

# Biotechnology for sustainable agriculture, food security and poverty reduction in Africa

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*Africa is still faced with mass poverty and remains the poorest continent. Sub-Saharan Africa in particular has the majority of its population living in absolute poverty, subsisting on less than US \$ 1 a day, and suffering from chronic hunger, malnutrition and pandemic diseases. Seventy-five percent of the rural population is comprised of peasant farmers who earn a living from small plots of poor soils, mainly in tropical environments that are increasingly prone to drought, floods, bushfires, and hurricanes. Crop yields in these areas are low and stagnant and epidemics of pests and diseases often ruin crops. Livestock suffers from endemic diseases, some of which also affect humans.*

*Conventional methods of crop and livestock improvement in the national agricultural research and development systems have in the past served the purpose of increasing productivity. However, these options can no longer sustain production, hence new intensive techniques are now required to augment productivity. Recent advances in biological sciences and agricultural research have injected new energy into efforts to improve crops and livestock, and thus offer better solutions to many of the agricultural problems faced by farmers in developing countries.*

*Biotechnology has the potential to provide new opportunities for achieving enhanced crop and livestock productivity in a way that will alleviate poverty, improve food security and nutrition, and promote sustainable use of natural resources. African countries, like many others in the developing world, must develop the scientific and technological capacity to ensure that innovative technologies, particularly biotechnology, become a key tool that can reverse the poor economic situation and contribute to sustainable development and improved welfare of the people. Indeed, biotechnology is not a panacea to solve all the problems of food insecurity and poverty. However, it could provide a critical component to the solution if it is guided by appropriate policies.*

*We review here the development challenges facing Africa and try to elucidate how biotechnology can contribute to food security, poverty reduction and sustainable socio-economic development in the region. Our aim is to identify lessons and best practices relevant to African countries and to suggest strategies for promoting biotechnology in Africa.*

## Introduction

Poverty eradication and food security have moved to the centre stage of the global development agenda. These are the greatest global challenges and their redress is an indispensable requirement for sustainable development in developing countries, particularly in Africa (Boon and Ahenkan, 2002; WSSD, 2002). The world's leaders pledged their commitment to eliminate hunger, malnutrition and to halt global poverty by 2015 at the World Food Summit (WFS, 1996) and the Millennium Summit in 2006. At the World Summit on Sustainable Development (WSSD) held in Johannesburg in 2002, the international community reaffirmed its commitment to develop national and local programmes for sustainable development, poverty eradication and food security. The AU/NEPAD strategy for 2010-2015 also emphasizes poverty alleviation and putting African countries on the path to socio-economic development. Despite these commitments, the last decade has witnessed an increased poverty level, especially in most African countries.

Worldwide, 854 million people still remain hungry and undernourished, of whom 820 million live in the developing countries (FAO, 2006). In one-third of African countries, the mean daily calorie availability per capita is below the intake level of 2350 calories recommended by FAO (2000). In addition, almost two billion people in the developing world suffer from iron deficiency, 140 million people experience iodine deficiency, and 140 million children experience vitamin A deficiency. As a result of low food availability and profound poverty, about 200 million people in Africa are undernourished or unable to meet their daily dietary energy requirements including 31 million children under five years of age, one in three of whom suffers from mental retardation, blindness, and other illnesses brought on by malnutrition (Mallaby, 2002). Although some data indicate that the global prevalence of child malnutrition has declined significantly in the last 25 years, in Africa the reduction of malnutrition is much lower compared to other continents (De Onis et al., 2004).

Today, extreme poverty ravages the lives of one in every four in the developing world (OECD, 2001). It is estimated that over 180 million people living in extreme poverty are found in the rural areas of Africa (World Bank 1996). This number is expected to exceed 300 million by 2020 (Amoako, 1999). About 80 % of all Africans live on a daily income of less than US\$ 2 and nearly half struggle to survive on US\$ 1 a day or less. Rural people strive to feed themselves, while the urban population spend more than 70% of its earnings on food, leaving only 30% for other minimum basic needs such as housing, education, health care, water and livelihood (Roy-Macauley, 2002).. Hunger, poverty and malnutrition are the main factors interacting to create an enormous set back to socio-economic development, especially in the rural areas of Africa.

The agricultural sector is the largest contributor to the economies and livelihoods of many African countries. It accounts for 35% of the continent's gross domestic product (GDP), 40% of export earnings and 70% of employment and it is expected that reliance on natural resources will remain high at least for the next generation (Dione 2002). Over the last two decades Africa has witnessed a considerable decline in agricultural productivity, with the annual agricultural growth rate falling from 2.3 % in the 70s to 2.0 % between 1980 and 1992 (Roy-Macauley, 2002). The average

yield for major food crops such as maize, rice and sorghum, stands at 1.2 tons ha<sup>-1</sup>, compared to 4.9 tons ha<sup>-1</sup> for China and 6.6 tons ha<sup>-1</sup> for the USA (Roy-Macauley, 2002). Some of the most important factors limiting agricultural productivity in Africa include small size of farms, inadequate water resources, poor crop varieties and livestock breeds, biotic and abiotic stresses, poor livestock forage, inadequate use of agro-inputs, poor rural infrastructure, inadequate technological base, poor marketing systems, inadequate financial resources and weak enabling policy environment.

With an increasing population and poor performing agriculture aggravated by invasive pests, weeds, land degradation, erosion, droughts and the effects of climate change, Africa faces one of the biggest challenges of its time – assuring its increasing population of a sustainable food supply (Mataruka, 2009). African population growth rates remain among the highest in the world, despite the projected increases in mortality resulting from infectious diseases. Africa's population is presently estimated at 840 million and is projected to increase to 1.75 billion by 2050 (FAO, 2006). While population grows at a rate of 3.5 % per annum, food production increase is 2.5 % or less depending on the country. As a result the per capita food production in Africa has been declining while the rest of the world has experienced an increase (FAO, 2002).

### **Need for strategies to improve food security in Africa**

To attain improved nutritional well-being and sustainable food security in Africa, emphasis should be put on strategies that will reduce the problems of poverty and underdevelopment because these are the underlying impediments to adequate access to food by all individuals. Since agriculture is the mainstay of the economies in many African countries, emphasis should therefore be put in developing strategies that will improve agricultural and farming systems, reduce post harvest food losses and improve food processing and marketing systems.

The Green Revolution, launched in the 1960s and 1970s, used advances in science and technology (S&T) to double and/or triple the yields of rice, wheat, and maize in Asia, saving hundreds of millions of lives. However, the Green Revolution bypassed Africa. For Africa to realize the benefits of a Green Revolution, a lot of effort, commitment and focus are required from the governments. The continent currently lacks the five key instruments of the Asian Green Revolution — development and use of high-yielding varieties, improved utilization of water through irrigation systems, utilization of farm inputs such as fertilizer and pesticides, availability of credit facilities (micro-finance) and rural infrastructure.

To move forward, Africa will not only need to address these aspects but to also recognize the new challenges the world is facing and new technological advancement presented by biotechnology.

### **Potential role of biotechnology for sustainable development**

Science and technology are recognized globally as drivers of increased wealth and continuously improving standards of living. There is ample evidence that economic advances in the developed and newly industrializing countries are results of technological and organizational innovations. These countries have succeeded by

reinvesting a growing percentage of their gross domestic product (2.6%) in further advancement of research compared to African countries that currently spend an average of only 0.85 % (IFPRI, 2002). Technological innovation is associated with turning scientific knowledge into products and processes, and adjusting them to respond to socio-economic conditions (Juma 2005). Application of new technologies will provide opportunities for improving developing-country economies and the well-being of the people, and offer a means for increasing agricultural production, improving human health, and addressing environmental degradation.

The New Partnership for Africa's Development (NEPAD) recognizes that science and technology are central to its goals of promoting economic recovery, poverty reduction, better human health and environmental sustainability in Africa. One of its overall objectives is to bridge the technological divide between Africa and the rest of the world. It calls for the formulation and implementation of measures to promote cross-border co-operation and connectivity by utilizing knowledge currently available in existing centres of excellence and generate critical mass of technology expertise in target areas that offer high growth potential, especially in biotechnology and geo-science (NEPAD, 2001).

There is now ample evidence to demonstrate the opportunities offered by biotechnology in developing economies such as China, India and Brazil, from which Africa should learn. In the early 1980s Chinese leaders decided that S&T, especially biotechnology, would be one of the drivers to improve the agricultural sector, and committed substantial public investments in biotechnology, e.g. rice biotechnology (mapping rice genome) and rice breeding (to develop hybrid rice varieties), cotton biotechnology for insect resistance, production of value-added horticultural crops, and complementary innovations such as use of nematodes for biological pest control leading to increased export markets. Currently, hybrid rice accounts for over 30% of rice in China and over 5 million small farmers are growing Bt-cotton<sup>1</sup> on 1 million hectares of land. Use of biological control has reduced pesticide use on cotton by 30% nationally. Today, horticultural exports are expanding. Thus, through a deliberate effort to revolutionize agriculture, China is making quantum leaps in agricultural productivity and sustainability improvements. The country is now moving to the 'post-Green Revolution era' towards becoming an industrialized nation. An efficient agricultural sector ensures food security and enables industrial development. India is another country where there are substantial investments in agricultural biotechnology.

Genetically-modified (GM) crops are often considered as the products of multinational corporations, but a survey conducted by Cohen (2005) at 61 public research institutes in 15 developing countries in Africa, Asia and Latin America revealed that there is considerable research being undertaken by these public institutions. These institutes had produced 201 genetic transformation events<sup>2</sup> for 45 different crops including cereals, horticultural crops, oil crops, sugar cane, legumes, cotton, root and tubers. Many are nearing or are in confined field trials; others are in

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<sup>1</sup> Bt-cotton is modified using *Bacillus thuringiensis*.

<sup>2</sup> Agronomic properties, bacterial resistance, fungal resistance, herbicide tolerance, insect resistance, product quality and virus resistance.

the later stages of field testing and seeking broader approval. The International Crop Research Institute for Semi Arid Tropics (ICRISAT) in India has developed the world's first GM groundnut. This new plant promises resistance to the Peanut Clump Virus (PCV), which is wide-spread in India and several West African countries. PCV is responsible for annual losses of about US \$ 40 million globally. This is regarded as a major step towards addressing specific needs of the resource poor farmers of the semi-arid tropics through the application of biotechnological interventions for food crop production and poverty reduction.

## **Proposed strategic interventions for promoting biotechnology in Africa**

As with Green Revolution, biotechnology has so far failed to take root in Africa (Juma and Serageldin, 2007). Broadly, some of the major constraints on biotechnology promotion in most African countries include inadequate human resource and infrastructure capacity, lack of supportive policies and regulatory frameworks, inadequate funding, lack of public and private investments at levels that can make a difference, and absence of systems for the delivery of technologies to potential users, as well as inadequate awareness and understanding leading to misconceptions about the potential of, and risks posed by, biotechnology. For African countries to be able to benefit from the potential offered by biotechnology, the following recommendations are made:

### **1. Setting priorities and research agenda for biotechnology R&D**

African development problems are numerous and multidisciplinary in their nature and biotechnology in isolation is unlikely to solve them (Izquierdo, 2000). African countries need to identify specific biotechnology priority areas that offer high potential for contributing to the economy and people's livelihood. Food security, nutrition, healthcare and environmental sustainability are among Africa's biggest challenges. Biotechnology should not be seen as a technology for a 'Quick fix' for Africa's problems. Rather it should be viewed as one part of a comprehensive, sustainable poverty-reduction strategy. African countries must exploit a range of options to ensure that future biotechnology initiatives reach their full potential for alleviating poverty, securing food security and reducing impact of biotic and abiotic stresses.

African countries need to develop knowledge appropriate to their own situations and choose the most appropriate biotechnology tools. Biotechnology expertise should complement existing technologies and be demand- and product-driven. Biotechnology is expensive and requires more skills than conventional technology, so it should be used only to solve specific problems where it has comparative advantage.

Biotechnology investment strategies should also address the needs of the poor, who depend on agriculture for their livelihoods, particularly in marginal areas where productivity increases will be difficult to achieve. In addition to technical considerations, priority setting should take into account national development policies, private sector interests and market opportunities. Since African countries lack adequate resources, infrastructure and the business environment to attract new

technologies and related investments, biotechnology development agendas need to be developed taking into consideration Africa's opportunities and constraints. The strategy should include lessons learned, best-practice examples, strategic partnerships that are successful, products and processes proven to work and ways to encourage new innovative ideas and initiatives.

Specifically, and among other strategic investment options, African countries should seek to promote Africa-focused biotechnology R&D in the following areas:

*(i) Biotechnology to improve human and animal health*

Some of the tropical diseases that continue to cause health problems in Africa include HIV/AIDS, tuberculosis and other bacterial diseases, as well as vector-borne protozoan diseases such as malaria, trypanosomiasis and parasitic worms. Zoonotic diseases also cause considerable losses in livestock production, which result in loss of incomes and food insecurity for small-scale farmers. Biotechnology can contribute to improving health by making direct interventions in the following strategic actions:

- Developing and scaling up disease diagnostic, control and management programmes for communicable and non-communicable diseases. Especially recognizing the unprecedented challenges posed by HIV/AIDS and the burden of tuberculosis, malaria, childhood diarrhoea and pneumonia, malnutrition, and the resurgence of trypanosomiasis.
- Enhancing the capacity for local production of essential drugs, vaccines using traditional knowledge and local resources.

*(ii) Application of tissue culture for mass propagation of virus-free planting material of vegetatively propagated and neglected/orphan crops*

Tissue culture is seen as a main technology for developing countries for the large-scale production of disease-free, high-quality planting material of crops such as banana, cassava, sweet potato and fruit crops. In commercial applications, such as fruit-export production and floriculture, it also generates much-needed employment, particularly for women. These techniques are very appropriate particularly for Africa because they are relatively simple and inexpensive.

*(iii) Use of marker technology for livestock and important food crops*

DNA markers could be used to identify traits in livestock and plants important to Africa such as maize, rice, wheat, banana and cassava. These markers assist in the development of new breeds/crop varieties, which could be resistant to biotic and abiotic stresses.

Marker technology is appropriate to Africa because genes associated with important traits can now be detected by simple laboratory tests in embryos and/or young plantlets. It is therefore no longer necessary to grow plants to maturity in the field to find out whether or not they possess a particular trait. As such, the time it takes to develop a new variety could be greatly reduced through the use of accurate markers for a gene or genes.

Molecular markers are also used to analyze genetic variability or to assess the relationships between populations or gene pools. This helps in the search for potentially useful materials, which could be used in breeding, or to decide on conservation measures for threatened crop and neglected/orphan African commodities particularly millet, yams and local chicken.

*(iv) Biotechnology for bio-processing and value addition*

A significant amount of the food produced in African countries is lost after harvest thereby aggravating hunger. Most food crops of Africa such as cassava, banana and sweet potatoes are perishable crops with a lot of storage and post-harvest problems. Productivity is limited by their rapid rate of deterioration soon after harvesting, if processing into more shelf-stable products is delayed. Estimates of post-harvest losses in Africa are hard to determine, but some authorities put losses to as high as 50 percent of what is produced. It is therefore, important to develop and deploy crop varieties with improved shelf life.

Biotechnology can also be used to convert agricultural waste into useful products such as industrial fibres, bioethanol, wine, beers, animal feeds, fertilizers, cosmetics and pharmaceuticals. African countries should use biotechnology to generate new technologies and up-scale known and proven technologies for value addition, reducing and/or eliminating post-harvest losses. Technologies for processing and/or value addition are available in some parts of Africa but not yet transferred to other countries. For instant, South Africa has equipment for processing banana into juice, paper and fibre and yet the technology is not available in other parts of Africa.

*(v) Genetic engineering*

Currently there are three African countries that are growing GM crops at commercial scale. These are South Africa (since 2001) and Egypt and Bukina Faso since 2008. The total acreage of GM crops – Bt-maize, soya and cotton – in South Africa has increased from 19 000 ha in 2001 to 1.8 million hectares in 2008. In 2008 Burkina Faso for the first time planted 8500 ha of Bt-cotton while Egypt planted 700 ha hybrid Bt-yellow maize (Karembu et al. 2009). The three countries can be considered as role models for promoting GM technology in their regions and provide an opportunity for more African farmers to become practitioners of biotech and to benefit directly from 'learning by doing', which has proven to be an important feature in the success of Bt cotton in China and India.

In recognition of the role of GM technology in contributing to food security and poverty reduction a number of African countries have established R&D programmes in genetic engineering (Table 1).

## **2. Enhancing human resource, infrastructure and financial capacities**

Africa's ability to effectively use existing and emerging biotechnologies will depend largely on the level of investment in building physical, human, institutional and financial capacities. Biotechnology R&D requires skilled staff, backed up by well-equipped laboratories, strong and organised marketing/ outreach services and suitable institutions and infrastructures to facilitate its adoption. In deciding to adopt biotechnology a country must be prepared to commit itself to guaranteeing substantial

**Table 1:** Some on-going biotechnology/GM crop research in Africa.

Country	Crop	Trait	Event involved	Institutions	Stage
Kenya	Maize, <i>Zea mays L.</i>	Insect resistance	Mon 810 <i>Cry1Ab 216</i> <i>Cry1 Ba</i>	KARI, CIMMYT, Monsanto, University of Ottawa, Syngenta and Rockefeller Foundations	Confined field trials (CFT)
	Cotton, <i>Gossypium hirsutum L.</i>	Insect resistance	Bollgard II	KARI/ Monsanto	CFT
	Cassava, <i>Manihot esculenta</i>	Cassava mosaic disease (CMD)	ACI-B	KARI/ Danforth Plant Science Center	CFT
	Sweet potato, <i>Ipomea batatas</i>	Viral disease	CPT-560	KARI/ Monsanto	CFT
Uganda	Cotton, <i>Gossypium barbadense.</i>	Insect resistance/ herbicide tolerance	Bollgard IR/HT	NARO/ Monsanto, ABSPII, USAID & Cornell University	CFT approved
	Banana, <i>Musa sp.</i>	Black sigatoka	Chitinase gene	NARO, University of Leuven	CFT
	Cassava, <i>Manihot esculenta</i>	CMD and Cassava brown streak disease (CBSD)		NARO-NaCRRI, CIP, Danforth Plant Science Center	Application for CFT approved by NBC
Nigeria, Burkina Faso, Ghana	Cowpea, <i>Vigna unguiculata</i>	Insect resistance	<i>Cry1AB</i> and <i>nptII</i> genes	AATF, NGICA IITA, Purdue University, Monsanto, Rockefeller Foundation, USAID, DFID, CSIRO Australia, INERA, IAR, The Kirkhouse Trust	CFT approved in Nigeria
Kenya, Tanzania, Uganda, South Africa & Mozambique	Maize, <i>Zea mays L.</i>	Drought tolerance	CspB-Zm event 1	AATF, NARIs in the 5 countries, CIMMYT, Monsanto, Bill & Melinda Gates Foundation, Howard G. Buffett Foundation	CFTs pending regulatory approval except South Africa – approved and on-going
South Africa, Burkina Faso, Kenya	Sorghum, <i>Sorghum bicolor</i>	High lysine Readily available micronutrients	ABS 32 (Kenya) ABS 1 (South Africa)	A consortium of 9 institutions led by AHBFI and funded by Bill & Melinda Gates Foundation	Contained Greenhouse Trials (CGH) – Kenya & South Africa
South Africa	Maize, <i>Zea mays L.</i>	Drought tolerance	MON 89034, MON 87460	Monsanto	CFT
		Herbicide tolerant	Syngenta GA21	Syngenta   Pioneer	Field trial release
		Insect resistance	Syngenta MIR162		
		Insect/herbicide tolerance	Syngenta BT11xGA21		
			BT11x MIR162		
			Pioneer 98140		
Pioneer 98140xMon810	CFT				

**Table 1:** Some on-going biotechnology/GM crop research in Africa (continued).

Country	Crop	Trait	Event	Institutions involved	Stage	
South Africa (continued)	Cassava, <i>Manihot esculenta</i>	Starch enhanced	TMS60444	ARC-IIC	CGH	
	Cotton, <i>Gossypium hirsutum</i> L.	Insect/herbicide tolerance	Bayer BG11x RR FLEX	Bayer	Trial release	
			GHB119			
			BG11xLLCotton25			
		Cotton T304-40				
		Herbicide tolerance	Cotton GHB614			
		Cotton GHB614x LLCotton25				
Potato, <i>Solanum tuberosum</i> L.	Insect resistance	G2 Spunta	ARC-OVI	Field trials		
Sugarcane, <i>Saccharum officinarum</i>	Alternative sugar	NCo310	SASRI	Field trials		
Egypt	Maize, <i>Zea mays</i> L.	Insect resistance	MON810	Monsanto	Approved for commercialisation	
		Insect resistance	Not available	Pioneer	Field trials	
	Cotton, <i>Gossypium barbadense</i> .	Salt tolerant	MTLd	AGERI	CGH	
		Wheat, <i>Triticum durum</i> L.	Drought tolerant		HVA	Field trials
			Fungal resistance		Chitinase	CGH
	Salt tolerant		MTLd		CGH	
	Potato, <i>Solanum tuberosum</i> L.	Viral resistance	Cry V		Field trials	
			CP-PVY		Field trials	
	Banana, <i>Musa</i> sp.	Viral resistance	CP-Banana CMV		CGH	
	Cucumber, <i>Cucumis sativus</i>	Viral resistance	Cp-ZYMV		Field trials	
	Melon, <i>Cucumis melo</i>	Viral resistance	Cp-ZYMV		Field trials	
	Squash, <i>Cucurbita pepo</i>	Viral resistance	Cp-ZYMV		CGH	
	Tomato, <i>Lycopersicon esculentum</i>	Viral resistance	CP-REP-TYLV		CGH	

Source: Karembu et al, 2009

financial support for infrastructure and human resource development. The current level of investment in agricultural biotechnology in most African countries is very low, hardly 2% of the total agricultural research funds (Amoako, 2002).

More specifically, Africa will need to focus on creating and reforming existing knowledge-based institutions, especially institutions of higher learning, to serve as centres of diffusion of new technologies into the economy (Juma and Serageldine 2007). Investing in critical and cutting-edge capabilities is central to Africa's ability to benefit from its resources. In countries where biotechnology has taken off, it is

observed that high government investment has been at the base of the building of national and international enterprises. One fundamental reason for biotechnology successes in China, India, Cuba and other developing countries has been the creation of a special budget provision research and commercialization of biotechnology products.

### ***3. Establishing strategic partnerships to promote marketing and commercialization***

To improve commercialization and business capacity, Africa needs to foster R&D cooperative partnerships at the local, regional and international levels and create marketing structures/policy instruments that enable business incubation and development. Certain types of social, economic and technological advances can only be achieved by private firms, public sector organisations, universities, NGOs or civil society working together. Partnerships have become an increasingly important means of creating and diffusing scientific and technical knowledge. This is of great importance particularly in biotechnology-related activities. The partnerships may be complex (combining all activities in the product development chain such as research, product/technology development, marketing dissemination) and may require involvement of multiple players such as individual innovators, research organisations, universities, small to medium scale private companies, resource-poor farmers etc.

### ***4. Development of enabling policies for biotechnology promotion and regulation***

Africa should adopt a proactive strategy to capture economic, health, environmental, and industrial benefits from biotechnology and manage potential challenges, risks and tradeoffs associated with the application of the technology, product development and commercialization. There is a need to develop African-owned biotechnology policies, where all the relevant stakeholders, including government, private sector, civil society and farmer organizations are involved in the formulation and implementation of the national plans and strategies. New programmes for awareness campaigns need to be created to facilitate public awareness and education on biotechnology issues. Emphasis should be on maximizing the benefits associated with new technologies while reducing the negative impacts. Of strategic importance is to develop and harmonize regional policies governing research and development, commercialization of biotechnology products and services, consumers' choices, intellectual property rights (IPR) and biosafety. In addition, Africa should strengthen its capacity to respond to issues associated with modern biotechnology as they emerge in international negotiations at the World Trade Organization (WTO) and other international forums.

## **Conclusion**

Agricultural biotechnology, including tissue culture, DNA-marker-assisted breeding and GM technology, has the potential to increase crop productivity and food security in Africa more efficiently through the development of improved varieties with increased yields, nutritional content and storage characteristics. African countries

should continue to build capacity in GM technology, giving priority to traits and crops that are of economic importance to Africa such as drought tolerance in food crops such as maize, rice and sorghum, salinity or flood tolerance in rice, increased nutrition value and improved shelf life. Stronger and more diversified collaborations between and among the public sector, private industry and civil society – coupled with the appropriate policy environment and organizational structures are needed to influence the formation of effective innovation systems that will turn ideas into products and services. Each country should decide how much of the technology should be developed locally and how much imported and adapted. A good mix of the two can be synergistic and reduce both the time and cost of developing products for the market.

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