people who had sufficient means would only use imported cement to build their house, i.e. only the poor used domestic construction materials.

⁵⁶ See: MINECOFIN Budget Planning ANNEX II-6: 2015/18 Budget by Budget Agency

⁵⁷ See: http://www.tbs.go.tz/index.php/highlights/view/over_1500_east_african_standards_harmonized

⁵⁸ <http://www.newtimes.co.rw/section/article/2016-04-20/199119/>

⁵⁹ See: MINECOFIN Budget Planning ANNEX II-6: 2015/18 Budget by Budget Agency

⁶⁰ Information provided by RAB during interview with UNCTAD mission on 27 April 2015.

⁶¹ For example, the Jomo Kenyatta University of Agriculture and Technology trains 1800 students, with 300 at the bachelor level with tuition fees of between \$370 to \$1,250. In 2015, 60 students graduated, of which about 60% found jobs in government bodies.

⁶² A 2013 study in Kenya concluded that: "Sending SMS messages with agricultural advice to smallholder farmers increased yields by 11.5% relative to a control group with no messages. These effects are concentrated among farmers who had no agronomy training and had little interaction with (the agro-food) company..." (Casaburi L et. al, 2013).

⁶³ It is a successor to the Institut de Recherche Scientifique et Technique.

⁶⁴ See: MINECOFIN Budget Planning ANNEX II-6: 2015/18 Budget by Budget Agency

⁶⁵ Information provided by NIRDA during interview with UNCTAD mission on 27 April 2015.

⁶⁶ See MINEDUC (2013a), Table 7: Profiles of primary school pupils, staff and schools from 2008 to 2012; page 12.

⁶⁷ Ibid. Figure 10: Secondary education Gross and Net enrolment Rate from 2008 to 2012; page 20.

⁶⁸ According to UR CST College Principal Prof. Manasses Mbonye, "...this past year the College of Science and Technology graduated close to 1400 scientists and engineers. The skills gap analysis shows that the number still falls short of what is needed. However, the existing industrial base is not yet capable of accommodating such a number." See: <http://cst.ur.ac.rw/index.php/news/113-cst-improves-students-entrepreneurial-capacity>

⁶⁹ These areas include energy, natural resources and environment, industry development and technology transfer, information and communications technology (ICT), public health and medicine, construction, transport and communications, science and technology in education, business development, legislation and regulation, defence and security.

⁷⁰ At the time of writing a National Council of Science and Technology has had a first meeting. The Council serves in an advisory role.

⁷¹ For more information on Finland see: www.minedu.fi/OPM/Tiede/tutkimus_ja_innovaationneuvosto/?lang=en

⁷² There are currently five clusters, including manufacturing, ICT, construction, energy and agriculture. As seen, the coverage of each cluster, defined on standard broad topics, is large, and there would be a need to develop specialized sub-clusters, as well as to ensure a good cross fertilization among them.

⁷³ See: <http://www.un.org/sustainabledevelopment/energy/#>

⁷⁴ See: <http://www.se4all.org>

⁷⁵ See: Kandeh Yumkella, UN Secretary-General's Special Representative for Sustainable Energy for All, interview in OFID Quarterly, January 2014.

⁷⁶ Current members are: Burundi, Democratic Republic of Congo (DRC), Egypt, Ethiopia, Kenya, Rwanda, Sudan and Tanzania.

⁷⁷ See: http://www.mininfra.gov.rw/fileadmin/user_upload/new_tender/REP_17th_March_2015.pdf

⁷⁸ REG is a successor organization of the Energy, Water and Sanitation Authority.

⁷⁹ As the names suggest, EUC trades electricity while EDC invests in capacity and distribution.

⁸⁰ The electrification rate indicates number of people with electricity access as a percentage of the total population group; e.g. in Rwanda 67% of the urban population have access to electricity, but only 16.8% of the total population has access.

⁸¹ The electrification rate indicates number of people with electricity access as a percentage of the total population group; e.g. in Rwanda 67% of the urban population have access to electricity, but only 16.8% of the total population has access. Total energy use is calculated based on electricity, oil and biomass consumption.

⁸² Biomass is unaccounted for in total energy use figures for Uganda and Burundi.

⁸³ Vision 2020 and the Human Settlement Policy 2009 envisage that those dwelling in dispersed rural houses move to nearby existing or planned settlements in order for the Government to better and more cost-effectively provide infrastructure and amenities, as well as to reduce the number of people living in high risk zone or in poor habitats.

⁸⁴ For example, in the US a kWh costs about \$0.10. In Kenya, a kWh costs \$0.19. However, the US has a GDP/capita 30 times that of Rwanda, while Kenya GDP/capita is 80% greater. In this sense, Rwanda's households and firms are paying the equivalent of \$4.5/kWh or \$0.34/kWh.

⁸⁵ Total planned capacity for Rusizi IV Power Station is 287 MW, however this capacity will be shared with Burundi and the Democratic Republic of Congo.

⁸⁶ While there is no official classification, a large power plant would typically have a capacity of 1,000 MW or more. There are no planned power plants of this size in Rwanda or its neighbours at the time of writing.

⁸⁷ This is a rough approximation based on the latest estimates of build costs by the US Energy Information Administration (2016).

⁸⁸ Development Bank of Rwanda investing in the energy sector. *The New Times* (2016). See: <http://www.newtimes.co.rw/section/article/2016-09-19/203659/>

⁸⁹ The figures are from 2013 and are only indicative, as there are no formal criteria by MW capacity for micro or pico hydro plants (UNIDO and ICSHP, 2013).

⁹⁰ Estimates are based on World Bank data adjusted for growth in the recent period. For example, CO₂ emissions in Uganda would be around 0.15 tons per capita, in Nigeria between 0.5 and 1.0, while in France and Germany they would be 6 and 9 tons respectively.

⁹¹ Most Rwandan companies are SMEs and small enough to quickly acquire the absorptive capacities needed for ICT. There are no large legacy industries or firms that have strong vested interests that are threatened by a strong ICT strategy.

⁹² SMART Rwanda Master Plan 2015-2020.

⁹³ President Paul Kagame speaking at the Transform Africa summit held in Kigali, in October 2013, on the future of broadband in Africa. See: <http://www.un.org/africarenewal/magazine/april-2014/big-dreams-rwanda%E2%80%99s-ict-sector>

⁹⁴ The year designates the end of the policy cycle, e.g. NICI-2005 refers to the period 2001 to 2005.

⁹⁵ The NICI-2010 pillars are, 1. Education, 2. Human capacity development, 3. Infrastructure, equipment and content, 4. Economic development, 5. Social development, 6. E-government and e-governance, 7. Private sector development, 8. Rural and community access, 9. Legal, regulatory and institutional provisions and standards, and 10. National security, law and order.

⁹⁶ The work on NICI III+ (2013-2018), also referred to as the ICT Sector Strategic Plan, was subsumed into SRMP.

⁹⁷ This means that many people will have two or more mobile contracts.

⁹⁸ See: <http://www.newtimes.co.rw/section/article/2016-10-06/204202/>

⁹⁹ The government has a 49 per cent stake in KT Rwanda Networks, while Korea Telecom has a 51 per cent share. See: <http://www.newtimes.co.rw/section/article/2016-07-22/201939/>

¹⁰⁰ Data based on website offers of Airtel, MTN and Tigo accessed on 9 November 2016.

¹⁰¹ See: <http://laptop.org/map/rwanda>

¹⁰² See: <http://www.un.org/africarenewal/magazine/april-2014/big-dreams-rwanda%E2%80%99s-ict-sector>

¹⁰³ The ICT sector refers to firms and institutions producing equipment and services related to broadcasting, computing and telecommunications.

¹⁰⁴ Fixed line broadband internet access is a technology phase that has been largely leapfrogged. Most broadband access in Rwanda is wireless, regardless of whether it is accessed through mobile smartphones or using PCs.

¹⁰⁵ Information gatekeepers are positions at the top of managerial hierarchies in firms or institutions that have the capacity to allow, censor or reject communication with other entities.

¹⁰⁶ A similar sounding project, the Rwandopedia.rw, deals with collecting and presenting documents, images, videos and audio recordings that together tell the story of Rwanda's development, and hosts about 1,500 files. Rwandopedia.rw is funded by the African Development Bank and aims to present the progress made in social, economic and governance sectors, as well as key cultural and historical events in Rwanda. This project is not open to voluntary external content contributors.

¹⁰⁷ See: <http://www.myict.gov.rw/about-us/mission-vision/>

¹⁰⁸ See: <http://www.klab.rw/public/about>

¹⁰⁹ See: <http://www.huckmagazine.com/perspectives/reportage-2/safemotos-rwanda-tech-startup-taking-africas-second-biggest-killer/> and <http://klab.rw/public/startups/startup/59>

¹¹⁰ An example of a three-by-three policy matrix along EDPRS 2 lines would be a vertical axis on which there would be as objectives: (1) economic transformation and rural development, (2) productivity and youth employment, and (3) governance. The horizontal axis would propose as actions (A) human capacity development, (B) infrastructure development and (C) business development. This would result in nine fields which would then be populated with policies that are amenable to measurement and evaluation.

¹¹¹ The CAADP operates as a programme element of the African Union in the New Partnership for Africa's Development (NEPAD).

¹¹² EDPRS 2 (2013-2018) was preceded by EDPRS 1 (2008-2012) and the Poverty Reduction Strategy (2002-2007).

¹¹³ Poultry feed is largely imported. In addition, hatchlings have been imported, sometimes from as far away as the Netherlands. See <http://www.thepoultrysite.com/poultrynews/37135/new-hatchery-to-boost-poultry-farming-in-rwanda/>

¹¹⁴ Season A starts in September and ends in February of the following year, season B starts in March and ends in June of the same year; and season C starts in July and ends in September of the same year, coinciding with the annual dry season.

¹¹⁵ It should be noted that objectively assessing the level of linkage functionality would require a deep institutional audit which may be overkill given the competent level of governance and the *Imihigo* system.

¹¹⁶ The figure is arrived at by subtracting 2015 production from 2015 exports (NAEB, 2015) and dividing by current population.

¹¹⁷ These estimates are calculated from data in current RWF. Growth figures in US dollars will be smaller by around one third.

¹¹⁸ A globalized world is interconnected and interdependent, with increasingly free international trade in goods and services, financial flows and labour. The result is seen in intensifying commercial linkages across borders. The Internet of Things is the Internet-based networking of physical appliances able to collect and exchange data, evaluate their environment and adjust their performance and functionality. Alternative funding mainly refers to private VC, PPP VC, private equity, grants, seed funds, public support for innovation hubs and business incubators.

¹¹⁹ The construction sector represents around half of all industrial activity in Rwanda.

¹²⁰ Issues that impeded and enable agricultural development are discussed in chapter 10 on agriculture.

¹²¹ There have been indications that imports packed in plastic will also be restricted by the Rwanda Environmental Management Authority, as the Government seeks to level the field for domestic producers and encourage the implementation of the EAC Polythene Materials Control Bill of 2011 in neighbouring countries.

¹²² See: <http://www.minicom.gov.rw/index.php?id=151>

¹²³ See: https://www.wto.org/English/tratop_e/trips_e/techtransfer_e.htm