Chapter 1
Appropriate Technologies for Sustainable Development

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1.1 Introduction

Technological innovation – combined with scientific research – has always constituted a driving force of transformation in our societies. From the moment it turns into an industrial and economic tool, any form of societal innovation involves change in production processes: the creation and development of new lines of business, increased marketing of new products, and therefore the set-up of new organizational modes of social interaction, as much within as between societies across the world.

But technology is also a process, a social mechanism which becomes inclusive over time and brings individuals together, or drives some away; it creates special-interest groups, impacts the natural or developed environments in which these individuals evolve, and alters cultural patterns, the way we think and act, and the way we see the world and understand it, whether we have taken ownership of these technologies or are marginalized by their development.

Technologies – their emergence, dissemination, transformation, development, and even disappearance for the benefit of more sophisticated ones – are, and increasingly rapidly so, catalysts for change within and between contemporary human societies. They are the fundamental constituents of what will determine the future, and the reference points outlining the present.

We live in a world in which technologies play a prevalent role in the globalization of exchanges (not only of information but also of people and culture) and in the creation of new living patterns (settling down, moving around, working, eating and staying healthy, communicating, enjoying ourselves, interacting, etc.), as well as the geographical distribution of the assets, knowledge, and products that are driven by growth. In fact, the world is no longer divided into self-contained hegemonic blocks,

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be they political or economic groupings. The world has turned into a throng of countries and regions constantly competing with each other. They have all adopted a similar vision of what progress means, both economic and material as well as cultural and social, teetering between aggressive behavior and cooperation, between living and working patterns that are either site specific – and yet similar worldwide – or mixed.

In the future, developing and emerging countries, given their demographic and geographical weight as well as the potential for growth that some of them have unlocked, will face the major challenges that humankind is currently grappling with but will do so much more effectively than the old industrialized powers by offering the most fitting responses to solve them – provided they have the resources necessary and the capacity to do so.

In this light, generally speaking but for developing countries in particular, scientific and technological breakthroughs may not only create wonderful opportunities but may also convey risks that should not be overlooked (James 2002a).

In the future, only high-level human skills will provide the means of seizing these opportunities and forging them into development tools; this is in sectors that international organizations consider to be key points for improving living standards in countries of the South, for example, agriculture, health, access to water, the fight against the deterioration of the environment, and energy (Watson et al. 2003). It is therefore necessary to implement public policies that promote science and technology, most notably in favor of information and communication technologies (ICTs) – which clearly provide better access to knowledge – as well as educational policies that are in line with these priorities.

A study of the links between technologies and development should first address the contribution of modern technologies to sustainable development in all its environmental, social, and economic aspects, in order to cover the basis of this concept (Brundtland 1987).[1] Secondly, it is necessary to examine the relationship formed by individuals – and more globally, by contemporary societies – with present and future technologies.

This is a universal issue since technological innovation has been an evolutionary process through an increasingly widespread, complex, and sophisticated use of such technologies and their ever-growing dissemination across the planet. There is almost always a deep belief that technologies will improve the life of individuals, whoever they are and wherever they live. However, it has also been proven many times that technologies have unfortunately only partially succeeded in eradicating socioeconomic disparities, both within and between societies.

The North-South relationship has long been a matter of debate, first in economic and then in political terms, and from a sociocultural standpoint. From this point forward, the relationships between regions of the world, between nations, and

[1] Besides, sustainable development, in its quest for balance, cannot overlook the spatial dimension, through fair territorial distribution of development, or the cultural dimension – development models must be designed to adapt to the socio-spatial contexts upon which they bear their imprint.

between the populations of these countries must also be perceived in terms of technology. And here, several lines of thought can be explored:

- Is technological innovation universal in nature or, conversely, is it specifically intended for particular sectors? Does it fulfill the particular needs of certain societies in conditions inherent to each context, with particular reference to developing countries? If the universal nature of technological innovations is undisputed, their effects can be sharply contrasting, depending on the development of individual countries, public policies applied, and the social configuration in place. As Anton et al. (2001) put it: "Those not willing or able to retrain and adapt to new business opportunities may fall further behind."
- Focusing as a priority on developing countries, scientists and technologists of the North and South, as well as public and private decision-makers, are faced with great social, economic, and environmental needs that are not entirely or are only partially met and for which technological solutions must be created, implemented, and adapted to conditions prevailing in societies of the South. The issue of investing in priority sectors to guarantee more sustainable development for the benefit of all is paramount, as much on a political as on a financial, economic, and societal level.
- With this is mind, the issue of appropriate technologies and technological transfer opens up a vast debate on the choices to be made and their defining criteria. Although intrinsically there are no "poor" technologies designed for poor countries or innovating technologies designed for rich countries, societal contexts vary widely and so do human and financial resources. And these specific environments will impact on technological creation, as well as its ability to offer solutions that fit the needs, and the extent to which additional advantages can be drawn from this technology for the benefit of all. Decision-making criteria related to future technological choices are therefore crucial and should (a) meet the priority needs of the countries and regions concerned, (b) concentrate on the nature of the innovations that are put forward, (c) adapt to the specificities of users in all societies, and (d) promote the full inclusion of these countries in international exchanges (Murphy et al. 2009). The implementation of a technological innovation strategy raises the following question regarding the stakeholders involved directly or indirectly in this scientific, technological, and socioeconomic development process, as much in the Southern countries concerned as within international scientific cooperation projects and programs: who are the decision-makers, how are decisions made, and in favor of whom?
- The last vital issue to address concerns access to technologies. It is clear that the development of research is generally very costly, as are transferring and implementing this research and then managing and maintaining it. But those in charge of managing technologies will also have to be watchful and ensure their development and sustainability, all the while guaranteeing the profitability of each innovation. Whatever their socioeconomic status, users will inevitably have to pay for this service, either fully or partially, with the risk – often demonstrated – that *technologies adapted to a territorial and societal context can lead to segregation* in

society, as a majority of disadvantaged sections of the population cannot afford access to these innovations. It is therefore essential to identify pathways and means of fighting against these new forms of inequality (SDC 1999) and to commit to scientific cooperation projects addressing these problems.

As James (2002b) quite rightly says, "for the majority of developing countries, the goal of policy should be to promote universal access, as opposed to individual ownership of information and communication technologies."

These fundamental issues will guide our reflection and ensuing proposals in order to address a de facto situation which is relentlessly deteriorating the terms of economic and technological exchange between industrialized or emerging countries on the one hand, and the vast majority of developing countries on the other hand.

1.2 The Role of Innovation and Technology in the World

The world has been undergoing radical transformation over the last two to three decades. From now on, the globalization of trade is setting the course for a fully globalized economy. On the subject, Cohen (2004) recalls that from 1950 to 2000, the share of trade in Gross Domestic Product (GDP) has more than doubled.

Yet the opening of external trade is one of the three key factors in the dissemination of technological advances, along with direct overseas investments and contacts established between emigrated populations and their families of origin, in particular through financial remittances (World Bank 2008).

Technological advances have therefore led to the implementation of telecommunications and information system networks that are continuously linking up, in real time, all the inhabited areas of the world.

This technological revolution and the globalization of economic exchanges on an international level have not, however, significantly reduced the poverty that is still rife in many regions of the world (Bolay 2004; Stern et al. 2002). Whether at an international level or more narrowly, within each country's own internal structure, globalization does not concur with a widespread reduction of inequalities. On the contrary, as highlighted by Williamson (1998), there are growing disparities between countries and between individuals.

Technological progress also contributes to these disparities. Thus, the technological gap between rich and poor countries remains significant, on the one hand because rich countries own resources that less advantaged countries do not possess and on the other hand because rich countries have more individuals and companies with the skills needed to make the most of available technologies. However, developing countries have achieved remarkable technological advances, sometimes even twice as fast as developed countries. Such progress was notably rapid in lower-income countries, with some catching up with high-income countries: for example, in Chile, Hungary, and Poland, the level of technological development

increased by more than 125% during the 1990s. During the 2000s, a coalition of 132 developing countries stressed the need for developing countries to build scientific capacity and close the technological gap between them and industrialized nations. According to Arunachalam (2005), such a perspective will depend on increased scientific cooperation, including setting up networks of researchers and a consortium on science and technology.[2] And a key proposal is to share information on scientific results and technological innovations through institutional open-access archives in developing countries (UNESCO 2007).

Alongside the expansion of international trade and the globalization of economies, the pace of technological dissemination has also increased dramatically over the last two centuries. At the onset of the nineteenth century, an average of 84 years were necessary to introduce new technologies in all developing countries; in the 1950s, the delay was reduced to 26 years, and in 1975, it dropped to 18 years (Arunachalam 2005).

Technological progress is dividing fast-growing economies (Southeast Asia and developing European countries) and slow-growing economies (Latin America, Middle East and Africa). The measurement of technological progress remains flawed: it is based entirely on total factor productivity, namely the efficacy with which an economy produces goods and services, given a particular level of manpower and capital, and attributes to technology that portion of revenue growth which cannot be attributed to investment or available manpower. Nevertheless, in absolute terms, it is now widely recognized that technological progress has largely contributed to reducing poverty in developing countries.[3]

The first determining component of technological dynamics – chosen directions and spawned innovations – relates to the promotion and definition of "human capital," that is, education and advanced training (Acemoglu 2002). This is in addition to investment in Research and Development (R&D) which extends its effects (Afonso and Aguaiar 2004). Also, in both areas, we can clearly distinguish great discrepancies between countries, as well as between regions in today's world.

Although there seems to be an established link between information technologies and economic productivity, the more complex relationship between these technologies and social development has attracted less attention (Corea 2005). Several studies have pointed to a positive correlation in the most industrialized countries between new information and communication technologies (NICTs) and socioeconomic development. However, this link is not so straightforward in developing countries, thereby encouraging them to invest in both material and human resources, as they lack the skills to embrace these new technologies.

[2] In this regard, UNESCO Chairs and UNITWIN networks are unique models that encourage knowledge circulation and the reinforcement of capacities through innovative ways of North-South and South-South cooperation.

[3] The poverty rate has dropped from 29% in 1990 to 18% in 2004, according to the World Bank (2008).

Indeed, public authorities can take various measures to promote technological progress, most importantly: openness to trade, continuous improvement of the investment climate to enable businesses to flourish, reinforcement of infrastructures, improvements in the quality and quantity of education, and enhancement of R&D guidelines and delivery programs.

Yet investment in R&D – the driving force of innovation – remains highly clustered (Mustar and Esterle 2006). The United States is in the lead with close to a third of the world's total investment, followed by the European Union (25%), Japan (13%), and China (9%). Other countries around the world – all regions combined – account for only 18% of R&D expenditure. This is a very low figure. As a result, the most disadvantaged regions of the world fully depend on innovations produced elsewhere, a situation which turns them into consumers of high value-added products. Similar discrepancies can also be observed in the number of researchers involved in the scientific sector, be it public or private. For 2002, the same study forecasts the equivalent of 5.3 million (full time) jobs in the field of research across the world: 23.7% in the United States, 21.4% in the European Union, 15.2% in China, 12.1% in Japan, and 9.2% in Russia, meaning that other countries, including emerging and developing countries, share the remaining 18%.

The UNESCO Science Report (2006) highlighted once more the great divisions in our world: 77.8% of R&D investment takes place in developed countries, which bring together 70.8% of world researchers, while developing countries – with 69.5% of the world's population and 39.1% of the world's GDP – allocate 22.1% of investment to the scientific field and account for 29.1% of researchers. As regards less-developed countries – that is 11.1% of the world's population and 1.5% of the world's GDP – funding of R&D amounts to 0.1% of the total world figure, for a corresponding 0.1% of world researchers. These figures signal a total and alarming marginalization of the poorest countries in the face of the technological changes dominating our modern economies, where education, science, and technology serve as drivers in societies that are increasingly fed by information and knowledge as significant factors of production.

Africa is probably the continent that is the most symptomatic of such socio-spatial disparities. For the nations on this continent, R&D amounts on average to 0.3% of GDP, though South Africa alone represents 90% of the 3.5 billion dollars invested every year in this sector across Africa. The remaining African countries share a tiny fraction of research funding (OECD 2007).

This is a dramatic situation since many international experts recognize that science and technology are prime drivers of development (PNUD 2001). Whatever the region, the modern world is now plugged into and driven by the information and knowledge economy, a "virtual" world which is nonetheless an integral part of our daily lives. Since global economic growth and the underlying technological explosion do not fuel social equality and a fair distribution of the fruits of growth, the only remaining way to manage the "challenges of globalization" described by Thimonier (2005) is through cooperation.

Considering priority sectors for the development of countries of the South and possible cooperation strategies, we can identify four fields which open up possibilities for international cooperation, representing both real challenges for the scientific community and significant issues for public and private decision-makers, at national and international levels.

These essential components, although not exhaustive, establish a link between scientific and technological skills and strategic areas of development; they represent a first-rate potential for research and a genuine tool for development cooperation – both key elements for long-term sustainable development.

They are the following:

- Technologies for sustainable habitat and cities
- Information and communication technologies for the environment
- Science and technology for disaster risk reduction
- Technologies for sustainable energy production

In this fashion, and with the aim of promoting research for technologies and innovations that are appropriate for developing countries and which enable solutions for the key significant challenges faced by the most vulnerable populations, the EPFL UNESCO Chair International Scientific Conference on Technologies for Development was held from 8 to 10 February 2010 in Lausanne, Switzerland, offering a platform for discussion and scientific exchange. The conference addressed the aforementioned priority sectors in different interdisciplinary workshops.

1.3 Technologies for Sustainable Habitat and Cities

In 2008, a symbolic milestone was reached when, for the first time in the history of mankind, over half of the world's 6.8 billion total population was living in an urban environment. This growth primarily concerns developing countries: according to the United Nations (UN), in 2030, 81% of the world's urban population will be living in developing countries, with 70% of this population living in Africa and Asia. In fact, the poorest populations will be the first to contribute to this phenomenon. The struggle against social and spatial segregation will thus add to the many challenges already confronting Southern cities, such as demographic transformation, access to community infrastructures and services, mobility needs, globalization of economic exchanges, environmental degradation and climate change. Yet, despite these deficiencies, the city is already acting as the prime driving force behind progress: a concentration of persons, resources, power, and knowledge. In this context, technological innovation is both the cause and effect of urban development, not only playing a decisive role in the structuring of cities but also representing a means of fulfilling the new needs being expressed. In view of this,

the international community has for several years been urging the transfer of urban technologies to developing countries and the joint creation of technologies adapted to the major problems confronting public authorities, economic actors and users. There are five particularly suitable domains for this transfer in the urban environment: water, energy, transport, sanitation, and habitat. The aim of this workshop was to examine the link between technology and development in an urban environment by:

- Questioning the contribution of contemporary technologies to the sustainability of development in its environmental, social, and economic aspects
- Analyzing individual perception of technologies according to sectors, needs, and access

1.4 Information and Communication Technologies for the Environment

ICTs offer promising potential for the environment in developing countries: mobile information and communication systems are used to build wireless sensor networks and produce complete sets of data on the environment, Global Systems for Mobile communications (GSM) applications can support data transfer for various applications, and cell phone networks and many Internet applications contribute to a better understanding or governance of the environment. Although new technologies are available, enabling of ICTs in developing countries remains a challenge in the form of obstacles to technology transfer, closing of numeric gaps, and contributions to ensure environmental sustainability. The latter is a major objective worldwide and one of the UN Millennium Development Goals (MDGs) in the fight against poverty. Closing the numeric gap is also a concern on the international agenda (Gerster and Zimmerman 2003). Part of the environmental challenge is directly linked to economy and governance: although resources may be sufficient, poverty, competition, and poor choices make sustainability rare. Adequate information and communication are essential to obtain data, monitor and manage the use of resources, and inform. When environmental management fails, ICTs can provide innovative solutions that will encourage sustainability. The idea of this workshop was to generate discussion of new technology, examples of applications, and innovative uses, which will enable ICTs to be used for environmental management in developing countries. The workshop aimed to exchange ideas and pilot experiences involving mobile information and communication systems, GSM applications, cell-phone networks, the Internet, and other ICTs. The objective of the workshop was to review emerging ICTs, discuss innovative applications of ICTs and the conditions for successful implementation, such as the importance of tackling challenges relating to development.

1.5 Science and Technology for Disaster Risk Reduction

Over the past few decades, the number of major disasters and persons affected by them throughout the world has steadily increased. This particularly applies to natural disasters involving hydrometeorological phenomena. According to work carried out by the Intergovernmental Panel on Climate Change (IPCC 2007), this trend can be expected to continue due to the possible impacts of global warming, including the likely – even very likely – increase in the number of extreme phenomena. Not all countries are equally equipped to cope with these risks, however, since a community's adaptive ability is closely linked to its level of development. Poverty and unequal access to resources are both factors that are likely to increase vulnerability in the face of natural hazards and climate change. Science and technological innovations are essential components of "Disaster Risk Reduction." They play a role at every stage of the process right through to the actual crisis: from risk analysis (identification of hazards and vulnerabilities) to mitigation measures (impact mitigation in case of unavoidable hazards) and preparedness (early warning systems in particular). The aim of this workshop was to reflect on the following questions: which technologies for what sort of development in the field of natural disaster reduction, and how can their effectiveness in coping with these disasters be improved and better adapted to local environments and their populations?

1.6 Technologies for Sustainable Energy Production

Strong demographic growth, the rapid industrialization of large countries emerging on the international economic scene, and the environmental impact of industrial, agricultural, and urban activities mean that energy choices made over recent decades have to be rethought. In view of the anticipated depletion of fossil fuels (oil, gas, coal) and their proven contribution to the deteriorating living conditions on the Earth (pollution, climate change), it is essential that dependence on these inherently nonrenewable energy resources be reduced. The energy crisis is however not just linked to a problem of resource supply and shrewd effluent management – it also involves economic and social aspects: the extremely volatile nature of fuel prices, large disparities in access to energy sources, and ambivalent public policies regarding consumer prices. These questions, if posed on a global basis for the planet as a whole, entail especially serious consequences for developing countries. The precariousness of populations, whether rural or urban, also has energy implications: although the changes observed in ways of life in developing countries result in an overall increase in energy consumption, one quarter of the human race is entirely reliant on "noncommercial" biomass fuels (particularly firewood), while 1.6 billion people still have no access to electricity. Developing countries are confronted with a dual challenge: gaining access to alternative and renewable energies with low

environmental impact, adapted to their geographical and climatic conditions, and encouraging the use of local primary energies, produced at reasonable cost and efficiently transformable into energies accessible to the vast majority of low-income inhabitants. The aim of this workshop was to reflect on the links that exist between energies, appropriate technologies, and socioeconomic development in Southern countries by:

- Evaluating the potential of contemporary technologies for sustainable development relating to energy and the environment
- Focusing workshop participants' attention on the major innovations in the energy sector and the necessary conditions for adapting these to the context of developing countries
- Examining individual perception of technologies according to sectors, needs, and access possibilities

1.7 Conclusions

In conclusion, the issue of "Technologies for Development," as addressed during the EPFL UNESCO Chair International Scientific Conference on Technologies for Development in February 2010, leads us to define the specific technologies we are discussing, their aims, their particular contexts in relation to countries of the South, their accessibility for users, and their appropriation by producers and stakeholders in the field of development both in the North and South. These questions have been the main guidelines for the various chapters and contributions to the present publication.

Analyzing the four technological areas chosen for the occasion, presentations were illustrated by case studies and theoretical considerations. The resulting observations were developed from fundamental issues, both aiming at sustainable development which benefits the whole population of the regions concerned and taking into consideration their historical and cultural diversities:

What are the characteristics of technologies exported or created in emerging and developing countries?

The question of appropriation clearly emerges from the identification of technologies implemented in developing countries. The vast majority of technologies, emerging within a context of globalized trade and heightened economic competition, are there not only to solve practical development issues but also to act as weapons in a ruthless "economic war" between producers of goods and services, promoters, and users. However, the questions of adaptability to a context, to a society, and to management and maintenance capacities, or the question of natural resources conservation, do not appear to be essential criteria in the choice of technologies and the practical aspects of their transfer.

What are the societal needs aimed at through these technologies?
Opening up toward so-called "appropriate" technologies brings us closer to the guiding principles of sustainable development, in the sense that whether imported or indigenous, old or newly created, their aim is to respond to the demands of a society which is focusing not only on economic profitability but also on social and environmental issues. This also brings into question the stakeholders involved in designing and implementing these technologies, in an attempt to determine who defines the idea of "need" and its content, in the face of "social demand" – another less discussed notion – thereby confronting scientists and technologists with users' renewed necessities.

How unique and innovative are they in relation to contemporary sciences and technologies?
There have been, over the last decades, outstanding and recognized breakthroughs in technology, increasingly focusing on confirmed links between theoretical research, its experimental applications, and the development of new prototypes and products. Despite this, technologies used in developing countries are characterized by their great diversity: created through the use of ancient traditions, "turnkey" imported products from highly industrialized countries as well as mixed solutions which are socially and technologically more innovative. It remains to be seen what part of the scientific and commercial market will be occupied by these appropriate technologies, and to what extent they will be viable in the context of global trends which influence both production and social and institutional demand.

Can these technologies be adapted to the geopolitical context into which they are being integrated?
The evaluation of technologies – their relevance, their adaptability, and the solutions they bring to known problems – must also focus on the context into which these technologies will be deployed, both the geophysical and climatic context on the one hand and the social and political context on the other hand. Taking into account the environment into which these technologies are incorporated will affect both their actions and results. And, we have a duty to not limit their evaluation simply to their technical performance, partly because this context has varying levels: local, because attention is focused on the characteristics of their location; regional and national, because a technology is always connected to other technical and social networks; and global, because technologies today are for the most part completely dependent on global trends and markets. These levels of intervention, the individuals determining their orientation, the conflicts and negotiations leading to their implementation, and the resources available to enhance their functionality, will be the criteria used to judge the impact and appropriation of technologies at a specific time in history and in a chosen territory.

How do they contribute to sustainable development through their environmental, social and economic compatibilities?
Despite all the potential they embody for the development of both industrialized and developing contemporary societies, technologies remain an instrument, a tool, an often highly sophisticated means of scientific innovation, and the result of

advanced research, all of this with the aim of improving the performance of the priority sectors of society. This can apply to energy systems and their networks, construction materials and their impact on the expansion of cities, or communication methods and their role in technological exchanges. To play their part, these technological means must be sustainable – not as such (innovations evolve and are continuously transformed), but in their function, which must answer to societal demands, taking into consideration not only the necessity of economic profitability but also that of social cohesion and inclusion and respect for natural resources.

What is the role of technologies in the context of scientific cooperation for development?

Those participating in the creation, development, and expansion of technologies, first-hand players of this endless progress, are known and recognized by all: academic researchers, industries, public and private companies, and indirect instigators such as governments and public authorities and national and international organizations supporting innovation and research. Bi- and multilateral agencies for cooperation and development remain somewhat lagging compared to the other stakeholders identified here. Although aware of the effects of science and technology, they seem intimidated by the complexity of situations and by short-, medium-, and long-term commitments. All the while, these same authorities recognize the positive role of technologies in a sustainable and global development. It is worthwhile to capture the position held by international cooperation and the role it hopes to play in the future among other incumbent stakeholders: that of promoter like other official entities, of intermediary between technologists and users, or of leader in favor of disadvantaged sectors of the world population and areas neglected by key research and industry players. The question remains open.

With the contributions of the various authors of this publication, and within a spirit of sharing and exchange encouraged by UNESCO Chairs' UNITWIN Network, we should be able to set out guidelines for the establishment of future North-South scientific cooperation projects. These will aim at scientific and technological innovation in favor of an equitable development tackling disparities in emerging and developing countries, promoting the reinforcement of human capital capacities through fairer knowledge sharing between developed and developing countries, and supporting a growth respectful of human beings and their natural and built environment, both today and in the future.

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