

**Innovation for Development: Knowledge and Research  
Application to Address International Development Goals  
A Toolkit**



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## **Innovation for Development - a Toolkit**

### **Forward**

Innovation is frequently a topic for discussion, but it is its reality that matters. It is also fortunate that the reality is commonly practiced in all fields of life, though most often the subject is thought of in terms of technology. In the original text, written in 1999, technological innovation was the principal focus, but it was recognised that technology is only one of many forces, albeit a major one, in human development and *vice versa*. In this revised and updated text a similar pattern to its 1999 predecessor is followed but there are some considerable extensions to it. The promotion of co-operation between universities and industry is universally considered to be a fundamental part of industrial, economic and social development and this is a further aspect that is borne in mind throughout this enlarged Toolkit. The Toolkit is intended for use by planners, policy and decision makers, and other relevant bodies in government, NGOs and the private sector. Specifically, it is aimed at countries in the initial stages of development and those in transition to higher stages. There is a particular emphasis on Africa, acknowledging the diversity of that continent, and the BRIC group of countries that have come into the foreground since 1999. The Toolkit is also intended for use by regional and international organisations, including UN agencies and financial institutions. Furthermore, the Toolkit is written for teachers and students at later undergraduate and early postgraduate levels and for those concerned with continuing professional education in engineering, science and technology, management and economics all in relation to development.

The text is signposted deliberately to enable the Toolkit to be consulted easily with further pointers, where necessary, toward more detailed material. However, every effort has been made not to sacrifice quality and incisiveness in the endeavor to be concise. The text attempts a happy marriage between the minimum of theory necessary to support its practical intent: a resumé of recent developments in relevant theory is included in an Appendix. However, in the main text there are many signposts to theoretical papers, but all of these need to be underwritten by the *caveat* that many practical aspects of innovation are not readily captured, if they can be at all, in the multitude of theoretical publications. The Toolkit is built around a number of case studies (these have been updated and extended), all of which are fundamental to the process of development, though each case study involves different technologies and situations.

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## Preface

### The Millennium Goals

#### **Goal 1: Eradicate extreme poverty and hunger**

##### **Targets**

- Target 1a: Reduce by half the proportion of people living on less than a dollar a day
- Target 1b: Achieve full and productive employment and decent work for all, including women and young people
- Target 1c: Reduce by half the proportion of people who suffer from hunger
- 

#### **Goal 2: Achieve universal primary education**

##### **Targets**

- Target 2a: Ensure that all boys and girls complete a full course of primary schooling
- 

#### **Goal 3: Promote gender equality and empower women**

##### **Targets**

- Target 3a: Eliminate gender disparity in primary and secondary education preferably by 2005, and at all levels by 2015
- 

#### **Goal 4: Reduce child mortality**

##### **Targets**

- Target 4a: Reduce by two thirds the mortality rate among children under five
- 

#### **Goal 5: Improve maternal health**

##### **Indicators**

- Target 5a: Reduce by three quarters the maternal mortality ratio
- Target 5b: Achieve, by 2015, universal access to reproductive health
- 

#### **Goal 6: Combat HIV/AIDS, malaria and other diseases**

##### **Targets**

- Target 6a: Halt and begin to reverse the spread of HIV/AIDS
- Target 6b: Achieve, by 2010, universal access to treatment for HIV/AIDS for all those who need it
- Target 6c: Halt and begin to reverse the incidence of malaria and other major diseases
- 

#### **Goal 7: Ensure environmental sustainability**

##### **Targets**

- Target 7a: Integrate the principles of sustainable development into country policies and programmes; reverse loss of environmental resources
- Target 7b: Reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss
- Target 7c: Reduce by half the proportion of people without sustainable access to safe drinking water and basic sanitation
- Target 7d: Achieve significant improvement in lives of at least 100 million slum dwellers, by 2020
- 

#### **Goal 8: A global partnership for development**

##### **Targets**

- Target 8a: Develop further an open, rule-based, predictable, non-discriminatory trading and financial system **Includes a commitment to good**

- governance, development and poverty reduction; both nationally and internationally**
- Target 8b: Address the special needs of the least developed countries: **Includes tariff and quota free access for the least developed countries' exports; enhanced programme of debt relief for heavily indebted poor countries (HIPC) and cancellation of official bilateral debt; and more generous ODA for countries committed to poverty reduction**
- Target 8c: Address the special needs of landlocked developing countries and small island developing States **through the Programme of Action for the Sustainable Development of Small Island Developing States and the outcome of the twenty-second special session of the General Assembly**
- Target 8d: Deal comprehensively with the debt problems of developing countries **through national and international measures in order to make debt sustainable in the long term.**

### Summary

Many of the Millennium Goals<sup>1</sup> are accompanied by suggested indicators of progress: these will be used as necessary later in the text. In other respects the objectives of the Goals are self explanatory.

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<sup>1</sup> Calestous J., Yee-Cheong, L. (2005) Innovation:applying knowledge in development: Achieving the Millenium Goals. Millenium Project Task Force on Science, Technology and Innovation, United Nations Development Programme. London: Earthscan.



## Chapter 1 Introduction

### 1.1 Description of Toolkit project

The first decade of the new Millennium has been one of tumult throughout the world that has created an inheritance of benefits and problems for the present together with new 'grand challenges' for future generations. The latter reveal or mask opportunities while posing some widespread immediate and long term threats possibly to all human societies. Many of these 'grand challenges' have been known for a long time though their *rediscovery* has proceeded apace during the last decade. Needless to say there is uncertain evidence of some less familiar 'grand challenges': these will be indicated briefly. The notion of 'grand challenges' will exert a background influence throughout the Toolkit. They will, in several ways that will become apparent, diminish the focus on science and technology and its inheritance, which may seem formidable to developing countries. The ethics of these legacies and future challenges, and opportunities, are of particular concern to UNESCO whose Director General has stressed the need for a "clear-sighted, forward-looking view on the world" to enable future generations to harvest the fruits of current foresight. As the pace of scientific breakthrough and invention, and technological innovation has quickened, public concern and the need for accountability have also gathered pace. In all countries, the need to maximize the contribution science and technology, and changing lifestyles make to social and economic development is widely accepted. As a result, there is an opportunity and a role for UNESCO, in cooperation with governments, intergovernmental and non-governmental organisations (NGOs) and the private sector to promote the two way transfer, between developed and developing countries, of experience in invention and scientific breakthrough together with the processes of innovation and their role in social and economic development.

To address this opportunity and to promote advocacy, UNESCO's UNISPAR programme includes the development of a 'Toolkit on Innovation for Development' (Toolkit hereafter). The Toolkit provides awareness information, teaching and learning material related to innovation and related topics, based mainly on experience from developed countries but acknowledging that there is a two way flow between developed and developing countries. Case studies are included to illustrate this dual process. The Toolkit is part of a series of UNISPAR Toolkits designed to promote innovation through enhanced university-industry cooperation, particularly in engineering, science and technology throughout the developed and developing countries. The Toolkit has the objective of providing;

- Information that can be used in advocacy to promote awareness of the need for innovation
- Learning and teaching material concerning innovation for development
- Means of acknowledging the two way flow of innovation between the developed and developing countries

While the emphasis of this Toolkit will be on the promotion of innovation for development in the current developing countries the presence of the two way flow,

already referred to, will be in mind throughout. UNESCO invites potential partners and sponsors from government, intergovernmental and NGOs to cooperate in and support the development of the production and publication of the Toolkit.

## 1.2 Clarification of terms - what innovation is and what it is not

The term 'innovation' is often used loosely to cover both scientific breakthrough and invention, and new ways of doing things that have not been used before. Throughout the Toolkit this ambiguity will be avoided by using definitions of 'invention' and 'innovation' that are commonly used and that also clearly separate the two activities. These definitions are:

**Invention** is the act of either making a scientific breakthrough or of assembling existing knowledge in uncommon ways to create an artifact that is both new and works in a way not previously known. The common understanding of invention has hitherto been related almost entirely to products and scientific breakthroughs. The term artifact is used deliberately to cover scientific breakthrough relating to products and processes, and new services, and ways of living that may conform to the notion of an invention. The creation of the transistor was an act of invention and resulted from breakthroughs in the scientific understanding of materials. The creation of the Internet was a software invention, initially for defence purposes in the USA, that later enabled diverse science groups to exchange information freely. The World Wide Web (WWW) was an extension of the Internet and both, in combination, may be considered as the invention of a service. Inventions are prolific outside science and nowhere more so than in ways of living and money. In the latter the way that fiat money has superseded coinage has been followed by the creation of a plethora of financial instruments at a rate far surpassing other fields.

**Innovation** is the process of introducing a new product, process, service or organisational form (under the colloquial name of artifacts) into the marketplace and the social sphere. In that sense it is not a technical term, but a social and economic one. The criteria for innovation are not science and technology, but lie in the effect it has on the economic and social milieu where it occurs. Innovation is then concerned with the way people live and work, and with potential action, but not with the creation of new knowledge in the scientific or inventive sense. The widespread introduction of the personal computer was an act of innovation, enabling many work tasks to be carried out more effectively (e.g. by using word processing software document preparation was made much simpler).

## 1.3 Why innovation is necessary

Human societies are always in a state of change, sometimes radically or disruptively, while at other times change proceeds more placidly. Because of these continual fluctuations, any society must be able to adapt to the new conditions in which it finds itself; this is the cause of invention and the subsequent innovation. The drivers for invention and innovation include;

- Demographic changes such as changes in the birth and death rates, causes of disease, expected life span and public health matters
- Changes in individual hopes and desires resulting from perceptions of how other people live derived from television, the WWW and other information sources
- Availability of new products and services
- Need to create social equity, and
- For businesses, successful continuity through securing future profits and market share

Innovation, as the widespread introduction of new products, processes and ways of living, is necessary to meet the changes these forms of drivers bring to any society. Gunderson and Holling (2002) proposed a metaphor, under the name of 'panarchy', that describes cyclic transformations typical of invention and innovation. The panarchy metaphor is to quote:

"capable of organizing .... Understanding of economic, ecological and institutional systems ..... explain situations where all three types of system interact. The cross-scale, interdisciplinary and dynamic nature ..... Its essential focus ... is to rationalize the interplay between change and persistence, between the predictable and the unpredictable"

Panarchy is then:

"... the hierarchical structure in which systems of nature ... human ... as well as combined human-nature systems ..... and social-ecological systems ... are interlinked in never-ending adaptive cycles of growth, accumulation, restructuring and renewal."

The metaphor uses a notional three dimensional framework of potential, connectedness and resilience to describe a cycle of exploitation (r), conservation (K), release (omega) and reorganization (alpha). The r and K phases are familiar in ecological theory, the addition of the omega and alpha phases completes the cycle which is partially open to enable adaptation. Panarchy is a powerful extension to metaphors that describe the process of invention and innovation. It will be used later in developing ideas about sustainability and sustainable development.

#### **1.4 Individual versus institutional innovation**

Both invention and innovation are possible through individuals and institutions; both can have local and wide influence. Often it is thought that individuals are more likely to have an influence locally but the poverty of this assumption can be seen throughout music, politics and the arts. So the panarchy metaphor has to be seen in a wider context in its way of explaining and anticipating how both individuals and organisations can have wider influences on both invention and innovation. The widespread adoption of inventions by major institutions, who introduce the dependent artifacts (products or services or ways of living) into society causing their widespread use, is a process called legitimization (see the growth curve illustrated in

Section 1.7). The latter is more often thought of or described as institutional innovation.

## 1.5 The notions of appropriate technology

In as much as technology is part of many innovations, the technology must, by definition, be **appropriate** to the time, place and skills available and to the application itself. For example, the introduction of a CAT scanner, to aid medical diagnosis, into a remote rural area would be inappropriate, but the advent of the *cold chain* described in **Chapter 4**, enabling the widespread use of vaccination, is appropriate. In this sense, an appropriate technology is neither second rate nor handed down and obsolescent. In choosing a technology to support an innovation it is the effectiveness of the technology in its function in the innovation that matters. Because the fluctuations in the development of a society are of uncertain timing and unknown duration, the rate of obsolescence of an innovation is also unknown. Appropriateness then introduces the dual notions of the speed with which a society can absorb an innovation to its benefit and the minimization of effort over the unknown lifetime of the innovation. These flexibilities exclude the notion of forcing an innovation to be retained beyond what has been recognised as the limit of its useful life.

The brief case studies set out in **Chapter 4** illustrate notions of appropriateness and each has a strong element of sustainable development.

## 1.6 Introduction to Sustainable development: scope and definitions

**Sustainable development**, in all its guises is more familiar now than in it was in 1999 when the first edition of the Toolkit was written: it remains perhaps the most slippery notion that inventors, researchers and innovators now face. Sustainable development is underlain by a series of notions relating to the development of global society: these are wider than concerns for the protection of the natural environment. At present there are at least 57 competing descriptions of what constitutes sustainable development (Murcott 1997). While all have one underlying theme, namely that current generations need to pay regard to the inheritance they leave for future generations, one observer has concluded that “Sustainability is like happiness - everyone believes in it and everyone has a different definition”.

The definition of sustainability used here is that of the Brundtland Commission<sup>2</sup>, a group assigned by the United Nations General Assembly in 1983 to create a “... global agenda for change ...”. The notions of sustainability, encapsulated in the Brundtland definition, are “Humanity has the ability to make development sustainable — to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs.”

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<sup>2</sup> The Report of the Brundtland Commission, *Our Common Future*, was published by Oxford University Press in 1987

Deceptively simple to state, the definition is both broad and deep in its content: it sets new rules for research and development, and for innovators.

The Brundtland Commission's definition of sustainability has been referred to by diverse bodies as a foundation for policies and practices that support a society that is economically, ecologically and culturally sustainable. The statement is at the heart of sustainability, and leaves open for discussion how human societies can achieve this goal of which the characteristics remain unknown.

Later in the Toolkit competing notions of sustainability and sustainable development will be set out in greater detail together with their likely influence on science, invention and dependent innovations. For the time being it is appropriate to indicate that throughout the text sustainability will be taken as a philosophical basis for its paractical counterpart of sustainable development. As will be seen later there are good reasons to use this combination that evolve from the panarchy metaphor.

## **1.7 Some comments on growth phenomena**

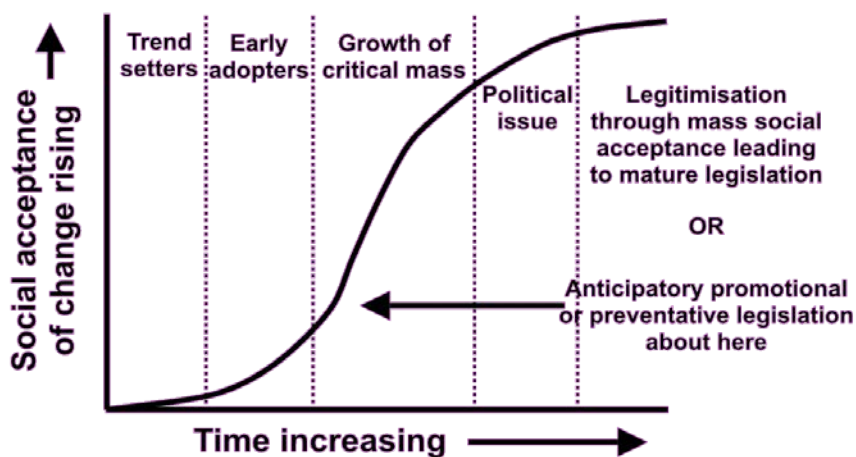
### **1.7.1 Ideas relating to growth**

In 1761 William Wallace was the first of modern commentators to indicate the problems of unrestrained growth. Wallace was followed by Thomas Malthus who, in 1798, wrote a well known pamphlet on the dangers of growth phenomena. Since then there have been many attempts to understand the phenomenon of growth and decline more precisely. Growth and decline accompany us all the time, not only in the obvious way of the physical growth of plants and animals, but also in the;

- Waxing and waning of opinions and beliefs
- Growth and decline of companies and whole industries
- Membership of clubs and organisations
- Growth and decline of political power in individuals and political organisations

The above are but a few examples. Considering the growth phenomenon is dynamic and pervasive, it needs to be better understood if its influence on society, and by inference, on innovation is to be put into context. The first and most important point to realize is that growth rarely continues indefinitely (perhaps the one exception is in the undifferentiated growth of cells that occurs in cancerous tumors until death of the host intervenes). Eventually growth will cease after some upper limit (or saturation) is reached. Thereafter decline begins, perhaps after a period in which saturation is maintained. The 'S-curve' (shown below) is a useful theoretical description of the growth phenomenon and illustrates three essential growth properties:

**Fig. 1.1 Notional growth of acceptance of an artifact**



- An initial period of low but accelerating growth. Over this period growth rates, measured in percentages, can appear phenomenally high, whereas in absolute terms they are not
- A middle period of sustained high annual growth in absolute terms
- A final period before saturation is reached in which growth slows down until the absolute rate is again low or non-existent

These phenomena need to be borne in mind when observing the influence of an innovation on society. It is not unknown for unreasonably high expectations to be created during the early phases of growth, only for them to be dashed as the inevitable slow down occurs with the passage of time.

### **1.7.2 Economic growth and sustainable development**

Notions relating to sustainable development and economic growth will be dealt with more fully later in the text (section on sustainability 2.4.5) but some brief introductory remarks follow. The notion of economic growth dominates Western ways of thinking to an alarming degree: it is based on a set of assumptions that have been questioned ever more trenchantly since the publication of 'The Limits to Growth' in 1972 and its subsequent reformulations during the ensuing decades. It is also generally assumed that invention and innovation are the keys to economic growth, an assumption that is also being ever more vigourously contested. As new ideas enter into economic debate a growing, but incomplete understanding of the ecology of the Earth as a system force attention on growing developments in alternative forms of industrial production. Climate change is but one aspect of the Earth system that will be included in the later section 2.4.5 on Sustainability and Sustainable Development.

## **1.8 Why neither appropriate technology nor sustainable development are soft options nor second class ones.**

As outlined in Section 1.5 the notion of appropriateness for the technology associated with an innovation, should not be associated in any sense with second class, obsolete or inferior technology. When allied to the principles of sustainable development, the demands of innovators and of innovations become high. Supporting technologies may then range from those that are simple and well established to high technologies that are at the leading edge of development. The important step is to see the innovation in the context of the system it serves, where the most appropriate technologies needed to underpin it (the innovation) will emerge from those that are available. In this context, 'availability' includes all the considerations that influence the society's ability to acquire the technology and the capability to use it effectively, as only satisfaction of those two conditions make the innovation feasible in its societal context. The wireless based communications infrastructure described in Chapter 4 illustrates how a high technology can also be an appropriate one in creating an essential service infrastructure.

## **1.9 Skill creation and technology transfer**

In chapter 2 the importance of technology transfer to the developing countries is described. It is also acknowledged that the flow of technology is no longer solely from the Developed to the developing countries. The success of technology transfer depends crucially on the transfer of associated skills and the promotion of them indigenously as part of the licensing or other legal processes, but also through the promotion of training programmes appropriate to the location. There is a relation here to the influence of geography on invention and innovation both of which are described in Appendix 2. The creation of indigenous skills is an important matter that needs to be in mind throughout the case studies set out in Chapter 4. All of them are underpinned by the creation of local skills able to build and maintain the equipment involved. As will be seen the skills needed in these examples range from relatively simple, in the case of building materials to complex in the cases of communications, drugs and health care. The latter, in particular, emphasizes the crucial nature of knowledge exchange and the indigenous creation of skills. It also exemplifies the kind of collaborative arrangements that need to be created between the Developed and developing countries to ensure that the necessary skills are created in both and are retained indigenously.

## **1.10 Brief summary of case studies**

- Case study 1 Appropriate Technology – Building Materials
- Case study 2 Appropriate Technology – Cooking Stoves
- Case study 3 Solar Power: Communications Infrastructure
- Case study 4 Solar Power: Refrigeration and Lighting
- Case study 5 Solar Power: Rural Electrification
- Case study 6 Irrigation using Solar Powered Water Pumping Systems
- Case study 7 Alternative Energy Technologies Electrification: Wind Power

### Case study 8 Orphan Drugs

Case studies demonstrating Innovation emerged from the developing world

Case study 9 Cuban biotechnology

Case study 10 Cataract Surgery

### **1.11 Chapter summary and link to next chapter**

In this first chapter the context and content of the Toolkit has been outlined. Chapter 2, Invention and Innovation in Action, takes matters further by discussing how the practical world of invention and innovation has changed since 1999, also indicating how much both activities have remained essentially the same. Many of the changes since 1999 lie in geopolitical shifts across the world. While these were in evidence in 1999 countries such as China, India and Russia have in many ways moved centre stage for differing reasons which will be discussed together with matters concerning intellectual property that often lies at the heart of invention and innovation. The latter will update the discussion presented in the 1999 version of the Toolkit.



## References Chapter 1

Gunderson, L., Holling, C. (eds) (2002) *Panarchy: Understanding Transformations in Human and Natural Systems*. Washington: Island Press

Murcott, S. (1997) Appendix A : *Definitions of Sustainable Development*. Paper presented at AAAS Annual Conference on Sustainable Indicator Symposium, Seattle, WA, February 16

## Chapter 2 Innovation in action

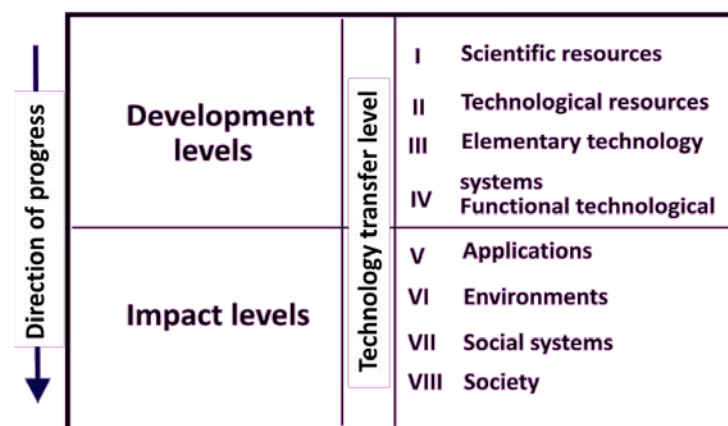
### 2.1 How innovation activity may be promoted

Most of the reported work on the theory and practice of innovation emanates from the Developed Countries and is relevant to their situations. *Care has to be taken in translating the implications of that work to very different states of development and to markedly different cultures.* It is almost certainly incorrect to assume that the newly developed and developing countries, as classified by the Swedish income definitions, will necessarily follow the same path as those countries that have preceded them in the development path. Typically, that path was from an agrarian society to small scale industrialisation followed later by large scale industrialisation accompanied by mass migrations of populations to form large urban areas surrounding the large production centres. In itself, to query whether the current group of Developing Countries will or even need to follow the traditional path to industrialisation and beyond, is itself an innovation, but not a recent one as it was first launched in the 1970s. In 1999 it was unclear whether this 'leapfrogging' would become possible. At that time the evidence for 'leapfrogging' was fragmentary and it remains so today. The evidence to the contrary lies with countries such as China following, within their own culture and political system, the pattern of industrialisation set in the Developed Countries of Europe, North America and Oceania. Evidence to the contrary in any region of the world is slim and elusive. However, as will be demonstrated in the case studies, it is unwise to assume that the Developed Countries remain the mentors of their developing counterparts as there is growing evidence of a reverse flow from them to the Developed Countries.

The necessity for invention and innovation is not disputed nor is the frequency of its occurrence. In this revised Toolkit the focus is shifted beyond invention and innovation to include a commentary on how science and technology have become evermore enmeshed in the social evolution of human societies. The emphasis is deliberate, since one aspect of the duo, innovation, is the application of technology most frequently, but not solely to the production of goods and services. For the developing countries indigenous science and technology now plays an increasingly important part in their development pathway and in some cases, notably China and India, an increasingly important part in the evolution of invention and innovation; an important shift since 1999. Of greater importance is how technology transfer has effectively become a multi-way process between most regions of the world. More fundamental are the choices of technology to transfer in relation to two aspects of innovation and development, namely:

- National aspirations
- National capabilities to complete the technology transfer effectively (this is often conveyed under the word 'appropriability,' the term used in the Toolkit)

The notional stages of technology transfer, evolved during the 1960s, are illustrated in **Fig. 2.1** from which the separation of the impact levels is clear.

**Fig. 2.1 Steps in technology transfer**

For the developing countries the boundary between the impact and development levels is important and relates to the two aspects of innovation referred to above. Throughout the remainder of this Toolkit, it will be assumed that innovation will need to be directed by what the society and social conditions demand rather than what science and technology can offer. For this reason, the way innovation can influence employment, unemployment and under-employment will be a matter of underlying interest. In this context, almost the first question to ask is whether these terms and ideas that underlie them, are appropriate to the developing countries. However, generalisations are not possible because of the enormous diversity of socio-cultural situations present in the developing countries and their very different levels of economic development. As important is the need to avoid believing that the essentially Western notions of development are in any sense appropriate to the developing countries. In 1974, Lauterbach pointed out that *“From the viewpoint of a modernizing nation, the developed countries look as if they have overcome most of the uncertainties, especially economic ones, that have plagued poverty-stricken populations since time immemorial”*, but the same countries might now wish to re-examine that assumption. For them, it is probably an innovation to ask ‘in transition to what form of society?’

## 2.2 Brief review of relevant academic metaphors of innovation

In this section academic thought about the nature of innovation, the widespread adoption of an invention, is described. *It is based entirely on Western thought and Developed Country experience: it must be treated with caution when relating these ideas to the very different socio-economic and cultural conditions in many developing countries.* Metaphors of the invention cum innovation process will be described touching on fields of endeavour where the Manchester Institute of Innovation Research (MIIoIR), as its title proclaims, has long experience. As already set out above, the purpose here is to set out briefly the 'metaphors' emanating from academic research concerning the nature of innovation. The description of the ideas presented as metaphors, rather than theories, is deliberate as the ideas set out are descriptive abstractions of real world events from which they have been derived. In that respect they are typical of the valuable academic process of codifying derived 'knowledge' remembering that is set against a backdrop of general ignorance concerning the

details of how innovation occurs in the real world with all its personal agendas and organisational power structures and conflicts. Codification of observations can only take place for what can be called 'explicit' knowledge, that can be set down clearly, within all the restraints imposed by language, for transmission to newcomers to an endeavour. 'Tacit', or deeply personal of 'knowing how to do something', cannot form part of these metaphors, but they influence deeply the success or otherwise of innovation. It must also be remembered that the metaphors described are derived from developed world observation of practical experience.

In academic studies of how innovations occur (invention is taken to be a pseudo-random process) two lines of thought have led to metaphors describing two themes: systems of innovation (hereafter SI) and the geography of innovation (hereafter GI). In essence these two themes are concerned with impersonal and high levels of aggregation. The underlying belief for SI is that innovations occur systematically or maybe even systemically enabling organisations to layout pathways for innovations to follow. In contrast the GI sets out a case for the influence geography can have in creating districts or regions in which innovations are favourably received. Considerable academic literature has been built up round both metaphors: this is explored briefly in an Appendix. What relevance do these academic metaphors have for the spread of innovations in the developing countries remembering their genesis? First a brief but essential expansion of both metaphors will enable the reader to make judgements about how they can help them in their trials of innovation, of bringing new ideas, services, new products and new processes into their social milieu.

Key authors provide conceptual clarity and set out the state of *explicit* knowledge associated with each metaphor while empirical work supports each approach. These authors include, from SI: work by Edquist (2001); studies edited by Andersen, Lundvall and Sornn-Friese (2002); and the comparative approach of Chang and Chen (2004). Publications focused on GI include: reviews of economic clustering by Breschi and Malerba (2001); 'Regional Innovation Systems in Europe', introduced by Leydesdorff, Cooke and Olazaran (2002); critical surveys in Regional Studies on territorial innovation models by Moulaert and Sekia (2003) and innovation and geographic space by Simmie (2005). Martin (1999) has contributed critical reviews of the role of geographers and the science of geography in an economic context including criticisms of the work on clustering by Martin and Sunley (2003).

Such reviews often indicate maturation of the literature; coalescence as core material and concepts seem to become well-founded appearing to display some common ground. Conversely it could be argued that these reviews may also reinforce the fragmentary, diverse, over-lapping and sometimes position-entrenched approaches to innovation studies. Discrepancies between these reviews (and acknowledgement of differing opinions) indicate that a unified theoretical position continues to elude researchers. The negative effects of these contrasting views include inconsistencies in terminology that hamper progress in innovation studies, impeding conceptual clarity and practical application of theory restricting the development of suitable practical policy actions. The resulting conceptual ambiguity within both the SI and GI fields of study may not be surprising but prevents intra-concept unity.

Antecedents to modern theories include the work of Adam Smith, Marshall and Schumpeter that provides the platform for the development of modern metaphors of the field of innovation studies and also creates the conditions for divergence in the SI and GI approaches. Adam Smith's, 'An inquiry into the Nature and Causes of the Wealth of Nations' (1776), provides the basis for the development of economics as an analytical concept and also identifies the importance of technological innovation as essential to economic progress; it did not separate the functions of invention and innovation. Smith's views on efficiencies resulting from specialisation and divisions of labour can be transposed forward in time to specialised research and development laboratories or departments. Smith's 'discovery principle', or 'recourse to new divisions of labour and new improvements in art' is his notion of 'drivers for incremental innovation.'

List (1841) postulated the notion of 'The National System of Political Economy' to attempt an economic explanation of the rise and fall of nations. List's other contribution was to stress the importance of infrastructure as an enabler of economic growth, with particularly emphasis on transport infrastructure in Germany (specifically railways) which permitted the circulation of commodities, individuals and information.

The key contributions by Schumpeter (1939, 1942) reinforce the importance of innovation as the key factor in dynamic, capitalist economies and stresses, in his earlier work, the role of entrepreneurs in delivering innovations (in later work Schumpeter acknowledges the importance of international links to scientific knowledge and the importance of large corporations). Schumpeter also distinguished between 'inventions' and 'innovations', the latter being the material economic benefit of the widespread use of new products, new processes or new devices.

Lastly, the broadening of the concept of innovation from restricted technical innovations to encompass new forms of production (Edquist, 1997) encompasses organisational forms which may flow from organisational, social, technical and market change.

Some have observed that Schumpeter was not concerned with the spatial distribution of innovations and that traditional agglomeration theory was not concerned with innovation. Schumpeterian aspects of technological evolution have, since the 1980s, become more apparent in economic geography. It has been argued that theories of economic processes should take space and location seriously in order to account of the reality of economic activity taking place in local, regional, national and global space. The latter include the mechanisms of economic development, growth and welfare which operate unevenly across space. Those mechanisms are themselves spatially differentiated and in part geographically constituted.

Marshall (1890) is generally credited with the identification of 'knowledge', "our most powerful engine of production", as being the fundamental mechanism of economic progress. The links between the system and space were further emphasised in

‘Industry and Trade’ (Marshall 1919). Dunning (1998) suggested that the principles behind the benefits realised from the agglomeration effects of related activities in a geographical concentration, had been relatively neglected by trade economists. Best (2001) describes Marshall’s major contribution as adding ‘organisation’ as the fourth factor of production to labour, land and capital. Marshall’s ‘industrial districts’ approach emphasised the beginnings of networks and complementary assets to support and enhance the innovation-promoting potential of firms (Dodgson 2000, p. 27).

The **SI** metaphor draws on evolutionary ideas associated with economics and technological change. SI has four sub-categories: national, sectoral, technological and regional. Systems of innovation as a concept appeared in 1980s and 1990s as a new approach to the study of innovation within economies (Acs and Varga 2002). The approach has become widely accepted in a relatively short period of time (Edquist, 2001). The publication of critical assessments and reviews of the state of the art to date are indications of growing maturity of the research area. Initially the approach reflected National Systems of Innovation (NSI) (Edquist 2001) which embodied a central premise of the systems approach, that individual firms do not carry out innovations in isolation (Edquist, 2001). The study of innovation from a systems perspective is conducted via a number of units of analysis: geographic (national or sub national/regional), technological and sectoral. These are discussed further in an Appendix.

Nelson and Rosenberg (1993) define SI as “a set of institutional actors that, together, plays the major role in influencing innovative performance” while Carlsson et al, (2002) prefer “...the function of an innovation system is to generate, diffuse and utilize technology. Thus the main features of the system are the capabilities (together representing economic competence) of the actors to generate, diffuse and utilize technologies (physical artefacts as well as technological know-how) that have economic value.” One of the problems in tightly defining the innovation system when employing broad definitions of innovation is that there is no specificity about what can be included or could be excluded (Nelson and Rosenberg 1993) which has implications for establishing the boundaries to the system. Edquist (2004), points to the essential requirement to specify boundaries if empirical studies are to be carried out proposing that boundaries can be identified: spatially/geographically or sectorally or in terms of activities.

SI has also been criticised for ‘conceptual diffuseness’. Evidence for this stems from variations in the definitions of key terms, particularly the term ‘institutions’ which is used inconsistently between authors, some seeing these as different kinds of organisation (Nelson and Rosenberg, 1993) while others take it to encapsulate rules of behaviour and the pervading norms, routines or laws that may be apparent within the system.

The **GI** metaphor considers that variations in economic wealth and economic output are not evenly distributed in space; this is the central issue in the geographic imperative in innovation. The heterogeneity in distribution and observable patterns of

distribution has to be explained by the processes which are deemed to generate such patterns (Lloyd and Dicken, 1977). It is therefore the spatial dimension, and more specifically the spatial arrangement and agglomeration of economic activity, which is at the core of GI. Two distinctive and contrasting explanations of geographical agglomeration have been proposed: the ‘new economic geography’ and the ‘new industrial geography’.

The ‘new economic geography’ of Krugman 1991, (see also Martin’s comments 1998, in Breschi and Malerba 2001) views the reasons for agglomeration to lie primarily in reductions to transport costs and the achievement of economies of scale. These elements can be measured and modelled. Knowledge and innovation were recognised but viewed largely as intangibles.

The ‘new industrial geography’ encompasses, according to Caniëls and Romijn (2003), “... innovation dynamics of regional agglomerations [studied] from non-mainstream economic, geographical and institutional-sociological points of view”. Much of the empirical evidence to support this claim is built on case studies such as Silicon Valley, Route 128, and the Italian SME industrial districts, all of which point to success as measured from their persistence in the literature as examples of agglomeration. In this way innovation can be seen as a “partly territorial phenomenon” (Doloreux and Parto, 2005). It needs to be remembered that these locations are the same as those used to support the notion of RSIs in the SI approach.

Piore and Sabel (1984) coined the phrase ‘flexible specialisation’ to encapsulate a strategy of permanent innovation. As a strategy flexible specialisation relies on departure from the vertically integrated firm to one which can draw on flexible, multi-use internal resources (including equipment and skills) and a range of external resources. The flexible specialisation thesis underpins a core concept of new industrial districts and innovative milieux. Elements of the flexible specialisation approach emphasise changing interactions between firms and between industry, and the state, suggesting a more systemic nature to these relationships. Other changes to business processes, such as the development of just-in-time delivery systems and the persistence of localised transactions within firms and between firms, also suggests there must be some spatial limits to the feasibility of such activities.

The *manifestation* of spatially bounded sets of economic actors are modelled as ‘new industrial districts’, ‘innovative milieu’ ‘local production systems’, ‘learning regions’ and clusters’. These are predominantly considered to be the enduring ‘territorial innovation models’ (after Moulaert and Sekia, 2003, in their critical survey of territorial innovation models).

Of necessity a fuller discussion of the current academic metaphors of SI and GI are left to an Appendix. It must be remembered that neither the SI nor GI constitute a formal ‘theory’ which is why they have been referred to as metaphors for the way in which the academic world tends to think of innovation processes. These metaphors have their influences in public policy but because of the way they have been created, from observations of real world activity, both are backward facing; their extension into the

future and in the markedly different cultural settings of the Developing, as opposed to Developed Countries is valuable but not unquestionable. Indeed, both the metaphors are not unquestionable even in the Developed Countries. How then ought they to be used in the developing countries? Mainly as guides to thinking in abstract terms about what is happening in the real world and to enable recognition of patterns of events that might be nudged in one direction rather than another if an innovation is to succeed at some point in the future. Prescription is not their purpose especially if it dulls thought processes.

### 2.3 Measurement of innovation performance including indicators

Some simple statistics may help to place innovation in context for various groups of developing countries, these data were drawn originally from the UNDP's Human Development Report and World Bank statistics published in 1998 and are updated here to 2010. Turning first to human development, UNDP developed a 'Human Development Index (HDI)' based on three indicators; longevity (life expectancy at birth), educational attainment (a combination of adult literacy and combined primary, secondary and tertiary enrollment ratios) and the standard of living (real GDP per capita expressed as the PPP in \$s). The following broad classification occurs (**Table 2.1**):

**Table 2.1 Summary of Human Development Index Data For Different Regions and Levels of Development<sup>3</sup>**

HDI Rank	HDI value (range for group)	HDI value (average for group)
<b>Very high human development</b>	0.788 to 0.938	0.854
<b>High human development</b>	0.677 to 0.784	0.726
<b>Medium human development</b>	0.488 to 0.669	0.590
<b>Low human development</b>	0.140 to 0.470	0.375
<b>Developed countries</b>	-	0.861
<b>All developing countries</b>	-	0.590
Arab States	-	0.588
East Asia and the Pacific	-	0.643
Europe and Central Asia	-	0.702
Latin America and the Caribbean	-	0.704
South Asia	-	0.516
Sub-Saharan Africa	-	0.389
<b>Least developed countries</b>	-	0.386
<b>World</b>	-	0.624

<sup>3</sup> Modified based on .xls file 'HDR 2010 Statistical Tables' from <http://hdr.undp.org/en/statistics/data/>. Cross-checked with .xls file 'HDI Trends 1980-2010, from <http://hdr.undp.org/en/statistics/hdi/>



More detailed information begins to point towards the most important roles for innovation in the developing countries; these data are shown in **Table 2.2**.

**Table 2.2 Detailed Data Relating to the Human Development Index**  
(All data are the average for the group or region for date shown)<sup>4</sup>

HDI Rank	Life expectancy at birth (2010)	Adult Literacy Rate 2005-2008* (%)	Real GDP per capita 2007 (PPP US\$)
<b>Very high human development</b>	80.3 (79.5)	(97.8)	38,297
<b>High human development</b>	72.6 (73.7)	92.3 (93.6)	13,649
<b>Medium human development</b>	69.3 (67.1)	80.7 (85.1)	4,491
<b>Low human development</b>	56.0 (55.1)	61.2 (58.9)	915,21
<b>Developed countries</b>	98.37	(94.51)	15,136
<b>All developing countries</b>	(67.2)	(79.7)	6,856
Arab States	69.1	72.1	8,202
East Asia and the Pacific	72.6	92.7	5,733
Europe and Central Asia	69.5	97.5	12,185
Latin America and the Caribbean	74.0	91.1	10,077
South Asia	65.1	62.4	2,905
Sub-Saharan Africa	52.7	62.4	2,031
<b>Least developed countries</b>	57.7	59.9	664 US\$
<b>World</b>	69.3	...	9,120

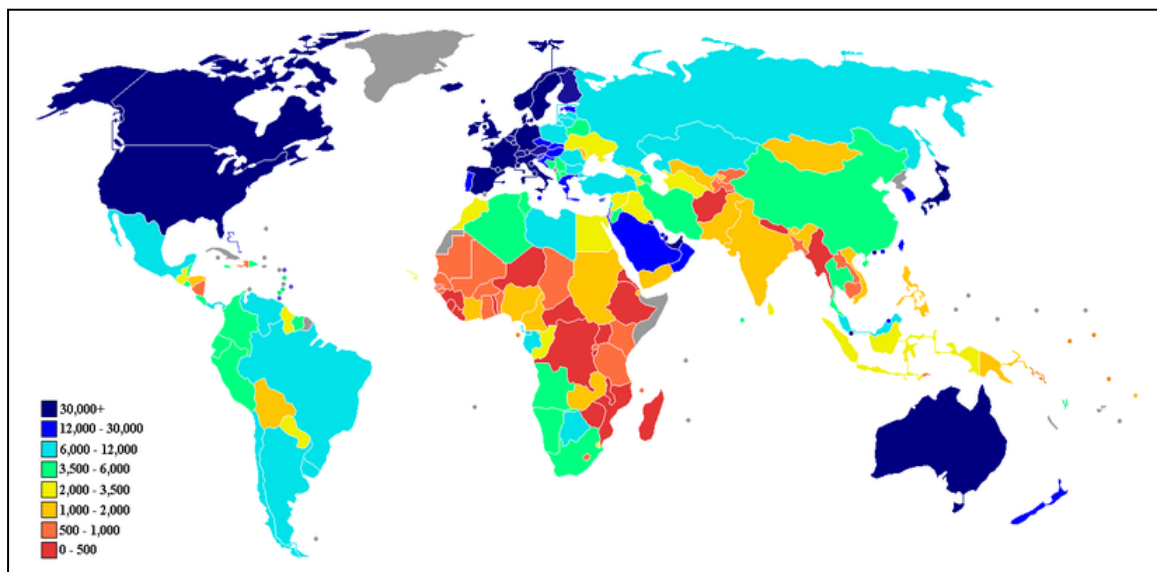
The World Bank data illustrates the geographic distribution of development based on GNP per capita as shown in **Fig. 2.2** below.

The simple statistics given below may not be familiar in the form used, but their general thrust indicates the importance of all the factors that lead to:

- Longer life expectancy at birth
- Raising adult literacy
- Raising real GDP per capita

<sup>4</sup> Modified based on .xls file 'HDR 2010 Statistical Tables', Table 1, available at <http://hdr.undp.org/en/statistics/data/>

**Fig. 2.2 World distribution of GNP per capita World Bank Development Data 2009  
(thousands of Dollars)<sup>5</sup>**



To be more specific, to raise life expectancy at birth will require innovations or their adoption or adaptation from elsewhere, in medical practice at all ages, but especially in gynaecology and pediatrics, and in public health. Similarly, innovations will be needed in all aspects of learning from the youngest ages upward, but these will need to be in line with national aspirations for the future regional and national socio-cultural, economic, ecological and political arrangements. These will be associated with raising the real GDP per capita, but there will also be a need for innovations in employment. The latter term needs careful study since its meaning in the industrial nations will often be entirely inappropriate in the developing countries. For example, the notion of work in many of the developing countries is very different to those in their industrial counterparts, while the terms 'job creation', 'unemployment' and 'underemployment' are often barely recognised in the developing countries and remain so after a decade into the new Millennium.

Similarly, the preoccupation in the industrial countries with competitiveness and the supporting role played in it by science and technology, is clearly inappropriate in the least developed countries and is only acknowledged as of growing importance in the countries in the advanced stages of changing into an industrial society. It is at this point that notions of the process of innovation need to be examined since these are believed to have influenced developments during industrialisation.

The practical notions of the processes of invention and innovation will be examined only in outline here, as they will be dwelt on later in an Appendix; the academic metaphors about innovation and how it proceeds have been described earlier.

<sup>5</sup> [http://en.wikipedia.org/wiki/List\\_of\\_countries\\_by\\_GDP\\_\(nominal\)\\_per\\_capita](http://en.wikipedia.org/wiki/List_of_countries_by_GDP_(nominal)_per_capita)

Throughout the distinction between invention and innovation set out earlier needs to be in mind. In the earliest days of the Industrial Revolution invention was usually the prerogative of one person, often the mill or factory owner or the mill manager. These were times when the knowledge needed for an invention and the subsequent innovation could easily be comprehended by one person. In many ways the initial steps in an invention and innovation in the modern world are the prerogative of one person, but the evolution of the invention or scientific breakthrough, and implementation of the innovation more often than not now requires a team of people. In socio-cultural terms, the factory or mill owner of the early Industrial Revolution could impose inventions; now the process has to be more subtle even if the outcome, the implementation of the invention to enable its widespread use (innovation), is the same. Trade unions and health and safety legislation now mean that an innovation has to be legitimated through persuasion and/or negotiation. These socio-cultural changes are not represented in the metaphors that have dominated academic studies of innovation, but they have influenced the academic understanding of the innovation process a great deal. Two practical models have dominated innovation and, it is claimed, have influenced the process itself. The two models are;

- (i) The *linear* process in which an invention is said to pass through successive stages during its implementation to become a successful innovation, stages that roughly parallel the structure of the organisation itself. For example, a technological innovation would pass through a product development department, to production development and finally to marketing and sales departments for introduction into the marketplace. Similar parallel routes to commercialisation would occur in service companies
- (ii) Recently what might be called a *parallel* process has been described in which an innovation follows multiple tracks simultaneously, or nearly so, toward implementation and commercialisation in the marketplace. In these circumstances, market testing, product development, process development and further technological development occur simultaneously and implementation involves many interdependent feedback loops, rather like a complicated control system but without the closed loop nature of a typical feedback control system

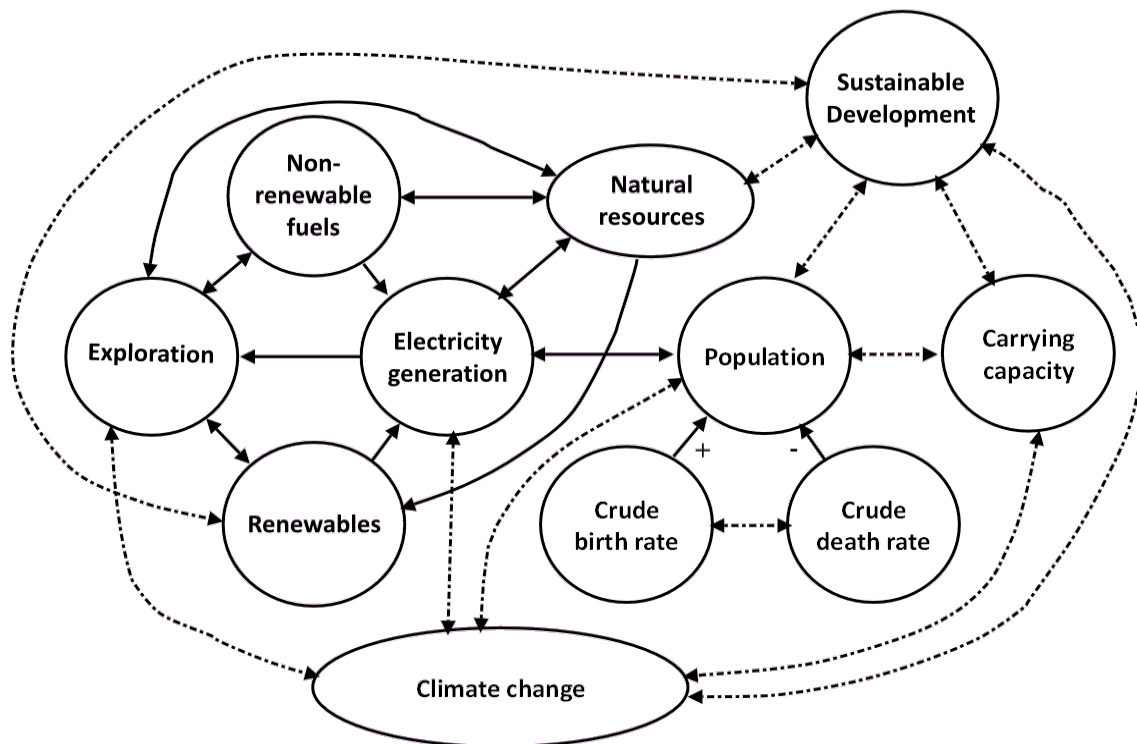
In truth, both 'models' are limited representations of practice more useful for academic purposes than for direct application in the real world. What matters is the creation of the appropriate conditions in which an innovation can occur successfully; these matters are discussed in **Section 2.4**. In the modern world these conditions often have to be global and the phenomenon of **Globalisation** is examined briefly in **Section 2.6**.

## 2.4 Innovation, Grand Challenges and the Millennium Goals

Since the first edition of the 'Toolkit' was prepared in 1999 the notion that the world's human population faces a number of 'grand challenges' that may shape its destiny, depending on how they are perceived and responded to. All have a long history, going

back to the late 1700's, mostly of inattentive scepticism; it is the latter that has changed in the last decade. Grand challenges are currently and most frequently perceived in the conventional way as a series of 'silos' containing for example climate change, fuel and energy supply, natural resources, population levels and their dynamics and last in this highly abridged list, sustainability. It is revealing to look at this list from a systems vantage point as is done in **Fig. 2.3**.

**Fig 2.3 Tentative interlinkages of grand challenges**

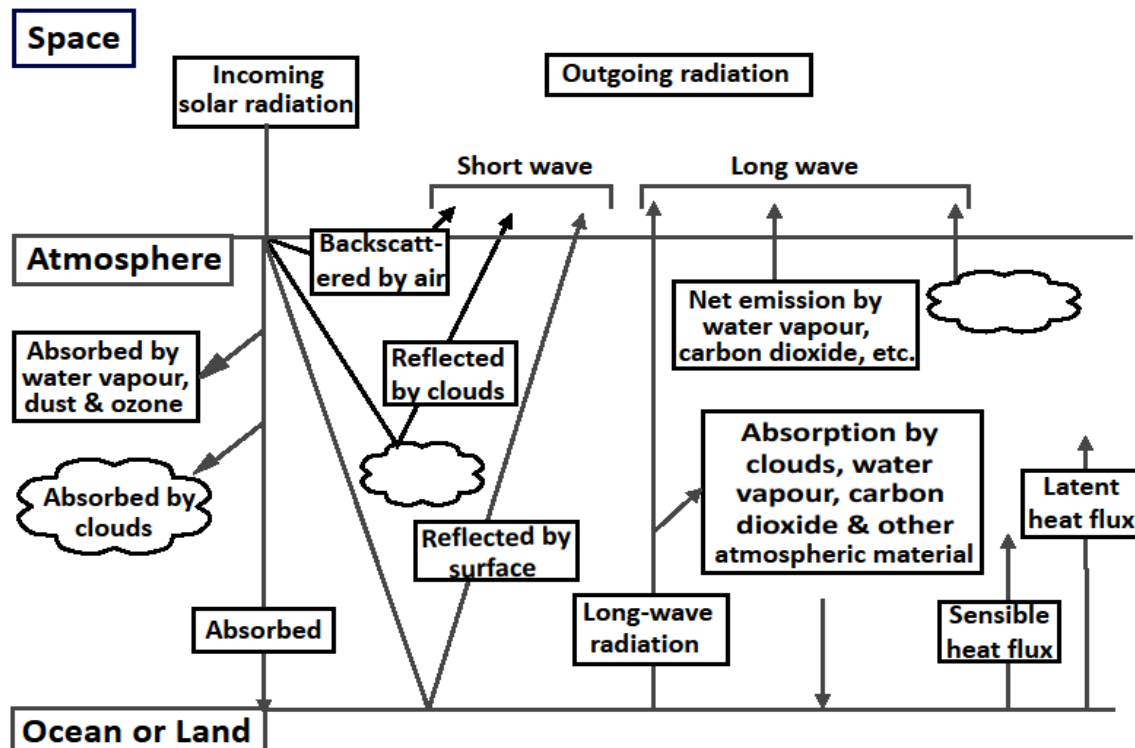


The simplicity of **Fig. 2.3**, known technically as an interaction diagram, hides the immense complexity of the real world. The representation of the real world situation as the intersecting sets they really are is too complicated to be easily presented diagrammatically. Far from these grand challenges being independent silos they are a group of intersecting sets in which the universal set is sustainability. Here it is necessary to paint a view that distinguishes between a philosophical notion of sustainability and its practical embodiment in sustainable development. There are good grounds for making this distinction that stem from the panarchy metaphor developed by Gunderson and Holling (2002). It is from this viewpoint that sustainability of *all* life on the Earth, the grandest of the 'grand challenges' and represented partially by climate change, fuel and energy supply, population and resources, will be discussed.

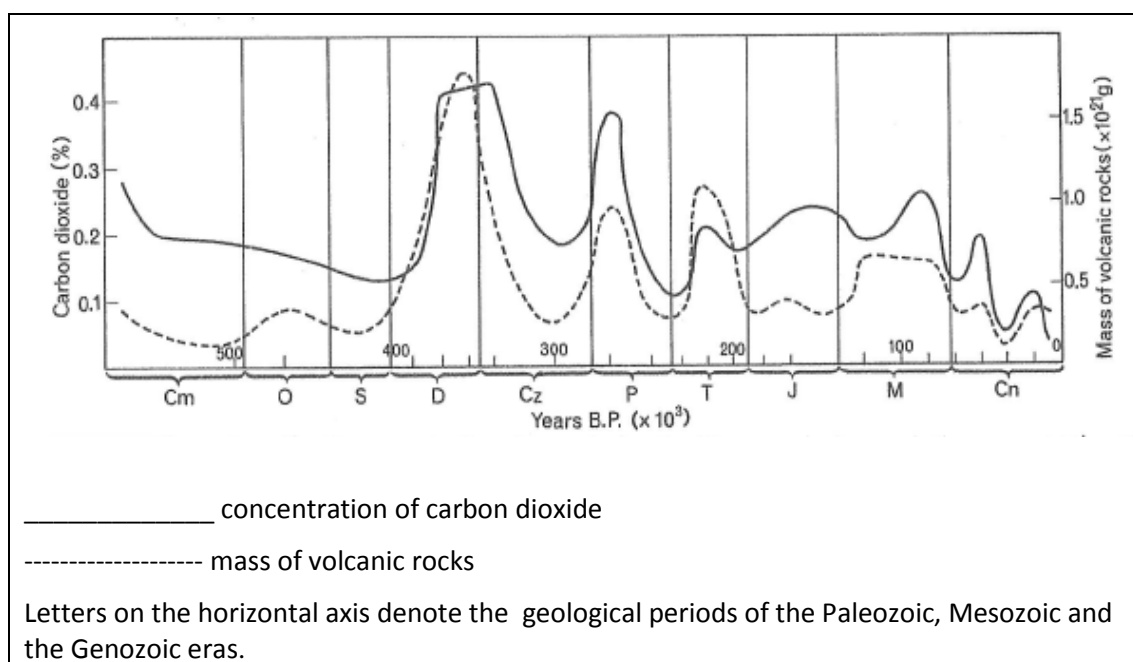
### 2.4.1 Climate change

The climate change debate came onto the popular horizon in the late 1970s and in the last decade has become a highly emotive subject in the world's polity. **Fig. 2.4** illustrates, in a simplified form, the main features of the Earth's atmosphere that enter into the climate change debate.

**Fig .2.4 Some factors that influence the heat balance on the Earth**



Unsurprisingly, climate data has a very long history illustrated in **Fig. 2.5**. The modern debate concerning climate change needs to be seen in the context of **Fig. 2.5**.

**Fig. 2.5 Carbon dioxide concentration change during the Phanerozoic.**

The emotive nature of the current debate has been accelerated through two mechanisms: computer modelling of the Earth's atmosphere allied to measurable changes in a number of physical and chemical features of the Earth at its surface, and in its atmosphere. Numerical modelling of the Earth's atmosphere began in the 1960s (Lorenz, 1963) with the advent of theories of complexity. These developments were first used in weather forecasting, but as time passed more comprehensive models of the Earth's atmosphere emerged. In parallel, there were significant increases in the speed of computation until, with the emergence of 'super computers' computed weather forecasts could keep up with real changes occurring in the atmosphere itself. At that point serious experiments began with limited computed scenarios of the future trends in the behaviour of the Earth's atmosphere. During the 1990s and early 2000s many shortcomings of the models were overcome though many significant uncertainties remain. The International Panel on Climate Change was formed in 1988 by the World Meteorological Organisation and the UNEP to draw together the science of climate change, its modelling and speculations about the future of the Earth's climate arising from the computed scenarios. The output in the scenarios tends to focus, for simplicity, on two objective functions: carbon dioxide concentration in the atmosphere and the associated likely rise in the global mean temperature. The IPCC's reports have explored the consequences of the scenarios through regular updating. Unsurprisingly, these reports are not without their critics and the most recent report has suffered particularly strong criticism of some of the data used and the dependent consequences in the scenarios.

There are competing interpretations of both the model and of the outcome of the modelling itself, as well as of the history of the Earth's climate and the factors that drive the behaviour of the atmosphere over both short and long historical periods. Evidence for the latter is derived from geological features, palaeontology,

dendrochronology and glaciology. Currently, the consensus, attributed to a majority of the climatology community, is that climate change is real, a hardly surprising conclusion, and that it is the result of human activity acting through an increase in the carbon dioxide concentration in the atmosphere. The latter is the point of contention with a minority of the scientific community, together with some serious questioning of some aspects of the climate models themselves many of which are shared throughout the scientific community. Bearing in mind that Lord Kelvin claimed that nothing is real until it can be measured, the argument can only be settled that way. However, the outcome will be ambiguous. Many actions, international, national and local, are predicated on human ability to mitigate the rising concerns about climate change in every aspect of its possible influences on the future of humanity, and *all* life on the Earth. Much of the latter is essential to human well-being. The claim that humanity can 'manage' the Earth's climate may or may not make sense, but in the end it is likely to be a question that cannot be decided. Only the continuing existence of life on the planet and of human life in particular, in whatever that condition may be, can provide an answer to that question.

Many of the activities now in vogue to mitigate climate change are common ground, but not universally accepted as relevant in either the Developed or developing countries. Most were anticipated at least 50 years ago: this is the reason for pointing earlier to a persistent mood of 'inattentive scepticism' throughout the last 50 years at least and possibly much longer. Nowhere is this seen better than in fuel and energy, the 'grand challenge' that is discussed next.

#### 2.4.2 Fuel and energy

**Fuel and energy** are connected easily to the current mood surrounding climate change: here the grand challenge is encapsulated in the buzz phrase 'decarbonisation of the human economy'. Before proceeding further it is necessary to clarify two points: the incidence of solar energy on the Earth is far greater than humans will ever need and too often the distinction between fuel and energy is overlooked and confused. The thermal power intercepted by the Earth's diametral plane is  $17.7 \times 10^{16}$  watts, about 100,000 times the installed electric-power capacity (Hubbert, 1969). The distinction between fuel and energy is not trivial. Fuel comes in many different guises, most obviously in carbonaceous form (wood, coal, oil, natural gas and combustible wastes) and in radioactive decay. All of these create 'combustion' processes to generate heat in usable form by human societies. As industrialisation proceeds the key use of this heat is in the generation of electricity which is, in this context, a secondary source of energy. The so-called renewable energy sources (photovoltaic, wind power, geothermal, hydro-power) are currently directed almost entirely to the generation of electricity with water heating being in an important *diminuendo*. Fuel and energy, particularly through enabling the supply of electricity, enter into every aspect of the set of human actions. As societies develop they become ever more dependent on a continuous and reliable supply of electricity and the means of its generation. Technological capability to utilize abundant solar radiation is limited, partly by the influence of the economics of the processes. Similarly, all forms of human endeavour intrude into the workings of the Earth's ecological system,

especially photosynthesis; the search for any of the primary fuels is a major factor in this intrusion which is often accentuated through politics and the expectations that can create. Lastly, the value placed on life runs through all of the foregoing and is often accelerated by the influence of short term norms designed to create expectations that often cannot be fulfilled in the proposed time scale and sometimes not at all.

The reality of this grand challenge is huge, but as with others it has been pursued in low key for many decades. Currently, and for the immediate future decades, the greatest concern will be for the continuity of access to and supply of primary fossil and nuclear fuels as they are the base from which any transition, either partial or total, towards a so-called 'carbon-free' world will occur. The key here is access to the multi-headed hydra of resources, the next 'grand challenge'.

### 2.4.3 Natural resources

**Natural resources** are a multiple theme covering everything from the absolute essentials of food and water, through to the esoteric use of rare earth elements in the production of electronic components, medical scanning procedures and some renewable energy equipment. The field is so broad and interconnected that approaching it systemically poses severe challenges. For the whole Earth the basic essentials of food and water (for humans potable) are of fundamental concern; they have obvious connections with climate change, and population (soon to be discussed), including health. The competition for food and water has to be seen in the predator-prey context of *all* life, not simply human beings. Technology has so far managed to keep up with the food demands of a growing human world population; whether that can continue into the more distant future is a hotly contested matter as there is a tight nexus between the politics of food and water, the economics and technology of food production (with its inevitable link to fuel and energy availability), social habits, determined by human values and norms (the latter expressed through advertising), with respect to social predilections for certain types of diet that can have immense effects on agriculture and horticulture. In turn these have major influences on the global ecology. So broad are the influences of accessibility to the basic essentials of food and water that it may be helpful to think of them in terms of the base of a pyramid, not unlike that of Maslow's behavioural hierarchy of human needs. Many of the increasingly esoteric uses of resources lie higher up the pyramid into the creation of artefacts of increasing complexity that typify a shift from the societies of the developing countries toward the Developed ones. There are exceptions as mobile telephones and television are now available globally throughout all levels of societies.

Trade and production capacity are two important aspects of resources. Many complex artefacts, ranging from electronics, chemicals and pharmaceuticals to call centres are now located in developing countries together with some high quality design services. At the base of the pyramid many developing countries are the suppliers of basic raw materials extending from mining through to growing many foods where much depends on geography and climate. Many of these activities are the basis of globalisation in which lower production and operating costs attract companies to



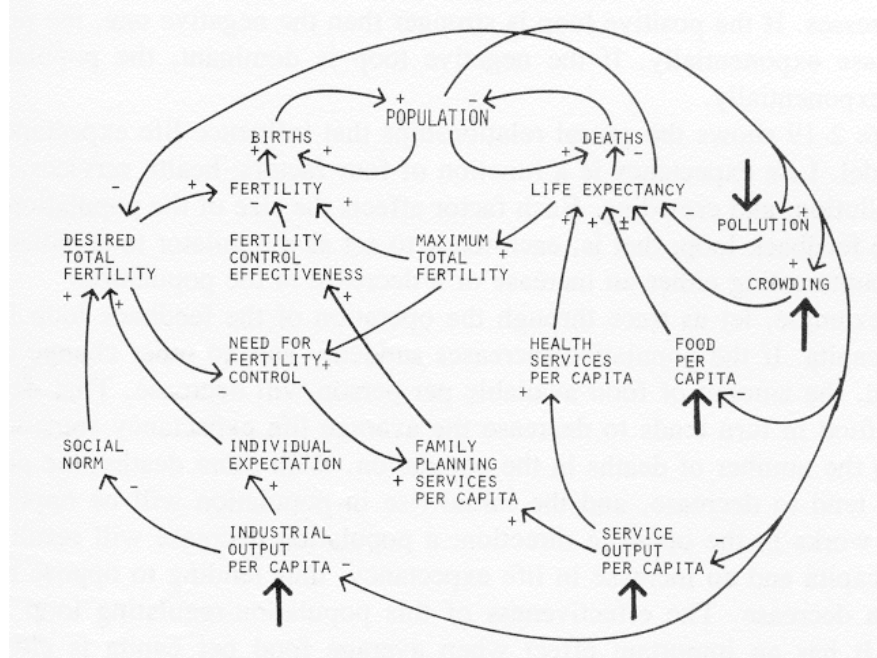
invest in developing countries. How long this trend will continue is debatable. Already there are indications of rising costs as societies in developing countries aspire to higher standards of living. However, the rising strength of the Pacific and Indian Ocean rim countries is possibly evidence of the long anticipated power shift away from the smaller populations of the Developed Countries, remembering that 80% of the world's population lies outside the Developed Countries. The latter is an important issue that is the next topic for discussion.

#### 2.4.4 Population

**Population** is the key underlying feature that intersects with *all* ‘grand challenges’: it is also probably the least discussed. Throughout history human population growth has been a common feature. The reasons and causes of population decline and its consequences are not often discussed. The fundamental question is one of carrying capacity of the Earth, not simply of human beings but of *all* forms of life which exist in a constant predator-prey relationship. Human societies simply do not understand the nature of the predator-prey relationship that keeps life on Earth in balance, or more appropriately, stops it getting seriously out of balance. Concern here is necessarily for the human population but its coexistence with *all* other life forms needs to be remembered even though humanity remains in ignorance of its complexity.

The obvious features of population dynamics are well known and are indicated in **Fig. 2.6** which is drawn from the work of Meadows et al (1972 & 1992).

**Fig. 2.6 Population dynamics as expressed by Meadows et al 1972**



Currently, the UN Population forecasts (presumably a median forecast from a set of scenarios) for the world indicate a population growth rate and total fertility rate (TFR) that asymptotes toward 0.4% and 2 respectively by 2050. Consequently, the world population approaches 9 billion people asymptotically again by 2050. These beliefs

are quite different to earlier prognostications in the 1960-70s when the world population was expected to lie between 7.5 and 30 billion by 2176 with a most likely figure of 15 billion (Kahn et al 1976: a figure of 12 billion was frequently referred to by other authors). Two questions arise: what will cause the world's population and its growth rate to decline toward a lower figure? And why have expectations of population levels and growth altered? Even so the third and only recently voiced question is one raised earlier namely: are the chess pieces of world power, through shifts in the combination of military/political and economic strength, moving. In doing so to create new dependencies, as they are doing already, where the distribution of people and their capabilities will move inexorably toward the newly Developed Countries and the current developing countries? Where the population growth rate and the TFR indicate a population in decline, as is the case in many OECD countries, with the implication of an aging population, the nature of these societies will change inexorably. Will Developed Countries with shrinking populations become decadent? If so why? And what will be the consequences for their aging populations? Will they continue to provide a learning capability for populations from the developing countries and for how long may that continue? Will people in low birth rate countries ever wish to return to larger families with all that implies for changes in life ways? The 'demographic shift', in which a decline in crude birth rates is shown to be associated with increasing GNP/capita (in constant money values) has proceeded inexorably over several decades – will this trend undergo a reversal? These, and other highly interconnected matters (as well as many behavioural 'taboos'), which themselves are interconnected with the content of other 'grand challenges', make the question of population fundamental to the discussion of sustainability.

#### 2.4.5 Sustainability and sustainable development

**Sustainability** is the entire set within which the example set above reside. Sustainability is 'the ability to prevent something from failing under stress' (Oxford Dictionary). It must also be remembered that the conditions that characterize sustainability are not known and may forever remain elusive, as the situation in which humanity exists changes continually. However, as with so many complex subjects the desire to define them produces nothing but confusion. Some 57 definitions of 'sustainability' were set down between 1979 and 1997 (Murcott *ibid*): there are probably many more now. Many people judge that the Brundtland (1987) description of sustainable development is the most acceptable:

*Humanity has the ability to make development sustainable – to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs. G.H. Brundtland, 'Our Common Future'*

The debate about sustainability is far from new and goes back to ancient times, but its modern incarnation began in 1761 with Robert Wallace's concern for population growth and food shortages. It is important that a deeper understanding of the dynamic history of the Earth that emerged from other disciplines some 200 years later. The ferocity of the current debate stems from social phenomena, some of which

emerged from single issue groups which characterize the 'environmental' field. Friends of the Earth and Greenpeace are just two of the current galaxy of organisations that circle round the notion of sustainability. Sadly, however, the current debate is but a repetition of events that occurred in the 1970s following the publication of 'The Limits to Growth' and the first 'oil crisis.' Understanding of the many phenomena involved and of the complexity of the Earth and its life support systems *may* have improved, but its politicisation has done little to improve the public perception or understanding of the underlying issues. The many *caveats* and qualifications attached to research outcomes are happily ignored in the search for 'clarity and simplicity' of presentation by the media and political institutions. The many warnings and entreaties for governments to take action in various fields were largely (but not entirely) ignored while industry was left to make the considerable progress it has in many aspects of sustainable development, through market forces and the influence of some regulation. Perhaps this is only right as - the real work lies in industry among the 'practical people' and activists who do things in the real world, sometimes at considerable personal risk. In the end it is people who will make *sustainability* and *sustainable development* a reality.

Is sustainability 'unavoidable' or simply an option? Sustainability is far older than man but the current emphasis on 'the environment' is narrow and misleading as it rests on a number of untenable assumptions. Chief amongst these is the unwritten one that man is in control of the planet, a belief that first emerged and died in the 1970s, but now seems to be re-emerging. Brundtland does not assume that humanity can manipulate the planet nor does it assume the existence of the human species in perpetuity. Sustainability concerns the continuation of any or all forms of life on the Earth. Successful life on the planet requires the complicated inter-working of factors ranging from the earth's position in the Solar system and its consequent dynamics, to the ecological web of organisms down to viruses. In these wide limits human activity has little and uncertain control, but brings many uncertain and unexpected outcomes. By contrast, the current interventions by politicians, policy makers, the media and single issue groups, relating to the environment (not sustainability), lack a proper historical perspective. These interventions are mostly rhetoric concerning the preservation (or otherwise) of particular ways of living that prevail in 'Western culture' and these have little to do with sustainability.

The notion of sustainability is not universally accepted nor is its practical counterpart sustainable development (Lovelock 2006), though Gunderson et al (2002) present an elegant explanation of the two phenomena derived from their evolution of the notion of 'panarchy.' Consequently, the ensuing politicisation of both ideas has simply diverted the debate away from the essence of the question, which is the continuance of life on the planet.

There is an argument, posed by Gow (1992) and Therivel et al (Therivel et al 1992) that sustainability and sustainable development are not equivalent. The latter authors emphasise that sustainable development is a subset of sustainability, claiming that it assumes that the concepts of sustainability and development cannot coexist. Therivel et al refer to Jacobs definition of sustainability (Jacobs 1991), one of the many

definitions, which relates solely to the 'environment' (without properly defining the term) and to the ability of future generations to '.. enjoy an equal measure of environmental consumption.' The notion of 'environmental consumption' is far removed from what is intended here; it should be far removed from any notion of sustainability and is equally far removed from the notion contained in the Brundtland definition. One can only assume that Jacobs did not intend the phrase to be interpreted in the most obvious way as it is the seed of the problem of carrying capacity (Hardin 1968). Therivel et al go on to say that carrying capacity is the cornerstone to sustainability, without knowing how it can be determined. Gunderson et al's elegant description of how sustainability and sustainable development can be related (Gunderson et al 2002), through the panarchy metaphor, is a further reason not to regard sustainability and sustainable development as synonymous, but as mutually supporting the second being the practical embodiment of the former: these are the reasons why the two terms are taken to be first the philosophy (of sustainability), the second for its implementation; the latter must now become the focus of attention.

#### **2.4.6 Innovation for the problems of living**

**Innovation for the problems of living** or sustainable development, will bring new ways of living and business opportunities, many of which will begin or have already begun in businesses large and small formed by intrapreneurs and entrepreneurs who have appreciated the needs of sustainability while recognising that the underpinning notions and conditions for it are unknowable.

#### **What does sustainable development mean for business and human society?**

*"Sustainability is like happiness - everyone believes in it and everyone has a different definition [of it]" (Gow, 1992)*

The touchstone of sustainable development is stewardship, the care, maintenance and development of what we have inherited, but within those narrow limits that human activity can influence. As has already been said, the belief that we are in charge of our future and can 'manage' the planet to our benefit is as undesirable as it is dangerous. Development is an important part of the philosophy of sustainability if only because the dynamic evolution of the planet is continuous and does not enable human society to stagnate or to remain at some constant state. The notion of dynamism is fundamental as there is no pure and unadulterated state to which the planet can be returned as if to atone for human activity, pollution or destruction. Species come and go as part of the natural evolution of the planet through alteration of the Earth's dynamics, predation and the carrying capacity for the species being exceeded; at some point extinction of the human species is highly likely.

The notion of stewardship is essentially that of an interface between human activity and everything that it comes into contact with and lies beyond it. All interfaces require protocols if they are to achieve their purpose of two way communication and transformation. However, in sustainable development communication is across an interface of great complexity where recognition of the signals from the non-human world requires unusual skills. Here the intention is only to outline a few of the themes

that this interface promotes and to begin to indicate their relevance to businesses of all sizes, and to human society.

#### 2.4.7 The precautionary principle

**The precautionary principle** is perhaps the most contentious of these themes as is its application. The precautionary principle originates from environmental impact analysis (EIA) and has been described by Gilpin as: 'A guiding rule in EIA to protect people and the environment against future risks, hazards, and adverse impacts, tending to emphasise safety considerations in the occasional absence of clear evidence.' The trenchant comment by Gow leads directly into the 'Alice in Wonderland' world of sustainability interpretations that have done so much to devalue its philosophy and implementation. The definition of the precautionary principle demands examination because of the potential intensity of its influence. If it was not clear to Gilpin in 1995 that use of the phrase "the occasional absence of clear evidence" would lead the notion of precaution into quicksand, then it should be abundantly clear now. EIA has to be conducted in a world of great complexity. As a result, the absence of clear evidence is normal and not occasional. In the present era of science, termed Post-Normal by Funtowicz and Ravetz (1990), science is "...neither value-free nor ethically neutral.." but is used to make decisions in the public domain on the basis of uncertain input information and often with some urgency. If the precautionary principle is to be of any value at all its proponents have to come to terms with the characteristics of post-normal science which is conducted in a world filled with complexity, accompanied by uncertainties and risks. If the principle is used bluntly, as some proponent's do, to forbid any activity in which clear evidence that it is 'safe' is absent, then there are three consequences:

- The nature of the real world is being denied
- All science and technology, and associated invention and innovation, will stop
- All development will cease, creating a stagnant world in which the capability of social, technological and value shifts to promote the dynamism needed to satisfy Brundtland (or any other notion of sustainability) will be denied

The time when scientists claimed certainty for science is long past, if it ever existed except in the media. There is now a mountain of evidence from all disciplines that the outcomes of research must be hedged about by qualifications and caveats that trap the unwary proponent in either the scientific community or the world of the media and politics, if not in both. Now that the courts are being resorted to in the search for 'integrity' in science, there is a double jeopardy for the unwary scientist. In some instances at least it seems that the time honoured 'peer review' is no longer good enough.

Should the precautionary be abandoned completely? The response is clearly 'no' as it is a valuable tool in innovation in the developing countries and elsewhere. Paradoxically, sustainable development depends as much on the abandonment or limitations to the use of the precautionary principle as it does on its application. The reason for this lies in the *dynamic* nature of the interfaces between human activity

and everything it comes into contact with. For example, the desirable reduction in the use of nitrogenous fertilisers, which cause degradation of the water supply and damage to water flows in rivers and watercourses, if achieved by enabling plants other than legumes to fix nitrogen directly from the air, is highly likely to involve genetic modification of the stock. To cope with these kinds of paradoxes, the precautionary principle needs to *embrace* the complexity involved and not attempt to destroy it by oversimplification, perhaps by objecting to the necessary genetic modifications to plants that may later be part of the living food chain. Precaution cannot be separated from risk, which is simultaneously objective and subjective, involving much psychology. For research intensive businesses, if not all businesses whatever their size, invocation of the precautionary principle by groups ranging from activists to governments, is one of ‘...the wider issues that now thrust themselves on any science and technology programme [and] is forced upon management’.

#### 2.4.8 Dematerialisation

Dematerialisation is the second important practical theme for sustainable development. Few fields have made greater strides in fundamental understanding in recent decades than that of materials science. Dematerialisation is then decades old, with constant effort being made to change the following factors in any artefact:

- Energy needed for manufacture
- Weight reduction
- Ease of processing
- Dimensional precision in the final product
- Elimination of scrap and waste
- Increased societal demand for user safety
- Vastly improved performance characteristics in the material and the product

Underlying the notion of dematerialisation is the second of three conditions for sustainable development (Daly 1973). It is also directed toward the need to extend the ***principle of parsimony*** into the field of artefact design. The *principle* is an extension of Occam’s Razor and if applied to the design of artefacts calls for the paring away of unnecessary functions and of unnecessary material in the execution of the functions chosen to be embodied in the artefact. While this may seem an obvious pair of principles in any good design it is not necessarily one that is observed in modern design practice where complicated artefacts embodying an excessive number of functions are often the design objective. It is not sufficient simply to apply the *principle* to artefact design without looking backward through the system to the origin of the materials used, while simultaneously applying the notion of *substitutability* of materials. At one time this latter notion was neither well recognised nor feasible; it has only become so during the last two decades as materials science has advanced out of all recognition (and continues to do so), particularly following the evolution of well characterized composite materials. The decline of the importance of metals with a corresponding rise in importance of carbon and silicon based materials is significant in this context. For dematerialisation, *recycling* is a conundrum that has not been solved. Arguing *in extremis* the combination of the *principle* and *total* recycling should

lead to a cessation of the demand for fresh input material; however unlikely this circumstance, new legislation is headed in the direction of total recyclability as a general *design principle* for all artefacts, an important omen for all businesses.

#### 2.4.9 Disintermediation

Disintermediation is the last of the three themes explored here. Hawken (1983) describes disintermediation as “..the elimination of middlemen and other intermediary people, processes and functions.” Pungently, Hawken claims, with some justification, that “The butcher, the baker and the candlestick maker have become the food systems analyst, the infection control co-ordinator and the utility command and control systems engineer.” Indeed, what is in a name?

*Intermediation* is a characteristic of the *mass economy* which evolved through the Industrial Revolution, so that for anyone to make an artifact from beginning to end is now less common than in the past. Hawken claimed in 1983 that the world was sending out contradictory signals, that it seemed to be moving in two directions at once. The first signal arose from the continuing move toward concentration of capital, resources and markets as the corporations and governments of the mass economy endeavoured to recreate their past in the future (and continue to do so). By contrast there was the beginnings of disintermediation and adaptation to new circumstances predicated on the re-emergence of the Malthusian dilemma (Malthus 1798) created by an ever growing population in a world of unknown carrying capacity. Hawken concluded that disintermediation and the individual are most likely to “..gain the upper hand because it is people, not corporations, that create economies.” Hawken’s viewpoint is unlikely to be widely accepted in conventional quarters, but since 1983 the signs have continued to be evident. Mergers, many of mega-proportions continue to drive the world’s stock markets. They are conducted in the name of ‘rationalisation to benefit the consumer’ through market power and new products that require research and development, sometimes of immense cost and complexity that can ‘only be funded by megacorporations.’ These are notions that need constant questioning, particularly now that exorbitant, and often unsubstantiated claims are made for the applications of new technology where the underlying science is often uncertain or highly contested.

It seems unavoidable that the *courts* will become yet more deeply involved in resolving, what are essentially arguments about the validity of scientific knowledge. In contrast to all this, e-commerce, in its current form, has the potential to take *disintermediation* to new levels in providing direct ways of purchasing, the ability to search for an artefact globally (which has implications for tax revenues) and to increase the individuals ability to manage his or her own affairs without the need for intermediaries. The tension between the providers of the mass economy and disintermediation of their world has grown considerably since 1983, to the extent that intermediaries are taking notice.

**Influences on business** arising from the three themes above are far from being the only ones that will influence business in the coming decades. However, they may be

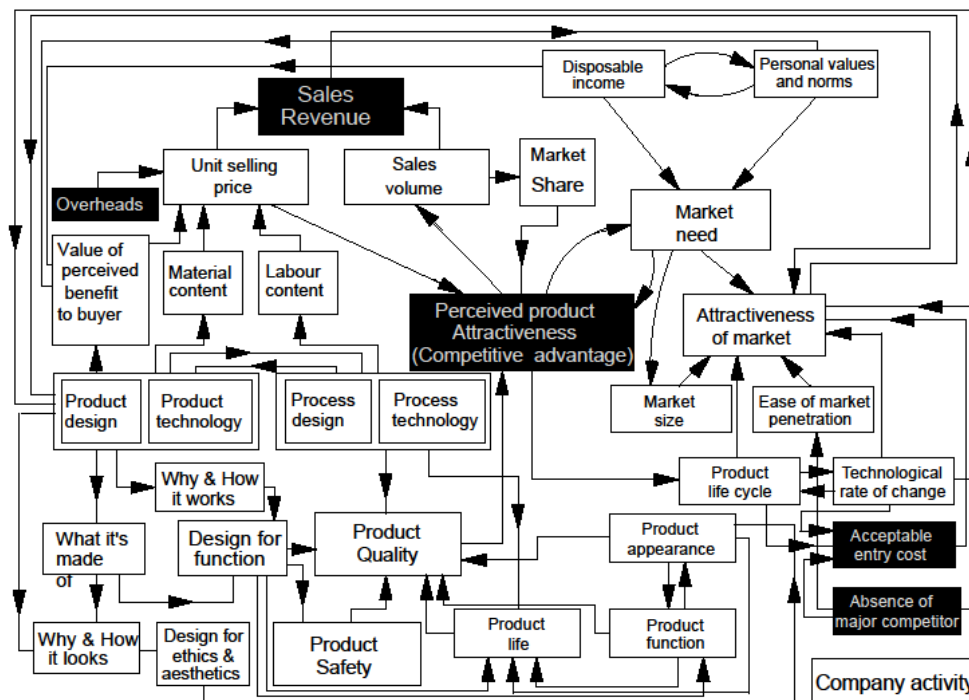
the three least recognised and may, as a result, produce some surprises. In the end, all businesses depend on the naive equation:

$$\text{Sales} \times \text{price} - \text{cost} = \text{surplus}$$

Successful continuity, a euphemism for a sustainable business, then depends on its ability to secure current positive surpluses and to take steps that may, as far as possible, secure future positive surpluses. The three independent variables of this naive equation can be influenced profoundly by the precautionary principle, by dematerialisation and by disintermediation; these will only be touched on in this brief exploration.

Lying behind any business is the unspoken assumption that what it does is and will continue to be relevant to the needs, wants and desires of the social milieu it sets out to serve. In other words the art of innovation through anticipation and adaptation, both of which will be necessary and is (in sustainable businesses) taken for granted, but not without creating internal and external tensions. The relevance of what a business does then depends on the *attractiveness* of its products whatever form they take. As Fig. 2.7 below indicates *product attractiveness* is characterized by *complexity*.

Fig. 2.7 Pproduct attractiveness



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The characteristics of *perceived product attractiveness* cannot be specified with a high degree of certainty, while paradoxically both successful and unsuccessful artefacts will be far from equilibrium in terms of perceived product attractiveness. However, the



over zealous application of the *precautionary principle* will tend to stifle invention (and innovation) by over-emphasising ethics and safety, which are seen from the diagram to be key factors in the creation of artefacts. The retention of the notions of risk within the precautionary principle brings both ideological and technical concerns neither of which can be easily resolved. Resolution through the courts is only a partial outcome since courts must make judgments about specific instances, whereas the science involved in those judgments may be uncertain, open to dispute (it always is when complexity is involved) and likely to change significantly over the lifetime of the judgment. In addition, court judgments do not always deter ideologically motivated activists. At this point it is appropriate to spend a moment examining the UN description of the precautionary principle referred to earlier. As a reminder it is “[w]here there are threats of *serious* or *irreversible* damage, lack of *full scientific certainty* shall *not* be used as a reason for *postponing cost-effective measures* to *prevent* environmental degradation.” It is the words in italics that have to be the focus of comment because of their importance for business in performing its role as a provider of artefacts that are perceived to be attractive. Bearing in mind that sustainability and sustainable development are characterized by complexity, the comments run as follows:

- *Serious* is a matter of judgment that will be based on evidence presented; this will always be uncertain, incomplete and contestable in court. The UN description admits of no measure of error or uncertainty
- *Irreversible* is a notion that applies strictly to thermodynamic systems. At anytime when a court or regulatory judgment may be made, it seems the possibility of remediation, rectification, substitution or scientific or technological advance at a later date, even if confidently anticipated, cannot be entered as a plea to moderate any proposed action. But since the description is said to concern threats it implies that none of the events have yet occurred and therefore may not
- *Full scientific certainty* is and always has been a myth; this condition is never present in systems that exhibit complexity. In any event, science is dynamic and constantly applies the principle of falsifiability in order to advance
- *Not*: it is reasonable to be cautious in the face of uncertainty
- *Postponing cost-effective measures* to prevent an unsubstantiated possibility or worse and unknown possibility (an internally contradictory phrase in itself) may involve more risks than the events it proposes to prevent. In many instances in sustainable development, neither costs nor benefits of proposed measures can be quantified other than by the most dubious methods.

Despite the precautionary principle being heavily mired in dispute it is nevertheless alive and well in organisations like the US FDA and similar institutions in other fields, and other Developed and developing countries. There is, if it is looked for, a mountain of practical evidence for its successful use for many decades in many different industries and different fields: that does not mean all is well. Dispute abounds and current concerns cannot happily be ignored. The principle is reaching into new fields and creating tensions between many.

In the naive business equation, the *precautionary principle* influences all the independent variables. Sales may be increased or decreased according to how

artefacts are perceived to satisfy the values and norms, and of ethics and aesthetics of the polity. Prices may be influenced in the same way (for example Body Shop pricing and 'organic' farm products). Similarly, the principle will work its way through the cost variables, many of which will be increased. Perhaps the greatest hazard in the cost variable lies in legal costs, particularly of patenting, defending infringement claims and, worst of all defending a claim for damages arising from real or supposed injury or from artefact misuse (Product Liability). For business the principle may seem arduous and frustrating, but its embodiment in design processes can only be beneficial.

**Dematerialisation** could be argued to have given rise to the so called 'knowledge economy' more than either of its two companions, the precautionary principle and disintermediation. The claim would be all very well were it not for the fact that dematerialization is a very old concern, even if it went through an acceleration some quarter of a century ago with the arrival of many kinds of new materials that have become well characterized. Alongside these developments, modern methods of finite element analysis and other design methods, when associated with rising computer power, have made design processes, especially simulation, much more powerful. However, when it comes to perceived product attractiveness the outcome remains a conundrum since prospective purchasers are unwilling to pay more than the current 'going rate' for a familiar artefact or one of considerable similarity and familiarity. Often the conventional expectation (encouraged by economic sooth-saying) is for an ever decreasing artefact price while the functionality of an artefact increases: this conflict is readily apparent in the whole range of consumer durables.

How then is the manufacturer or service provider to maintain the surplus indicated in the naive equation? Do modern design processes work so powerfully on the cost variable that it decreases at a much faster rate than social expectations of price decline? Or is sales revenue (in this case through frantically expanding markets?) rising so much that the cost of highly knowledge driven design and production processes is irrelevant?

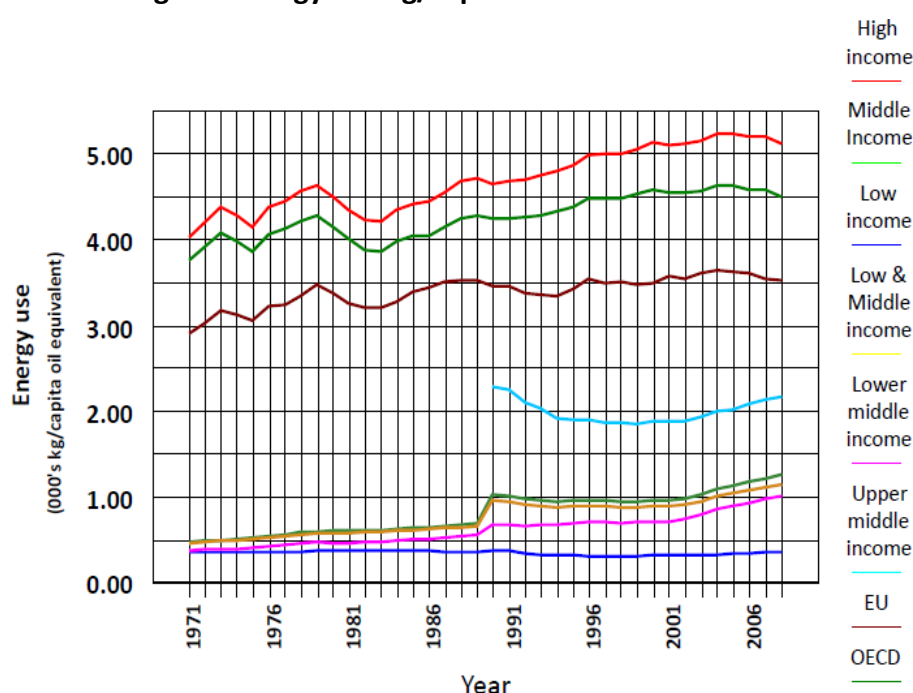
For *dematerialisation* the power of adapting the principle of parsimony is a self-evident and common practice. However, it now seems likely that regulation will require the wider use of *life cycle analysis* (LCA) as an adjunct to the design process; this will be a fearsome requirement needing a great many changes to the way organisations conduct their endeavours. However, LCA itself is not well developed lacking, for example, dimensions that involve toxicity which is an essential element of sustainable development. It needs to be remembered that *energy analysis*, first proposed by Soddy in 1922 underpins LCA and has serious implications for the adoption of the widespread use of recycling. Indeed, energy use underpins the philosophy of sustainability and of sustainable development.

As an aside, it is time for the widespread notion of 'energy conservation' to be disposed of, since the Law of Conservation of Energy is a fundamental one (it is the First Law of Thermodynamics). It is the conservation of fuel that is one of the keys to social and political harmony. Current endeavours should be to maintain the current quality of life or raise it, especially in the poorer regions of the world, without the

need for a commensurate ever increasing demand for fuel. In many respects the current rush into carbon taxes and tradable pollution permits needs much more examination. Imposing a blunt solution, based on dubious economic and ideological ideas, onto a situation characterized by complexity is probably going to be counterproductive, doing little to change the current relationship between the quality of life and energy used to create it.

Instead, a target reduction in energy per capita would leave the socio-economic system free to self organize ways in which the reduction could be achieved and from which, and rightly, no non-renewable fuel or 'renewable' energy supply would be excluded. The patterns of energy use, in Kg/capita (oil equivalent), between 1971 and 2006, is illustrated below.

**Fig. 2.8 Energy use Kg/capita between 1971 and 2006**



The last point to make is the influence *product life* has on dematerialization in the naive business equation. Here it is important to distinguish between *product life* and the more familiar *product life cycle*. Product life is literally the *lifetime* of the product from its birth to its death, from manufacture to its ultimate destruction: the relationship to dematerialization is obvious. By contrast, the *product life cycle* is market driven and is determined by the norms of life styles, rates of obsolescence of function, form, design and indirectly by a number of other factors: its relation to dematerialisation is, by contrast, more complicated than that for product life. However, a number of other paradoxical factors arise from product life and the product life cycle including:

- Extended product life reduces the rate at which material is processed, so that the perceived value of the product must compensate for this if cash flow is to be maintained through higher prices

- By contrast, the product life cycle may increase or decrease the quantity of material processed, depending on (a) the effect parsimony has in the design process in creating the perceived attractiveness of the artefact (b) the way in which the increased frequency with which new knowledge and new materials can influence parsimony and (c) the increased frequency with which new process knowledge can be introduced
- Extended product life decreases the opportunities to introduce new artefact and process design concepts, thus reducing the opportunities to apply parsimony but may be more effective in applying new knowledge in 'chunks' that are not trivial (which they may be in the product life cycle) and in the long run bring a more secure approach to sustainable development
- Once an artefact has been introduced there is, as has already been emphasised, generally a purchaser norm that expects its future forms to be of lower price even when the future form has considerably enhanced capabilities. Only if the future form is physically or psychologically perceived to be different is a price premium over existing artefacts likely to be acceptable. The problem is then how to create a flow of new knowledge for incorporation into the artefact in ways that enable the costs of its generation to be recovered when prices are expected to decline constantly and sometimes precipitately
- Design features may enable product life to be extended, sometimes considerably, by repairing or by enabling the up-rating of the original artefact, as has been the case for CPUs in personal computers: this may be considered as nesting and stretching if capabilities for this are provided in the original design concept
- The ability to include new knowledge frequently into an artefact referred to above, has importance for recycling. Again the conflict between product life and the product life cycle is complex. Extended product life may be synonymous with long production runs of artefacts that cannot be recycled or can only be partially recycled (usually the case now); design for disassembly is a relatively new notion. The product life cycle offers more frequent opportunities to remedy this situation, but may increase the amount of energy needed to cope with more frequent product and process changes allied to disassembly and recycling
- In both the above instances, the need for firmly based sciences and technologies of recycling, and for associated regulation and law, are paramount. The ability for inappropriate methods of recycling or waste management to create problems elsewhere in the ecosphere needs to be constantly in mind.

Dematerialisation then has many aspects that go to the heart of running any kind of enterprise. It is often a centrepiece of an invention and its subsequent innovation. Throughout the use of the term 'artefact' has been deliberate and needs to be read as including activities that elsewhere would be called either manufacturing or a service, as the 'service industries' are not immune to dematerialisation.

**Disintermediation** is not a new idea but has gone in and out of favour from time to time. Hawken's description of *disintermediation* as "...the elimination of middlemen and other intermediary people, processes and functions" clearly has many implications for business whatever form it takes. Just when the modern idea of disintermediation was created is obscure, but Hawken's statement in 1983 seems to

be a sensible defining moment. Taken to its logical extreme *disintermediation* implies the disappearance of the retail sector entirely, with artefact producers interfacing directly with purchasers. Could this happen? Most people would simply say “no,” but on a small scale disintermediation has always been present with farm shops, direct marketing by mills for woollen goods, share transactions and similar business activity. Retailing intermediaries came into being simply because it was easier and less costly for manufacturers to ‘outsource’ [*modern parlance*] the selling of goods than to do for themselves. Will producers of artefacts wish to return to direct selling in coming years? What would be the driving force behind such a major change? At each step in the value chain, each intermediary claims to add value to the artefact being processed. Often this added value is no more than bringing the artefact within the perception or physical reach of prospective purchasers.

Supposing that the intermediaries were removed would all the ‘added value’ accrue to the producer of the artefact? Currently, the outsourcing networks probably exert more power than the producer by claiming to reflect the purchaser’s perceptions of artefacts, including how they are valued. Until recently the procedures through which this reflection has been established have been clumsy, uncertain and full of time lags; it has been far from equilibrium and generally chaotic. Can these characteristics be removed? Yes, they can and they are being removed as retailers and credit agencies gather much detailed information from credit card transactions and through the use of ‘point-of-sale’ technologies. However, these methods, which pass largely unknown, introduce concerns for privacy and civil liberty as well as for sustainable development.

For Hawken’s vision of disintermediation even to appear over the horizon, and to begin its journey up the growth curve, will create tensions in the world of the current ‘mass society,’ while its appearance is likely to create real and potential for disruption, the extent of which will become increasingly apparent. If, as Hawken suggested, the indicator for this will be a headlong rush by companies into mergers and acquisitions (M&A) in an attempt to protect, through growing size, their position in mass society, and possibly to attempt to preserve that society as well, then there is plenty of evidence for his point of view. In the last three decades M&A activity has reached unparalleled levels and if anecdote is to be believed, its influence has been mostly ineffective. Whilst it is far from clear that all the frenetic M&A activity has done anything to strengthen the internal coherence and capability of companies, particularly by strengthening their internal knowledge base, it is obvious that in every case the successful predator ends up by increasing its capital assets. Here lies one of the threats of disintermediation, as it may well see the destruction of swathes of fixed assets in the form of redundant buildings and the like.

The present is a crucial time for disintermediation. The first real signs of its growth are now apparent in the ‘successes’ of on-line trading. The obvious examples are Amazon and other on-line bookstores (Amazon is now much more than a bookstore). Less well known are the moves being made by consumer organisations (e.g. ‘Which’) to introduce on-line purchasing of motor cars, by-passing conventional dealerships. Equally important is the development of on-line share trading and the extent to which the major banks are beginning to shed fixed assets by closing branches in favour of

on-line banking, while at least one company in the US is now supplying pharmaceuticals directly to purchasers via on-line ordering, thus providing a global service. Almost as an aside, it is worth recording that disintermediation has already entered the legal profession with some legal work being offered on-line in standard formats enabling the lay person to conduct simple legal affairs without recourse to face to face discussions with lawyers. Developments of this kind were anticipated by Suskind and are likely to proceed further in due course.

In many senses the developing countries are more familiar (unknowingly) with the idea of disintermediation as they are close to many of their cultures. All that can be said is that the portents of change toward disintermediation (in the Developed Countries) are now obvious whereas in 1983, when Hawken published his views, they were fragmentary. Where the final balance will lie between the present mass society and some future form, after disintermediation has wrought havoc after the current tendency for 'massification' by companies has been seen to fail and has gone into reverse, is difficult to judge. Substitution will not be complete, but the present 'massified' situation is unlikely to last, as giant companies are perceived to pay less and less attention to real human needs. In that sense the formation of giant companies runs against sustainability as they tend to have difficulty in operating in a world of complexity that operates far from equilibrium. The ability to adapt is an essential component of any living organism's tool-bag for survival when faced, as they all are, with changes in the 'world' they inhabit. Failure to adapt quickly enough leads to extinction. What the capital markets will make of disintermediation remains to be seen.

## **2.5 Influence of women and gender on Innovation**

Until very recently there has been little or no effort to understand the particular role of gender in innovation. There is no doubt that women have made very significant contributions to specific innovations, for example in creating software houses based on working from home and retail chains based on natural health care products. These examples have been relatively rare, mainly because it is only in recent years in the industrialised world that women have been prominent in innovation. In the developing countries there are networks of women engaged in innovation. However the specific role played by gender in innovation remains relatively little studied.

## **2.6 Influence of globalisation**

The term **globalisation** has become widely used in recent years to imply the way in which industrial and service activity has become independent of national and geographic boundaries. Typically, the phenomenon is seen to have grown from the way in which a small number of companies, mainly associated with manufacturing, began to place factories in the developing countries where the costs of production were lower than in their traditional industrial country bases. As an innovation, this step required these companies to ensure that the necessary skills were available in the host country. The creation of manufacturing in the host countries did not always proceed smoothly either due to misunderstandings related to the skills needed or due

to socio-cultural and political conflicts not being properly recognised or assessed. In many instances this led to factory closures and for a time there was considerable mobility of investment while companies learned to appreciate new factors that had to be taken into account when dealing with a potential host country.

In addition to appreciating new factors, the companies concerned in globalising their operations have also had to develop new ways of working internally to ensure that component parts made in one country were available at the correct times and at the required quality, elsewhere. In this sense these companies have had to create supply chains that will involve a network of external suppliers as well. The effectiveness of these matters will be reflected through the way the related value chain falls out. If the entire product was made in one location distribution systems had to be evolved to ensure that the products were available in the marketplace with all the requirements of the local market complied with, including many matters relating to product descriptions, safety and other local requirements regarding packaging, for example, taking religious or secular beliefs into account. Inverting this situation reveals the necessity for the host developing Countries to come to terms with procedures, requirements and even the handling, and use of materials that may come into conflict with local customs, taboos and socio-cultural beliefs, and organisational systems.

An essential issue to grasp here is that modern industry, whether it is involved in manufacturing or services, falls broadly into two categories as follows:

- (i) Assembly
- (ii) Whole product

These two categories have the following characteristics (**Table 2.3**):

**Table 2.3 Characteristics of ‘Assembly’ and ‘Whole product’ industry companies**

<b>Assembly industry companies</b>	<b>Whole product industry companies</b>
Designs artifacts from systems	Design and make complete products from basic raw or manufactured materials
Defines the major and minor subsystems that when assembled will make up the entire artifact	Reaction or reactor based processes that be either continuous or batch in character. Nanometre or molecular scale processes
Makes some parts of these systems but mostly subcontracts design of the subsystems to other companies	Distribution or either directly or end-user (who interacts with the general public) or to specialist component manufacturing companies which are part of the assembly industry set
Components for subsystems specified by subcontractors made and supplied to subcontractors by specialist companies	

Assembly industry companies	Whole product industry companies
Subcontractors assemble major and minor subsystems which are supplied to the assembly company	
Assembly company integrates all subsystems into the final artifact	
Dominant themes	
'Design and integrate' - technology based; continuous flow processes	'Design and make' - science based; nanometre or molecular scale processes

These characteristics are evident in the phenomenon of globalisation and have their effect on the opportunities for the developing countries. Examples of industries that fall into the two categories are given in **Table 2.4** below.

**Table 2.4 Industries typifying the 'Assembly' and 'Whole Product' categories**

Assembly industry companies	Whole product industry companies
Aircraft construction	Bulk and speciality chemicals
Motor vehicle construction	Genetically engineered materials
Locomotive building	Glass
Shipbuilding	Food products
Consumer electronics	Electronic components, especially integrated circuits
Retail stores	Materials extraction and processing
Building construction	Pharmaceuticals and drugs
Computer manufacture	Computer software
Photocopier and camera manufacture	Optical components and toners

The **assembly** industries are broadly those that design products that are then mainly assembled from components in the broadest meaning of the term. The companies themselves perhaps make only the key components in the whole assembly, but this is by no means a necessity. The strengths of these companies lie in design and innovation in response to a perceived market need: they are also particularly strong in their understanding of the assembly process, wherever that may be conducted. Their business is very dependent on access to a reliable network of suppliers who in themselves will lie at various positions along the assembled product value chain. While many companies in this group work at a macro-scale, more of them are beginning to work at the micro-scale.

**Whole product** industry companies both design and make their products in their entirety; they gain their competitive position from deep understanding of the necessary sciences and technologies in relation to product needs. They are not necessarily suppliers to assembly industries, though they may be in some fields. The



difference between the semiconductor and pharmaceutical industries illustrates this separation since the former's products, while designed and made in their entirety 'in house', are supplied to assembly companies. By contrast the pharmaceutical companies drug products are prescribed on their own, though it may be contended that the 'health industry' itself has the characteristics of an assembly industry.

The above classification of industries means that the developing countries are faced with choosing where their aspirations lie in relation to becoming part of an already established global pattern of industrial development, one that is unlikely to change as new manufacturing and service processes appear in the coming years. Many of the smaller industrial countries face similar choices, so that the Developing Countries are not alone in this respect, but will be in competition with existing industrial countries. In the developing countries, these choices will need to be made with a realistic assessment of skill levels, educational possibilities and national aspirations in mind.

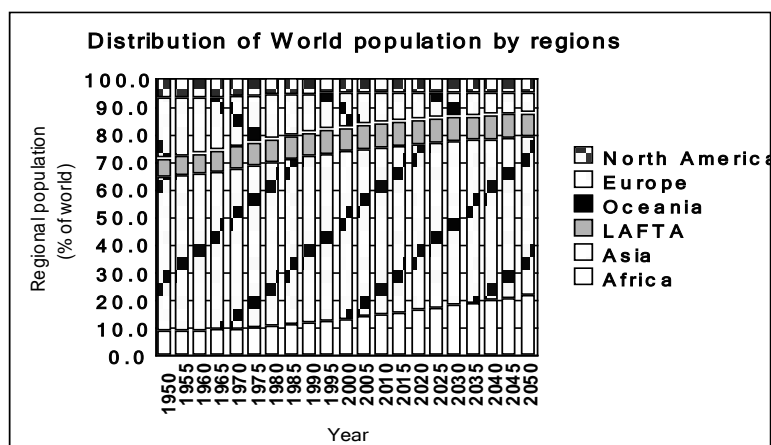
The role of indigenous science and technology in competitiveness, employment (including job creation, unemployment and underemployment) and socio-economic development in the developing countries, is complicated by their very wide spread of development. The role of science and technology *in the familiar sense* is not well known in the *least* developed and the *sub-Saharan* regions and is most likely to become recognizable to the industrialised countries from those countries of Medium HDI and upwards. However, as the **Case Studies (Section 4)** show, imported leading edge technologies are relevant to innovations in important infrastructure developments (e.g. communication systems based on wireless mobile telephony) that are influencing the future of the *least* developed countries whilst the mechanisms of financing have been created.

## **2.7 Geopolitical influences: the changing balance between Developed Countries and Developing Countries**

The influence of geopolitical forces throughout the world is a very complex matter involving political and economic power. It also faces the Clausewitzian doctrine that war (economic or military) is the conduct of political debate by 'other means'; while this will not be dwelt on it needs to be remembered (war-fighting capability and its economic equivalent, and the perceived or actual willingness to use them, are essential elements of any politico-economic balance) in the following necessarily brief commentary on the changing balance of geopolitical influence between the Developed and developing countries. There are two essential boundaries to the commentary presented and these are the means of grouping Developed and developing countries, a necessary but difficult, if not undesirable boundary to draw. The second essential boundary is the time horizon used. The former will make use of the human development index (HDI), a measure of essential qualities of a chosen part of the world's population. There are three essential components to the HDI, health, education and living standards. Recently, the original components have been revised into four in which life expectancy at birth (health); mean years of schooling + expected years of schooling (education); and gross national income per capita are the essential components. When combined in equal weights they make up the HDI. The

HDI may then be perceived to be a surrogate for the essential needs for the possibility of invention and innovation, and for the potential economic capability of the Earth's population (for a full explanation of the computation of an HDI see the Technical Note 1, Human Development Report 2010). The HDI is the clearest indicator of the imbalance that existed, until recent years, in the geopolitical influences between the Developed and developing countries. As shown in Fig. 2.9, three regions, LAFTA, Asia and Africa contained 80% of the world's population, while Asia alone makes up 60%.

**Fig. 2.9 World population by regions**



In proportions this picture is forecast to remain virtually unchanged up to 2050; this is a long established picture showing an inexorable dominance by the developing countries. The decline of total fertility rates in the Developed Countries, and the consequent combination of crude birth rates and death rates, have resulted in ageing populations in the Developed Countries. None of this has changed the phenomenon of the demographic shift in the developing countries that promotes the decline in crude birth rates as these countries become wealthier, a change that brings many new ways of living into each country.

Commonly, the OECD countries are taken to represent the Developed Countries that project what is perceived to be 'Western capitalism' as the dominant feature of world development. The OECD group comprises 31 countries classified as Very High Development according to the HDI ratings (**Tables 2.5 & 2.6**). There are exceptions; these are shown in **Tables 2.7 & 2.8**.

**Table 2.5 HDI by Development Group**

Group	HDI	Range
V. High	0.854	0.788-0.938
High	0.725	0.677-0.784
Medium	0.590	0.488-0.669
Low	0.375	0.140-0.470

**Table 2.6 OECD Countries by High HDI**

Country	HDI	GNI
Australia	0.937	38,692
Austria	0.851	37,056
Belgium	0.867	34,873
Canada	0.888	38,668
Czech Republic	0.841	22,678
Denmark	0.866	36,404
Estonia	0.812	17,168
Finland	0.871	33,872
France	0.872	34,341
Germany	0.885	35,308
Greece	0.855	27,580
Hungary	0.805	17,472
Iceland	0.869	22,917
Ireland	0.895	33,078
Israel	0.872	27,831
Italy	0.854	29,619
Japan	0.884	34,692
Korea	0.877	29,518
Luxembourg	0.852	51,109
Netherlands	0.890	40,658
New Zealand	0.907	25,438
Norway	0.938	58,810
Poland	0.795	17,803
Portugal	0.795	22,105
Slovak Republic	0.818	21,658
Slovenia	0.828	25,857
Spain	0.863	29,661
Sweden	0.885	36,936
Switzerland	0.874	39,849
United Kingdom	0.849	35,087
United States	0.902	47,094

**Table 2.7 Non-OECD Countries with Very High HDI**

Non-OECD V. High Development	HDI	GNI
Cyprus	0.810	21,962
Hong Kong	0.862	45,090
Liechtenstein	0.891	81,011
Malta	0.815	21,004
Qatar	0.803	79,426
Singapore	0.846	48,893
UAE	0.815	58,006

**Table 2.8 OECD Countries Not Very High Development**

OECD Not V. High Development	HDI	GNI
Chile	0.783	13,561
Mexico	0.750	13,971
Turkey	0.679	13,359

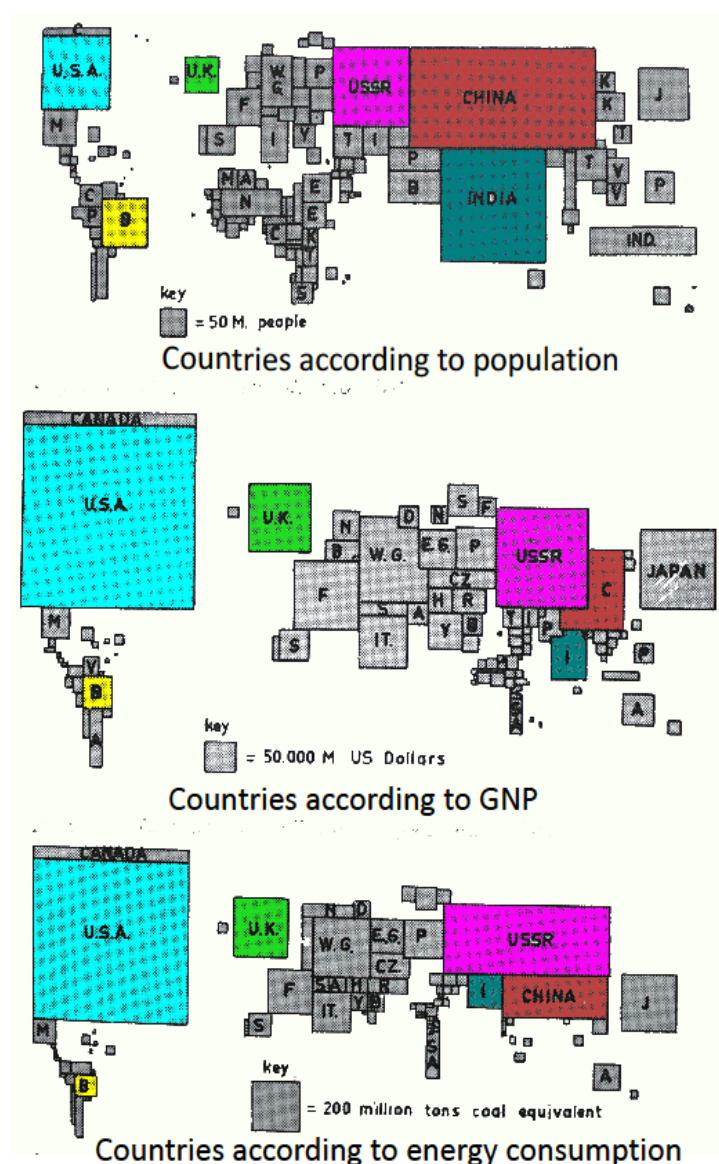
The OECD countries, with the exceptions indicated, have in many respects driven the geopolitical cum economic imbalances between the Developed and developing countries: this dominance is illustrated by a view of the world projected in 1973 prior to the first 'oil shock' (**Fig. 2.10**). These disparities have a long history and could be described as the last major rearrangement of the pieces on the chessboard that makes up the geopolitical cum economic influences around the world: that rearrangement took several centuries as the world's power and intellectual centres shifted slowly but inexorably from East to West. These influences accelerated toward their 'completion' during the late 19<sup>th</sup> and early 20<sup>th</sup> Centuries. Data concerning population and income per capita showed what seemed to be an ever increasing disparity between the US and N.W. Europe, as it was referred to in the 1950s before the Treaty of Rome, and China and S.E. Asia. However, the population data, allied to memories of how in past centuries these latter two regions had been the source of cultural and scientific cum technological advance, left a sense of unease about the long term future among some observers. The last 40 years have confirmed that sense of unease. The influence of China and India, and many smaller countries, the so-called Asian Tigers, began to create the feeling of a reverse of the centuries earlier shift to begin to re-establish a new dominance from the East. The trend is becoming established while the initial Asian Tigers (Japan and other smaller Pacific Rim countries) are in partial *diminendo*, Brazil, the Russian Federation, India, China and now South Africa are recognised as a geopolitical force to be reckoned with as discussed in the next section.

## **2.8 The BRICS countries: their influence on the geopolitical balance between the Developed and Developing Countries**

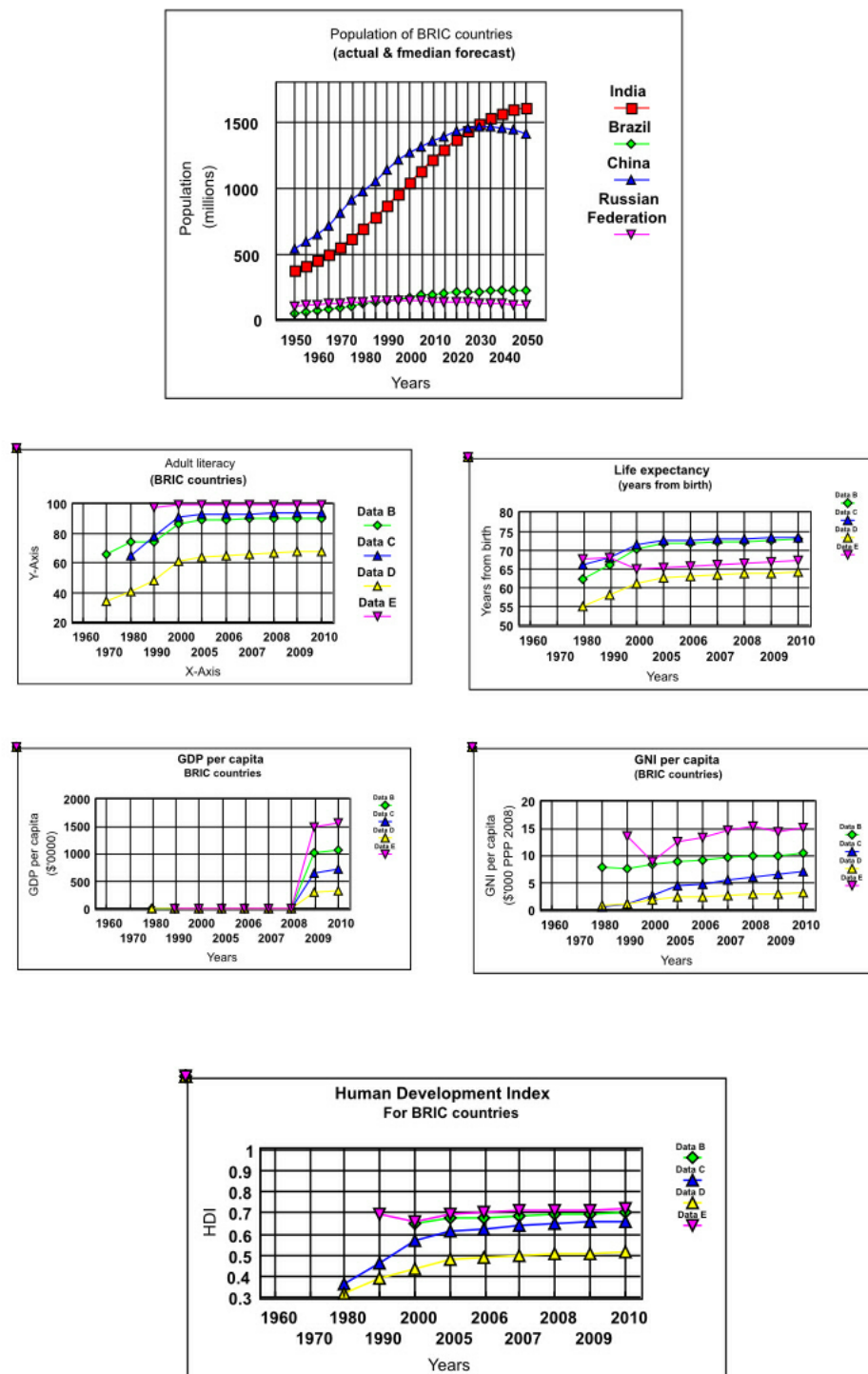
Brazil, Russian Federation, India, and China formed the original group now known as the BRIC countries. At the time of writing (April 2011) South Africa has attended BRIC country meetings but it is unclear whether it has become one of the group. The BRICs are becoming a powerhouse in world affairs. Brazil and Russia, together with other Latin American and African countries, are rich in basic resources that China and India value, particularly the former. As mentioned above, in the 1970s a weak signal of impending change was recognised. It concerned those countries and regions in which there was a combination of a rapidly growing population allied to a past history, maybe centuries ago, of significant scientific capability. Together these indicated a low but non-zero probability of a resurgence. China, India and more recently Russia were three such countries. Adding a further dimension, of abundant resources of essential kinds for industrialisation in the modern idiom, i.e. Western capitalism, brought the focus onto Russia, Brazil and, very recently, South Africa and other parts

of the African continent. In addition the influence of the Pacific Rim increased with the growing influence of Japan whose technology revolutionized many important industries from shipbuilding, to automobiles and to electronics. In 2001 research by Goldman Sachs crystallized their belief, and that of many observers, that Brazil, The Russian Federation, India and China, and now possibly South Africa, might well become a new industrial, but loosely aligned, powerhouse, led essentially by China. In 2005, after further research. Goldman Sachs added a further group of eleven countries (acronym N-11 including Bangladesh, Egypt, Indonesia, Iran, [South or a reunified] Korea, Mexico, Nigeria, Pakistan, Philippines, Turkey and Vietnam) in looking beyond the the BRIC group. Of the N-11 only Mexico and Korea were thought to be likely to graduate to the BRIC group by 2050.

**Fig 2.10 A World view in 1973**



**Fig. 2.11 BRIC countries basic information**



Unsurprisingly, the Goldman Sachs reports, which run from 2001 onwards, are focused on the BRICs as investment opportunities which, given the growth of the 'group', have been and look set to continue to be very attractive. Nevertheless considerable scope is given to how the views expressed might not come about. Before discussing these Fig. 2.11 above sets out some basic information about the BRIC countries from which some simple conclusions can be drawn. Population levels and growth rates separate the five countries into two distinct groups: India and China have populations far greater than Brazil, Russia (and South Africa if eventually included). China's population is forecast to begin to decline from 2030 while India's does not although the growth rate begins to decline. In contrast the Russian population is forecast to decline while Brazil's reaches a plateau. In terms of the HDI none of the BRICs fall into the Very High Development group. Russia and Brazil fall into the High Development group while China and India fall into the Medium Development group. As can be seen from **Table 2.9** below, many of the N-11 group have higher HDI's than the BRIC group. However, their smaller populations may prevent them from having the impact of the current BRIC group.

Country	HDI
Bangladesh	0.469
Egypt	0.620
Indonesia	0.600
Iran	0.702
Korea (S)	0.877
Mexico	0.750
Nigeria	0.423
Pakistan	0.490
Philippines	0.638
Turkey	0.679
Vietnam	0.572

Investors and governments alike need similar but diverse information though it may be used differently. The choice of information, especially composite indicators, is simply that, a matter of choice. For the BRIC and the N-11 countries investors need to be aware of the levels of risk involved; the nature of the financial instruments through which investment will take place and the order of returns they can expect. The extensive research and the assessment of the future risks involved for investors lies behind Goldman Sach's publications; for these the HDI may not be the most relevant indicator. Goldman Sach's also have a vested interest in promoting investment. For governments the HDI may be the more important indicator. The indicators have a story to tell. For the BRICs to have assumed high importance in the investment world the reasons lie in those matters that the HDI does not deal with, mostly to do with access to raw materials and politics. The BRICs, especially China, embarked some years ago on a conventional path to industrialisation. The 1999 Toolkit raised the possibility, however obliquely, of the developing countries by-passing the most disadvantageous aspects of industrialisation posing strong demands for two-way collaborations between the Developed and developing countries. The present conventional pathway to industrialisation being followed by the BRIC countries has to

be judged against the Millennium goals and the possible alternatives of by-passing much of that conventional pathway.

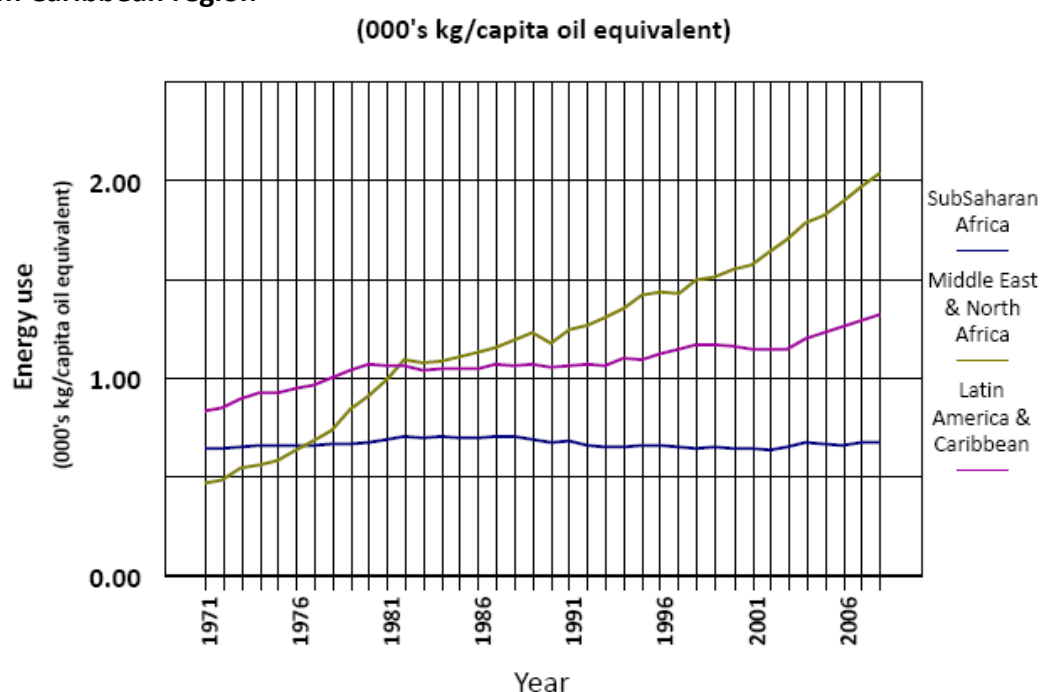
## 2.9 Africa

The diverse state of development throughout the African continent can be illustrated clearly from the spread of their HDI's; their energy use/capita and the distribution of preventable blindness when used as a surrogate for health matters. These three indicators are illustrated in **Table 2.10** and **Figs. 2.12 and 2.13**. In concert these indicate the effort that will need to be orchestrated if the Millennium goals are to be attained within a matter of decades.

**Table 2.10 Distribution of African countries by HDI**

Country Group	Number of Countries	HDI range	Group as % of total
High HDI	4	0.755-0.677	8
Medium HDI	10	0.648-0.488	21
Low HDI	34	0.470-0.140	71

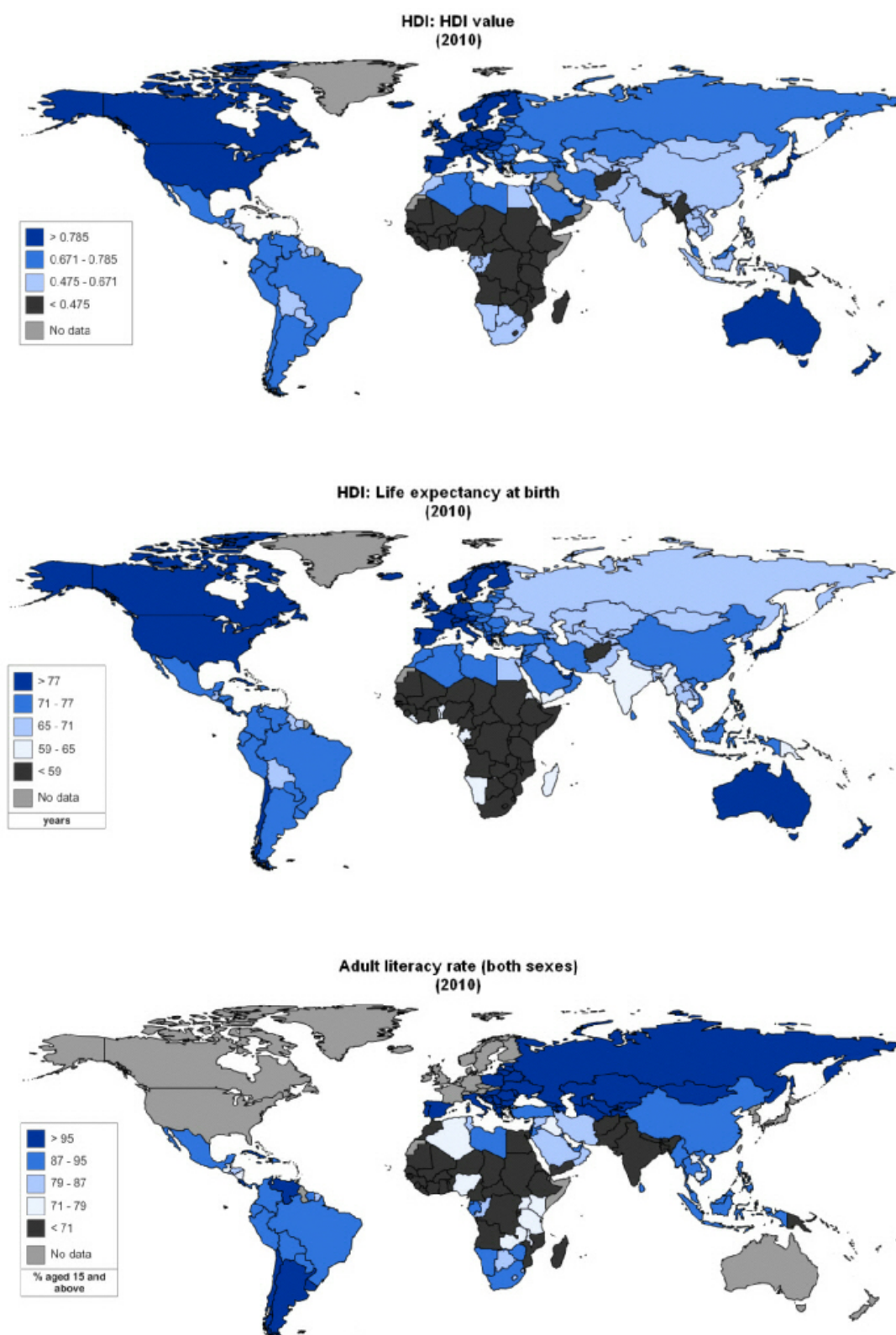
**Fig. 2.12 Geographic difference in energy use between the Sub-Saharan Africa and the Mediterranean cum North African regions compared with the Latin American cum Caribbean region**



The geographical distribution of the countries represented in **Table 2.10** is shown in **Fig. 2.13**. Preventable blindness (Case Study 10) can be taken as a surrogate for many specific aspects of health and health management/care and its distribution across the continent mirrors closely and not surprisingly, life expectancy and adult literacy



**Fig. 2.13 Africa: Values of the HDI, Life expectancy and Adult literacy by comparison with the rest of the world**



components of the HDI. The presence of this ecological, political and cultural value diversity across the continent poses particularly arduous requirements for the achievement of the Millennium goals any time soon. As **Fig. 2.13** illustrates only three countries on the Mediterranean coast, Algeria, Morocco and Libya, all of which, at the time of writing, are undergoing political instability, even though they are in the High Development group when rated by the HDI.

By contrast all the countries, irrespective of their position in the HDI scale, embrace modern technologies widely to enable electricity generation (photovoltaic panels) to power wireless communication systems, water pumps, cold storage for vaccines and other applications as indicated in the case studies set out later. In this respect the people in Africa readily adopt technologies appropriate to their needs, though at times it seems somewhat bizarre to find high technology equipment in shanty towns that exhibit all the properties of the Low and even the Lowest HDI countries.

The INNforMED project, carried out under the EU's FP6 programme, looked at questions of innovation in science and technology and their anticipated directions, in three Mediterranean African countries, Egypt and Morocco (both Medium HDI), and Tunisia (High HDI). The recommendations that emerged from the project were more in line with expectations aligned with the higher energy/capita background of these three countries. The proposals were also for projects that these expectations might support provided Foreign Direct Investment would support them. The level of appropriateness and appropriability were of a different kind to those that might be expected in Low HDI and low energy/capita regions (and countries) where financing would be more difficult. For example, it was noted that innovations in solar and wind systems for the large scale production of electricity would be appropriate.

In what can be no more than a signpost to change in Africa and among African's views of their future perhaps the most positive signs lie in the Sub-Saharan (SSA) regions. It is now many decades since colonialism began its retreat from SSA. During those decades many outside the region either despaired of its future or, more often, engaged in a form of 'resource pillage'. Does the shift that has occurred in South Africa mark the beginning of a new beginning for SSA? In a recent special edition of the journal Foresight the question was asked 'Is Africa the land of the future? It is not a given!' following much optimistic speculation about the 'emergence of Africa' in the 21<sup>st</sup> Century. The authors raise a series of important situations that flow from the above question. The depth of the examination can be judged from the topics involved including implications of the global crisis for African countries between 2010 and 2020. Four scenarios were developed and examined for their implications for groups of African countries, all related to the post current financial crisis. The four scenarios were as follows:

- South by South East (Stagnating West, Resurgent East)
- Western (Re)invention (US and EU reinvention)
- The Odd Couple (the rise of 'Chimerica')

- Rollercoaster (a financially unstable world)

Other matters not as separate scenarios were:

- Serious challenges of food security remain
- Concerns about foreign direct investment overwhelming local development priorities persist
- Major institutional and governance lapses run the risk for overturning the democratic gains on the continent
- The population of unemployed [*and underemployed*] and restless urban youth grows larger
- There is a criminal element in entrepreneurship activities

Lastly, it is the decisions that will be made by African and international policy-makers, businesses, civic organizations, and citizens today that will determine which direction Africa will be 'driven' towards tomorrow. With this background and from the scenario analysis the authors identified the following drivers of change:

- Perceptions
- Governance
- Knowledge and Education
- Technology
- Entrepreneurship
- Globalisation
- Society

The papers in the *Special Issue of Foresight*<sup>6</sup> are based on the proceedings of the 2010 Pardee Conference on 'Africa 2060: Good News from Africa'<sup>7</sup> a remarkable title in itself, four overarching conclusions had become evident:

- Africa's future will ultimately be driven by African decisions made in Africa and by Africans, in the face of many external forces, e.g. technology and globalisation, that are and will remain important over the time horizon chosen.
- How Africa sees itself and how Africans see themselves will determine the level of confidence the continent will assert in its own future
- Governance, at every relevant level, will remain a key challenge but also a key opportunity and is the most significant factor that steers all the drivers listed
- As claimed by Lauterbach (*ibid*) it will be how the mindset within African society develops over the next half century that will be as important as any economic force, external or internal

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<sup>6</sup> <http://www.ingentaconnect.com/content/mcb/273>

<sup>7</sup> <http://www.bu.edu/pardee/2010/04/06/good-news-from-africa/>

As with other developing parts of the world there will be exciting opportunities that await Africa. For all developing countries these involve hurdles including invention, innovation, entrepreneurship, technology and knowledge in a globalized world. There remains the potential reality of bad news. The choices are now African. From analysis of the scenarios the authors suggested that:

- Countries that are fuel importers and also dependent on both primary commodity exports and aid that will be most vulnerable to the changes taking place in the global economic environment
- There may be new scramble for Africa with a focus on Brazil and South Africa (there is already evidence for this from Chinese, Indian and Brazilian interests)
- The rise of Brazil, its pursuit of the African market and the alternatives for South Africa as the economic super power in the region in competing with Brazil for the African market.

Further the authors suggested the following 'good news' from Africa:

- Poverty is falling
- Food productivity is rising
- Inequality is falling
- Women are assuming positions of leadership
- Democracy and elections are becoming the norm
- Regional markets are developing
- Anti-corruption measures are gaining prominence
- Africa is becoming an important destination for foreign direct investment, especially from China
- African intelligentsia is finding a more prominent voice in defining Africa's options
- Continent-wide cultural expression is strengthening a positive continental identity)

There are also a number of persistent concerns and hurdles including:

- Serious health deficiencies plague the continent and many are increasing in intensity
- Access and availability of education in Africa remain dismal
- Even economies experiencing high growth rates have a high number of poor living at the margin.

## **2.10 The growth of city regions**

There are two aspects of the evolution of cities that encroach into the developing countries. The first was proposed by Jane Jacobs (1984), while the second, and more futuristic, was proposed by Doxiadis Associates in the notion described as Megalopolis a type of city, that forms an extensive metropolitan area or a long chain of continuous metropolitan areas. Ecumenopolis, a word proposed by Doxiadis in 1967, would be

the final outcome of this process of city growth, leading a to world city. Thus *ecumenopolises* represents the idea that future urban areas and megalopolises would eventually fuse: there would be a single continuous worldwide city as a progression from the current urbanization and population growth trends (these are sometimes referred to as *megacities*).

The initial steps towards ecumenopolis are the familiar ones of conventional industrialisation in which once factories are set up, cities grow round them and there is extensive migration from rural areas into the new employment regions. Population growth and the kind of industrial agglomeration that occurs then determines whether a city region of the kind described by Jane Jacobs occurs. Essentially, vibrant cities become economic entities on their own, a geographically large enough country may contain several of these city regions that can trade with other city regions. Populations in successful city regions are then capable of invention and innovations that can be traded. Agglomeration of city regions may eventually lead towards megacities and possibly ecumenopolis, though the latter may be no more than a guiding concept.

There is evidence for some of these eventualities. For example a global urbanized area extends across world regions along recognised transportation trunk lines. For example, an ecumenopolis in North America runs along I-95 from Portland, Maine down to Miami. In Southeast Asia, there is continuous development from Hanoi to Bangkok and via Phuket to Singapore, then over to Indonesia and the island of Java, ending at Bali. Similarly, Doxiadis Associates are studying the possibility of a new Pakistan city called DHA to be situated 35 kilometres away from Karachi, the largest city and port of Pakistan. DHA will have an area of 11,640 acres and is envisioned as a paradigm for other cities in the region. It is a landmark project for the city of Karachi that introduces new standards of planning and points the way to the expansion of the metropolis towards Hyderabad, the second largest city of the region, and toward a megacity.

## **2.11 Innovation management and useful procedures**

The comments made in this section are drawn from Developed Country experience: they can give a guide to necessities for the management of innovation in Developing Countries, and localities within them but adaptation of the ideas presented will be inevitable. Throughout the separation of the meanings of invention and innovation needs to be remembered. As a reminder, innovation (the subject here) is a socio-economic-ecologic-political and value/norm matter through which an artefact (physical product or service – physical and virtual) achieves widespread use. By contrast, invention is the creation of a new artefact and is a pseudo random process however much guidance it may receive.

### **2.11.1 Management issues**

Once the need for innovation is accepted (it should not be taken for granted that it is), the key management issue is the creation and maintenance of a working climate in

which innovation is accepted and encouraged: this needs to be done without losing control of the organisations affairs, whatever its size. Simple as it may seem, meeting this requirement has been the subject of considerable thought and experiment in all kinds of organisations in the Developed Countries. Much of the endeavour has been recorded in what has become a voluminous literature. How much of that literature is really influential or is likely to be helpful to the developing countries is another matter, given their diverse and different socio-cultural and political arrangements. There is one common feature to innovation wherever it is attempted: the need to allocate resources from a limited pool. Whatever the innovation, for it to proceed it will have to run the gauntlet of selection procedures: these can be manipulated easily as they are essentially political. The procedures for making these choices are neither rigorous nor consistent for the following reasons:

- (i) Judgements are made on the basis of historical and known practice
- (ii) The aspects considered in reaching these judgements vary widely from case to case
- (iii) The depth of consideration given is uneven
- (iv) The judgements are often based on what is described as combinations of 'faith' and 'hunch' accompanied by incomplete quantification (which may be unavoidable but may also be heavily biased) and limited assumptions
- (v) Weight is given only to those aspects on which 'good' information exists
- (vi) Political and social influences are overlooked

In this context, the more radical an innovation is, the less likely it is to pass all the hurdles that will be erected in its path, partly because it will be perceived to be more disruptive towards established routines, while it will in itself be more difficult to understand. It is easy to see that in organisations that vary from autocratic to participative and democratic, the creation of a transparent procedure for choosing which innovations to implement and exploit is more or less difficult.

It is then impossible to give specific directions that are guaranteed to succeed in creating an environment in which innovation *will* flourish. Perhaps the single common rule is *not to punish unsuccessful innovation too harshly*. By definition, innovation carries risks; if failed innovation is not punished in some way the atmosphere becomes libertarian and undisciplined. By contrast, severe punishment for failure quickly becomes demoralising and the willingness to innovate recedes. The balance between punishment and reward is a matter of judgement that depends on the socio-cultural mores of the locality, organisation and its managers. Another related matter is the well-known need for *champions* who will take responsibility for supporting and pushing forward an innovation, particularly in companies where the obstacles to an innovation are always considerable. Champions need to have the same level of commitment as an external entrepreneur (which is why they are often called *intrapreneurs*) being willing to take considerable personal risks in the corporate environment. Pinchot (1985) characterised intrapreneurs as being willing to:

- Go to work every day willing to be sacked
- Circumvent any attempt to stop the innovation project

- Do any job needed to make the project successful irrespective of formal job description
- Find people willing to help the project
- Follow intuition to choose the best people to work with
- Work underground as long as necessary or as long as possible to avoid the publicity that will trigger the corporate immuno-rejection phenomenon
- Take on the risks of the project but only if the intrapreneur is in charge
- Ask for forgiveness rather than permission (i.e. to act on one's own judgement and to accept the consequences)
- Be true to one's goals but to be realistic about how they can be achieved
- Honour one's sponsors

These characteristics (based on evidence from the Developed Countries, particularly the USA) have set the tone for some considerable innovation champions, without whom little would happen whatever the nature of the organisation. Some examples of what intrapreneurs have achieved are enlightening; they include:

- Kollmorgen's automatic wiring process and interconnect boards
- Apple Computers graphics tablet and plotter
- IBM's personal computer
- 3M's post it note pads
- Du Pont's automatic clinical analyser
- Lockheed's Starfighter, the U-2 and the SR-71

The immense range of the scale of these inventions cum innovations and of the commitments needed by their champions illustrates capabilities needed by the individuals themselves and how they were able to gather together the necessary resources for considerable periods of time, sometimes without the knowledge of their companies. The different case studies of **Chapter 4** will illustrate this further.

### **2.11.2 Technology Foresight and Technology Watch**

#### **Practical issues and implementation**

Foresight is a natural activity widely referred to in texts ranging from brain science, philosophy and the hard engineering sciences (this is typified by the Foresight Institute whose concern is near molecular scale technology), but there is a need to sensitise people to it. The purpose of foresight is to look for what other people do not perceive: to cultivate that ability requires practice. The art of foresight is to anticipate the unusual. The motto is 'Never take the world as it seems.' Sometimes foresight results from only the faintest and oddest information giving a clue to an important event or trend.

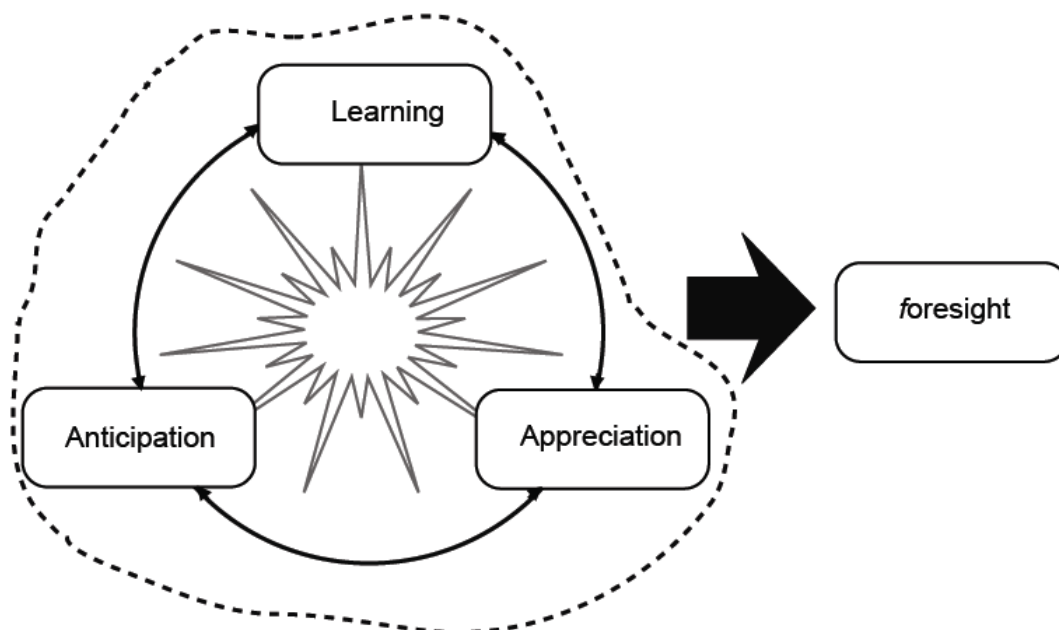
Foresight is simply the act of looking forward, it is not forecasting which presupposes that some action will follow from the activity. There are some embellishments to the meaning of foresight; these almost always refer to foresight as being systematic and a way of obtaining opinion on topics pertaining to the future. Technology Foresight is a

special case. For the United Kingdom's Technology Foresight Programme, it had the following definition;

'Technology foresight is a systematic means of assessing those scientific and technological developments which could have a strong impact on industrial competitiveness, wealth creation and quality of life. The aim is to advance the generation of generic technologies and their application in many industrial, social and economic fields.'

Notice the inclusion of the words systematic and assessing. Foresight *identifies* technologies or other developments that could have a strong influence on the future (a matter of subjective opinion), characterized in the UK technology foresight programme by wealth creation and the quality of life in the polity. Foresight is an art and not science in any sense of the word; it uses neither the principles nor the methods of science. Foresight is a marriage of intuition, knowledge of the directions being taken by science and technology and anticipation of, and a sensitivity to developing trends in society. The nature of this marriage, which depends on appreciative learning, anticipation and numeracy, is illustrated in **Fig. 2.13**. where the nature of the transition in the modes of thought is related to the shift from what is known to the more risky modes of thought involved in innovation; there knowledge extended into the future becomes increasingly uncertain. However, underlying this has to be a simple dictum pronounced by Al Haig, one time US Secretary of State, namely that "Vision without discipline is daydream." Disciplined thought, as illustrated in **Fig. 2.14** is an essential quality of foresight just as it is required by any other art form.

**Fig. 2.14 Foresight: Appreciation, Anticipation and Learning**

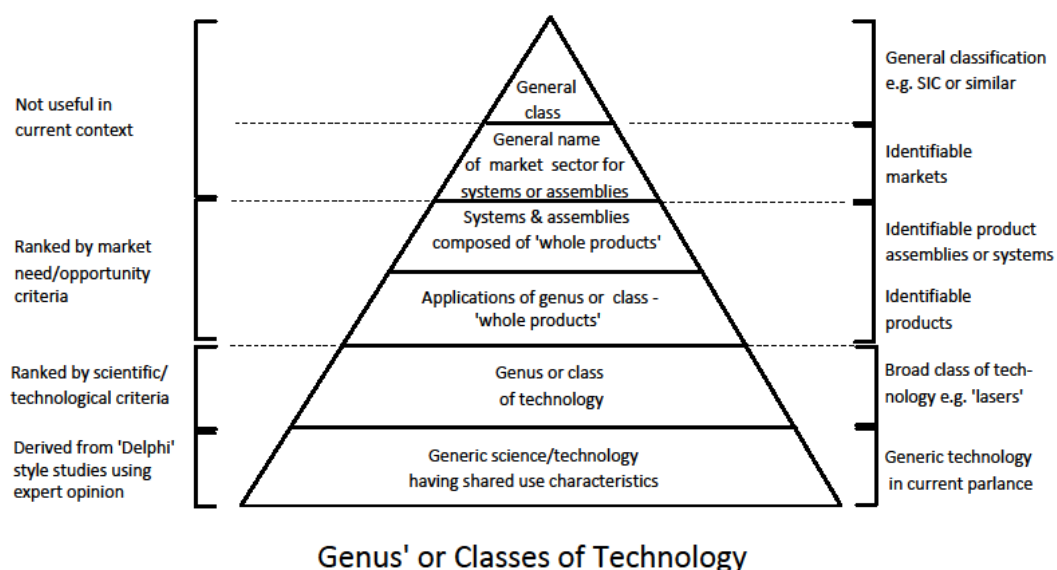




Sometimes the lack of a scientific basis causes difficulty in obtaining acceptance of foresight activity, but in the end foresight impinges on both the political and scientific worlds.

Foresight also advances the identification of what are called generic technologies and their application in many technological and economic themes. Generic technologies were defined, for the UK government, in the 1993 White Paper 'Realizing our Potential' as being those emerging sciences and technologies that would in future underpin many others. As will be seen shortly, this definition is very close to one set down by the RAND Corporation for *critical* technologies. For example, laser technology underpins many other technologies while the stepper motor underpins microelectronic technology and the mechanical forms of nanotechnology; these relationships are illustrated in **Fig. 2.15**.

**Fig. 2.15 Interrelationship of generic technologies**



For Developing Countries it is natural that generic technologies will be very different in nature to those just referred to and illustrated in **Fig. 2.15**, but, as will be seen in the case studies of **Chapter 4**, they may well involve advanced technology adapted for the local purposes. It cannot be stressed too highly that *appropriateness* and *appropriability* are two key concepts for innovation to be successful *anywhere* but especially so in the Developing Countries where resources have to be made to do so much (particularly in the *least* developed of the Developing Countries). However, the influence of communications technologies, particularly television, cannot be neglected in any foresight study relating to the aspirations of the developing

countries, as the television medium can have major influences on social expectations as well as creating socio-cultural tensions.

So far technology foresight programmes have been confined to the major industrial countries; the best way for the developing countries, particularly the poorer ones, to become involved in this activity, which has developed globally, is to make use of the outcome of those programmes all of which are freely available and are so far free of intellectual property considerations. Applying the tests of appropriateness and appropriability will lead these countries quickly to the items of interest.

Generic technologies are often, and sometimes confusingly, referred to as *critical* technologies, but until recently the notion of criticality has been a confused jumble of ideas. Recent thoughtful work at the RAND Corporation (Bimber & Popper 1994) has the prospect of bringing some order into this confused field by setting out rules for characterizing criticality. In the RAND Corporation's view a;

"Critical technology is generic and pre-competitive and recognizes the technology concerned as useful in many applications and likely to produce a wide array of returns not tied to any specific application. The technology is likely to have a synergistic or catalytic effect elsewhere"

Critical technology is then not concerned with national security or similar matters.

### **Foresight studies**

Typically these are carried out for a sponsor who appoints a high level group to manage the project and report the outcome to the sponsor. The detailed work is often carried out by a set of panels, whose work is specified to cover defined areas of either technology or a national economy. The panels may use any of a number of processes to complete their task, including brainstorming, surveys of opinion and scenario building for example. Their reports need to be clearly expressed, giving recommendations for concrete actions and enabling the whole set of reports to be integrated by the high level group into a report to the sponsor. Many of these reports are now becoming accessible via the Internet, but they are not yet in a common language, which can restrict their value. Scenario building is often part of a foresight programme, but it needs to be remembered that foresight is an essential *input* to scenarios and not *vice versa*.

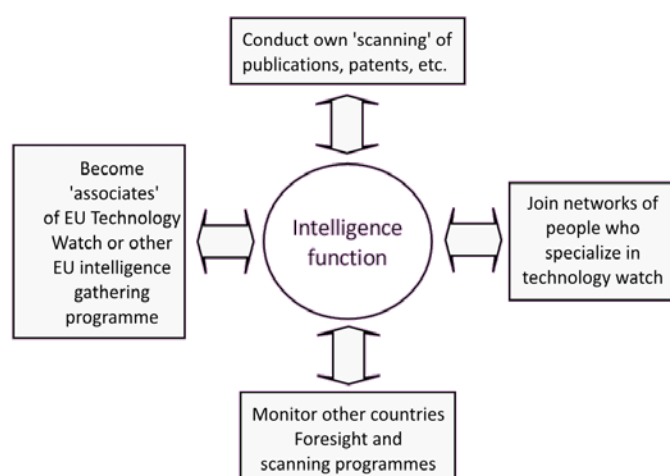
### **Technology watch**

Technology watch is not a well defined process but it is an adjunct to foresight. The notion of technology watch was first formalized by Allen (1970) in the early 1970s through technology 'gatekeepers.' These were people, particularly in companies, who had a natural interest in particular sciences and technologies that led them to keep in touch with developments in their fields of interest. These people were valuable to companies as sources of 'expert' knowledge of the directions being taken by various sciences and technologies. The 'gatekeeper' approach was successful only if there

were 'naturally occurring' sources of knowledge, appointed gatekeepers were never as successful nor as resourceful. At about the same time the American life insurance industry was becoming alarmed at the rising value of claims and wished to have a way of anticipating socio-technical changes that might lead to rising claims. An approach, known as *environmental scanning* not to be confused with the natural environment, was developed by Weiner, Edrich, Brown, Inc., which was remarkably successful. The approach was later developed further by SRI International and the Business Futures Network but their methods remain proprietary. Most recently the European Commission has established the European Science and Technology Observatory (ESTO) at its research centre at Seville. The EU Commission has created a number of other 'monitoring' programmes including the European Foresight Monitoring Network (EFMN) and the iKnow scanning project. In addition the Rockefeller Institute has also recently created a scanning project. All these scanning projects have the objective of creating databases of the so called 'weak signals of change' as does the work of the Global Business Network (GBN), SRI Consulting, the Business Futures Network (BFN), RAFFA P.C. and a number of other organisations (the list is not exhaustive). Technology watch is the declared objective of ESTO, which has spawned a number of offshoots, who have adopted an approach based on contributions from a large number of organisations throughout the European Union. How successful the programme will be in identifying the directions being taken by science and technology *and the consequent influences on the socio-economic world of the EU* remains to be seen. The developing countries need to be aware of what these organisations and programmes are doing to keep up to date with developments in science and technology and their influence on innovation by industry.

For the developing countries, technology watch is important. Any process needs to be simple but effective and might be along the lines illustrated in **Fig. 2.16**.

**Fig. 2.16 A possible technology watch arrangement**



### **2.11.3 Outcome of Manchester Institute of Innovation (MloIR)'s Global Experience**

MloIR was formed within the Manchester Business School in 2004 at the time of the merger between two universities, UMIST and the University of Manchester. Three existing organisations (PREST, CRIC and CROMTECH) were merged at that time. Here the Toolkit focuses on the MloIR's long experience globally in Foresight studies. PREST had been involved in Foresight programmes from the early 1990s and this global experience was inherited by MloIR. Much of this experience has been captured in two books authored by MloIR staff, one under sole authorship (Loveridge 2009) the other (Georghiou et al eds. 2008) has multiple authors some of whom have been collaborators with the MloIR: these books are listed in the Bibliography. For some years MloIR staff have been recognised as major players in the global use of Foresight as an approach to anticipating the future for organisations, governments and NGO's. In 1999 PREST developed a course for sponsors, organizers and Foresight practitioners, that has been absorbed into the MloIR toolbag. The course has run successfully with widespread international support since 1999. The history and concepts of the course over its first ten years have been described by Loveridge, Keenan & Saritas (2010). The course is run annually but can also be delivered anywhere in the world either directly or via videoconferencing increasing its availability.

### **2.11.4 Intellectual property and licensing**

Intellectual property (IP) is a difficult area for developing countries. In this section the way IP, its protection and the reasons for the edifice that surrounds IP is discussed in simple terms. The field itself changes with practice and precedents are frequently set. IP protection is essentially an extension of the legal system so that much depends on the intentions of IP owners to enforce their rights granted under IP law and practice. It is important for developing countries to come to terms with IP law and practice but it is equally important for them to make their voices heard in the current and future discussions surrounding the evolution of IP law.

Intellectual property (IP) can be protected either by patent or by copyright or by trademarks; these will be dealt with separately and each will be introduced with a short history to put them into perspective. It has to be remembered that intellectual property protection has caused much friction between the creators of the IP and its users. The contention of the creator is that he or she is entitled to a period of protection during which the content of the patent can be capitalised upon to earn an acceptable reward for risky financial, intellectual and physical investment. By contrast users may take an extreme position and maintain that intellectual property ought to be widely available at little or no cost. Licensing or assignment grants the non-patent holder the right to use the content of the patent in his or her business under agreed terms during the life of the patent. Licensing enables both licensee and licensor to accelerate their earnings and increase market power. It should be remembered that obtaining a patent is an expensive process.

In 2007 the European Patent Office (EPO) began a major study of the future of patenting (Scenarios for the future: how might IP regimes evolve by 2025? What global legitimacy might such regimes have?). The comments here have drawn on many sources of which the EPO's work is believed to be the most recent. The following quotation from the EPO study sets the scene comprehensively:

'The primary role of patents was to transfer technical knowledge. Patents provided a template for other inventors to refine the innovation; disclosure removed unnecessary redundancy in the knowledge production system. They were also used as an incentive to persuade foreign skilled workers to settle and foster local industries. The privilege granted was often calculated in terms of the benefit it provided to society.' Patents themselves are concerned with their quality, the certainty they provide for the patentor at the cost involved in their being granted.

Patents are granted by governments and give the exclusive right to the holder to make, use or sell an invention, for a limited period. Patents are granted to 'new and useful industrial machines, products and processes, and to patentable improvements of existing ones.' The relevant products may be of many kinds including new chemical compounds, foods, pharmaceutical and medicinal products, and the processes for producing them. Nowadays patents can be granted to living plant or animal forms developed through genetic engineering, though this is a contentious area. Stem cell research is particularly contentious and a recent judgement has introduced serious doubts about its future greatly increasing uncertainty and risk in future investments in the field. The EPO recognizes the cultural background in which the patent system works now has to acknowledge the influence of 'post-modernity' and its effects on matters relating to science, technology and business, and the control of knowledge including its creation.

Patents have a long history. The first patent is believed to have been granted in 1421 in Florence and established the principle of exclusivity. The privilege granted to inventors spread from Italy to other European countries over the next two centuries. In many cases patents influence the establishment of new industries, as happened in England at the time of Queen Elizabeth I. Initially, the unlimited duration of exclusive rights created unfair monopolies. Consequently, in 1623 the UK Parliament enacted the Statute of Monopolies which prohibited most royal monopolies while it specifically reserved the right to grant 'letters patent for inventions of new manufactures' protecting them for up to 14 years. In the United States, Article I, Section 8 of the Constitution authorized Congress to create a national patent system to 'promote the Progress of Science and useful Arts' by 'securing for limited times to . . . inventors the exclusive right to their respective . . . Discoveries.' Congress passed the first US Patent Statute in 1790. Similarly, France enacted its patent system in 1791 and by the end of the 19<sup>th</sup> century patent laws were widespread and have since spread to approximately 100 separate jurisdictions.

Patents deal with claims to an invention, which, in most cases, must be considered novel and useful. The invention must also represent what is judged to be a real advance in the state of the art and cannot be an obvious change from what is already

known. These rules are meant to reduce the number of 'inventions' in which existing products are simply modified in minimal ways. Once granted, the life of a patent can be extended for improvements of previously patented articles or processes if the requirements of patentability are otherwise met.

A patent is like 'personal property.' It may be assigned to others, by sale or otherwise, or mortgaged or may pass to the heirs of a deceased inventor. A lawsuit against infringement can be brought to court by the holder, who may ask for damages as well as an injunction to prevent further infringement. The life (the 'term') of a patent varies between countries but is usually from 16 to 20 years. After the term expires, the invention can be used openly by anyone. In some countries, including the former Soviet Union, property was treated differently and patents were not recognised. Instead, certificates were issued to inventors to ensure that they received some form of compensation for their work.

In most countries, patents are only granted after examination of an application by trained inspectors; the existence of previously published information (*prior art*) is particularly important, but the rigour of inspection varies between jurisdictions. While most countries grant the patent to the 'first person to file' the application, the United States is an exception, granting priority to the party who can prove it was the first actually to invent regardless of the time of filing.

In many instances, laws from the 19<sup>th</sup> century onwards have included various clauses that stipulate compulsory 'working' of an invention. The patentee must then manufacture the invention or license it to someone who will. Occasionally, patents may enable companies to form monopolies that affect entire fields of commerce. Antitrust suits may then be brought by government to force these companies to license those patents; this does not apply in the United States.

As commerce and business have become global, bilateral patent agreements between nations have become necessary. In general, inventors must apply for patents in each country where they wish to manufacture, use or sell their inventions; this is an essential element in any company patent strategy. International efforts have been made to help this by easing multinational patent differences. The International Convention for the Protection of Industrial Property, originally adopted in Paris in 1883 and amended several times since, was the first step in this direction. It gave inventors who filed an application in one member country the benefit of using that first filing date for applications in other member states. The 1970 Patent Cooperation Treaty simplified the way patent applications are filed for the same invention in different countries, by providing a centralized procedure and a standardized application format. Recently, the European Patent Convention, implemented in 1977, created the European Patent Office. European patents then acquired the status of a national patent in each of the member nations designated by the applicant.

Globally the World Intellectual Property Organisation (WIPO) promotes the worldwide protection of both industrial property (inventions, trademarks, and designs) and copyrighted materials (literary, musical, photographic, and other artistic

works). WIPO was established by a convention (signed in Stockholm in 1967) that came into force in 1970; in 1974 it became a specialized agency of the United Nations. The origins of WIPO lie in the United International Bureau for the Protection of Intellectual Property (BIRPI), which grew out of the secretariats of the Paris Union (International Union for the Protection of Industrial Property) and the Berne Union (International Union for the Protection of Literary and Artistic Works, 1886). Apart from promoting international cooperation for the protection of IP, WIPO supervises administrative cooperation between the Paris, Berne, and other intellectual unions regarding agreements on trademarks, patents, and protection of artistic and literary work. In this respect, UNESCO's encouragement of the free exchange of ideas and knowledge among peoples and nations is related to the intentions of WIPO.

The EPO recognised the changing social and political background to IP and began its work on the future of IP regimes in 2007. The long history of the protection of IP meant that 'There were several variations, yet the concept of a monopoly for invention remained constant. It was an exclusive right granted for a certain territory for a finite length of time, based on three criteria – novelty, non-obviousness and usefulness – in return for public dissemination of the information' (EPO, 2007). However, it had been recognised that the system was no longer 'fit-for-purpose' for the following reasons:

- New and sometimes contentious areas were being covered
- Standards of inspection had been 'eroded' permitting trivialisation of patenting
- Linking IP to global trade through the TRIPS agreement
- Lengthening timescales through 'supplementary protection' especially for drugs because of their very long development time due to regulatory matters

In addition the sheer volume, source and variety of patent applications has 'clogged' the system to the point of a loss of credibility, especially in the face of post-modern criticism and some disenchantment with it in the developing countries. From its study, the EPO concluded that five forces were likely to shape the future of the public management of IP in situations that are dynamic, global, complex, uncertain and unpredictable, as follows:

- **Power** which had 'traditionally been concentrated in the hands of established authority. However, globalisation has redefined this power structure' – this is now shared amongst many new players
- **A 'global jungle'** that has been created by globalisation and involves the integration of national economies via international trade, investment and capital flows and the ever present effect of post-modernity through socio-cultural and technological change
- **The rate of change** and the tensions it creates between the pace of short term satisfactions in business and politics and the long term cycles of political systems, legal institutions such as IP and of ecological change that is beginning to influence the human psyche

- **Systemic risks** that arise from now obvious global interdependencies in finance, goods, people, ideas and ideologies, all of which might be summarized as 'ways of living'
- **The Knowledge Paradox** which arises from the nature, availability and velocity to which society has access to knowledge and information through modern communications and the media, a further influence of post-modernity with its influence on IP and its protection.

The EPO work is both impressive and extensive. It proposes four scenarios for alternative possible ways the future of IP may develop. The purposes of the scenarios is as ever to attempt to break open conventional thinking bounded by 'what is' to mutate it into 'what might be' at the defined date in the future (2025). The latter is a short enough time horizon to accommodate the proposed global discussion of 'what might be' in the IP world. The four scenarios put forward are:

- **Market rules** – a world where business is the major driver
- **Whose Game** – a world where geopolitics dominates
- **Trees of knowledge** – society as the dominant driver
- **Blue Skies** – science and technology dominance

The scenarios and discussion of them is comprehensive: as usual the outcome remains to be seen.

By contrast to patents, **copyright** is more difficult to administer though easier to claim. The Universal Convention (UNESCO played an important part in establishing it) was established in 1952 after several years of consultation with copyright experts from various countries; it came into force in 1955. The main features of the convention are:

- No signatory nation should accord its domestic authors more favourable copyright treatment than the authors of other signatory nations, though no minimum protection for either domestic or foreign authors is stipulated
- A formal copyright notice must appear in all copies of a 'work' and must consist of the symbol Copyright, the name of the copyright owner, and the year of first publication
- The minimum term of copyright in member nations must be the life of the author plus 25 years (except for photographic works and works of applied art, which have a 10-year term)
- All adhering nations are required to grant an exclusive right of translation for a seven-year period, subject to a compulsory license under certain circumstances for the balance of the term of copyright.

The convention did not replace any existing multilateral or bilateral conventions or arrangements between two or more member states. Where there are any differences, the provisions of the Universal Copyright Convention (UCC) prevail. However, the Berne Convention takes priority over the UCC and conventions or arrangements between two or more American republics. Both Conventions were revised in 1971 to



meet, as far as possible, special needs of the developing countries. The liberalized regulations apply only to teaching, scholarship and research.

The Berne Convention goes back to 1886 and has been modified several times (Berlin, 1908; Rome, 1928; Brussels, 1948; Stockholm, 1967; and Paris, 1971). Signatories of the Convention constitute the Berne Copyright Union. The Berne Convention provides that each of the contracting countries 'shall grant automatic protection for works first published in other countries of the Berne union and for unpublished works whose authors are citizens of or resident in such other countries.'

Each country of the Union must guarantee authors, who are nationals of other member countries, the rights that its own laws grant to its own nationals. If the work was first published in a Berne country, but the author is a national of a non-Union country, the Union country may restrict the protection. After 1928 every work in the literary, scientific and artistic domain, regardless of the mode of expression, became protected. The 1948 revision added films and photographs. Both the 1928 and 1948 revisions protect works of art applied to industrial purposes so far as the domestic legislation of each country allows such protection.

In the 1928 revision the term of the copyright for most works became the life of the author plus 50 years, but it was recognised that some countries might have a shorter term. Both the 1928 and 1948 revisions protected the right to make translations. In the Stockholm Protocol, and the Paris revision, both the Developing and the Developed Countries reached a compromise that liberalized the rights of translation.

Copyright protects creative works from being reproduced, performed, or disseminated by others without permission. The owner of a copyright has the exclusive rights to reproduce, to prepare a derivative, to sell or lend copies of the protected work to the public and to perform protected works in public for profit, and to display copyrighted works publicly. These exclusive rights are subject to exceptions. The term *work* refers to any original creation of authorship produced in a tangible medium. Copyright does not protect an idea or concept, it only protects the way in which an author has expressed it. For an article that explains a new process for making an artefact, copyright prevents others from substantially copying the article; it does not prevent anyone from using the process described.

Copyright only becomes effective if a defined copyright notice is placed on all publicly distributed copies of a work and must take the form described earlier. As for patents, copyright can be sold or licensed to others. The sale or license of copyright made after January 1, 1978, can be terminated by the author (or by the author's family) 35 years after the sale or license was made, to allow an author to obtain more financial reward if the work remains commercially valuable over a long period of time. For sale or license made before 1978, the author has a right of termination after 56 years. In 1976, conditions were set for reproduction of copies by libraries and archives, and for transmission of audiovisual and other programmes; it also forbids unauthorized duplication of sound recordings.

Copyright infringement happens when the above exclusive rights are violated; for example, when an unauthorized copy of a copyrighted book is made. Infringement does not necessarily constitute word-for-word reproduction; 'substantial similarity' may also be infringement. Generally, copyright infringements are dealt with in civil lawsuits. An exception is *fair use*, which permits the reproduction of small amounts of copyrighted material when the copying will have little effect on the value of the original work. Examples are the quotation of excerpts from a book, poem, or play in a review for purposes of illustration or comment. Similarly, quotation of short passages in a scholarly or technical book may be used to illustrate or clarify the author's point of view.

Electronically stored information could not be foreseen when copyright law was first formulated. As a result, copyrightable material has now been widely accepted to include all 'original works of authorship fixed in any tangible medium of expression, now known or later developed .... from which they can be ..... communicated either directly or with the aid of a machine or device.'

Almost every nation has some form of copyright protection for authors and artists. Few require the stringent formalities necessary under US law, such as a formal copyright notice and registration with the Copyright Office. It is here that the UCC becomes effective. Although there is no such thing as an 'international copyright,' it is easy for an author to obtain copyright protection in many nations.

In 2008 Google launched a process (the Google Book Agreement) in response to a class action by authors and publishers, claiming that Google had violated their copyrights and those of other Rightsholders of Books and Inserts by scanning their Books, creating an electronic database and displaying short excerpts without the permission of the copyright holders (lawsuit is entitled *The Authors Guild, Inc., et al. v. Google Inc.*, Case No. 05 CV 8136 (S.D.N.Y.)). Preliminary approval was given to an amended Settlement Agreement in November 2009 but on March 22, 2011 the Court denied the parties' request for final settlement approval. The parties are considering their next steps. The eventual outcome remains in doubt. Google's intention under the agreement is to make access to books, many of which are difficult to obtain, widely available (an innovation in this field) through an electronic database.

Patenting and copyright are used by many businessmen to protect knowledge vital to their business against industrial espionage. Considerable amounts of data about a competitors activity comes from routine and undramatic sources, but trade secrets may find their way into the open market through several channels. Disloyal employees may sell confidential data to the highest bidder. Sometimes a group of employees may leave a company and set up their own business, a competitive firm, capitalizing on the knowledge they gained while working for their former employer. Alternatively, a company may attempt to recruit a valuable employee from a competitor (called 'poaching') through an attractive job offer hoping that he or she will make their knowledge available to their new employer. While 'poaching' is rare when the desired knowledge is in written form, nothing can stop a 'poached' employee making use of his or her 'know-how' provided the employee does not make explicit use of his or her previous employers key information.

If an employer believes that his or her key trade secrets have been adopted by a competitor, the company can seek redress by taking the competitor to court, seeking an injunction to prevent further use or loss of its commercial property. If the competitor is proved guilty, the penalties against it include an injunction against their making further use of the information, accounting for and repayment of all profits made from the utilization of the pilfered information, or additional punitive damages if a violation of the plaintiff company's rights has been flagrant.

For the developing countries, intellectual property protection by patents and copyright will remain a fact of life. In many instances the technology so protected will not be directly applicable in their very different socio-cultural arrangements. It will always be important for these countries whenever necessary to combine together to present a case in strength when seeking licences for patented technology.

### 2.11.5 Licensing of IP and Copyright

Licensing a technology is now commonplace and for the developing countries is an important aspect of innovation. The main practical aspects of licensing are illustrated in **Box 2. 1**.

#### **Box 2.1 Important practicalities of licensing**

Significant issues on which a prospective licensor and prospective licensee may find it difficult to reach agreement:

- **Determination of the scope and basis of a licence**  
For the licensor the wider the defined scope of a licence, which may define an area for the technology, has obvious benefits. A widely defined licence may present a licensee with some problems in the difficult area of improvements, which is dealt with later. A patent licence is more restricted in some senses, but may pose the licensee with some awkward decisions and some potential benefits, brought about by the geographical distribution of patent filings by the licensor.
- **Definition of the reasons for early termination of a licence**
- **Agreement on the term (or duration) of the licence**  
Aspects of a licence agreement which can give rise to problems during implementation, if not considered adequately during initial negotiations, include the following:
- **Ownership and rights to use improvements**  
The ownership and rights to use improvements to a licensed technology, unless clearly specified in the licence agreement, can be a continuing source of contention between a licensor and the licensees. The licensee usually wishes to obtain rights to use the licensor's improvements, but may well wish to retain control over his own, cross licensing them, if possible, to create his own stream of royalty income.

- **Jurisdiction**  
Very different legal processes are available in different countries or States in the USA, and due account must be taken of them in drafting agreements.
- **Provisions for the effective transfer of licensed technology**  
The provisions for the effective transfer of the licensed technology are important, are negotiable, and need to be clearly set out in the licence agreement; vagueness in this area is, perhaps, one of the most frequent causes of dissatisfaction with a licence agreement when it is implemented.
- **Payments and other rights**  
The terms and conditions for initial payments, royalty rate, basis of royalty calculations, rights to sub-licence, exclusivity or non-exclusivity, geographic constraints, other fees, e.g. for assistance during implementation of the licence.

Both licensor and licensee tend to gain in tangible and intangible ways if the relationship that grows is mutually beneficial. For both, the cash flows are spread over a considerable period; the licensor retains control over the technology and is usually free to licence it to more than one licensee (exclusive licences are now more likely to be subject to scrutiny by competition regulators both in Europe and the USA). However, the licensor may be required to accept certain residual responsibilities (for example: to maintain any patents involved or to undertake certain action if a patent infringement lawsuit arises). At the same time the licensee may not be free to sub-licence without the consent of the licensor. The acquisition of technologies carries with it certain rights and duties; these are set out in **Box 2.2**.

### **Box 2.2 Rights and duties in technology acquisition**

#### **Fundamental steps**

- Establish who owns the technology to be acquired and agreement of the terms under which rights to the technology or rights to its use can be acquired, if such an agreement is necessary (it is only **not necessary** if the technology is unequivocally in the public domain).
- For technologies that are not freely available, the above fundamental steps are accompanied by many pitfalls for the unwary. Because 'let the buyer beware' is still the predominant philosophy behind a transaction between a seller and a buyer, it is for the buyer to establish, to his own satisfaction, all matters relating to the seller's purported ownership of the good. The buyer must, therefore, conduct a thorough search before beginning negotiations for the right to acquire or use a technology he is interested in.
- **Some** of the questions to be answered when acquisition of a technology is proposed:
  - Is the technology the subject of a patent application or a granted patent?
  - If a patent has been granted;
    - Which countries does it cover?
    - Who holds the patent?

When was the patent filed?

If a patent application has been filed but not yet granted;

Has the application been 'examined'?

Are there any citations of prior art?

When was the application filed?

Which countries are covered?

Who is the applicant?

Are the claims generic or specific?

**If the technology is to be purchased outright**, with all rights and duties being passed on to the buyer, then the terms of the sale will reflect the value of the technology to the seller and buyer under the prevailing circumstances.

**If the technology is to be licensed or shared through some arrangement**, then there are many points to consider; these will include (the list is not exhaustive):

- The field of the licence
- The term of the licence
- The financial terms including either an initial payment or a royalty or a combination of both
- Reasons for termination
- Improvements to the technology and assistance during transfer
- Confidentiality

Joint ownership of a technology, resulting from sponsorship or some form of co-operation, say between companies or with a research institution, makes its own particular demands for clear legal arrangements. These should always be presumed to be for the guidance of the successors to the people immediately involved, people who will not have the shared understanding of the originators and will only have the legal framework for guidance. Each agreement will necessarily have its own characteristics, but the following elements should always be included:

- Division of financial responsibility
- Division of rights of use
- Causes for termination and residual rights
- Confidentiality
- The procedure to be followed when patentable solutions emerge during the course of the work, since the inventors may be employees of the contractor or of both the contractor and the sponsoring company
- Expectations to publish the results of research must be timed to fit in with the commercialisation of the patented matter.

Joint ventures, with their connotation of an expected continuation into a worthwhile new business need special care and commitment. It is also vital to maintain control over the way in which unsolicited inventions are offered to the company, to prevent later legal action or complaint that the company has benefited illicitly from information offered by a third party. Special care is needed in this matter as it can jeopardise internal research programmes even when these have been conducted

entirely independently and have even progressed beyond the point reached by the inventor, but nothing has been patented by the company. Good records of research findings and a simple vetting and confidentiality procedure are essential to inhibit unwise or uncontrolled presentations from external inventors.

#### 2.11.6 Commercialisation issues and approaches

Commercialisation, which is synonymous with innovation, is rarely straightforward. The rejection of an invention and its exploitation because it came from elsewhere is a frequent occurrence. It is a mind-set that can create many unsuspected barriers to the adoption and commercialisation of an invention. In this section technology transfer is first and foremost seen as a problem of *intelligence gathering* since the identification of the technology or technologies needed is the primary step. Following identification, there is the matter of how to transfer the technology, much of which has already been discussed under licensing but other matters will be raised here. Lastly, there is the question of making the transfer and of how this apparently desirable state of affairs is often fiercely resisted.

#### 2.11.7 Technology transfer and commercialisation; basic principles

Intelligence gathering is a close relation to environmental scanning referred to in **Section 2.4** and cannot be divorced from the notions of espionage though this need not imply law breaking. Much intelligence can be gathered from publicly available material and the use of intelligent and intuitive behaviour; this is a philosophy close to that used by R.V. Jones during the 1939-45 war. It is not a fashionable approach which Dedijer (1978) describes it as the “ .... *antithesis* of the caricature of government intelligence” which is set out in **Box 2.3**.

#### **Box 2.3 Representation of government's intelligence organisation**

- Hierarchically arranged infrastructures: agencies
- Boards, directorates, divisions, departments, committees, task-forces
- Continuous bureaucratic wars over internal pecking order
- Staff experts in all relevant subjects paid according to seniority on civil service rates
- Compartmentalization to secure 'need to know' boundaries, with communications rigidly controlled to the 'proper channels' and regulated by security rules that are constantly enforced and often penetrated by opponents
- The latest scientific and technological equipment
- Production of multiple classified outputs in all forms of media most of which rarely if ever lead to decisions and actions
- Engagement in ultra-secret operations that are poorly managed
- The delusion that failures are known but successes are secret whereas the inverse is a closer approximation to reality with their outputs being known to their opponents while remaining secret from their polity whose growth and security is the objective of the system's existence

By contrast Jones's principles are few and simple and its essential elements are set out in **Box 2.4**.

**Box 2.4 Jones's principles of intelligence gathering**

- Intelligence is of little use unless it leads to action
- Intelligence is gathered by source and output by subject; this requires an internal transformation requiring observation, memory, criticism, and correlation of different types of information which is then given expression to in a synthesized output
- The larger the organisation the less it is able to perform the above task; this means that intelligence staff need to be small in number but with great ability within the demands set out above
- Occam's razor, the principle of thinking simply is the key to good intelligence work, particularly when dealing with 'experts' whose views tend to be narrow and overoptimistic
- Do not fall into the trap of believing that your opponents, competitors and others, are omniscient and 'all seeing'

Dedijer (*ibid*) advanced two propositions that are relevant to developing countries when engaging in technology transfer:

- The Jones doctrine is applicable to social intelligence in general
- To the developing countries, the doctrine can lead to learning how other countries affect their development and how, in turn, they affect other countries.

For the developing countries it is important to evolve an organisation able to collect a broad range of intelligence aimed at *social intelligence* that asks:

- What may be the future impact of science and technology, and the growth of knowledge on countries large and small, developed and in transition?
- Is espionage of diminishing importance or simply being carried out by less obvious means that are more widely available?
- Is economic, political, cultural, psychological intelligence at the national level growing in importance relative to the hitherto dominance of military intelligence? This includes, for example, the influence of the growth of 'knowledge industries' on the developing countries.

Information processed into intelligence begets knowledge, in this instance about the world into which the developing countries are moving. For the formulation of a policy for science and technology this is a vital resource.

## Technology transfer

Technology transfer involves:

- Money
- Politics
- Bargaining and negotiation - this makes direct use of the knowledge derived from the intelligence function. These two skills are at the centre of technology transfer
- Information and learning - which relates to appropriateness and appropriability of the chosen technology. Both of these factors are of importance during the exploratory phases of technology transfer and after an agreement has been completed
- Corruption - which is often not regarded as such under different socio-cultural practices and can consequently be misunderstood by the transferor located in a different socio-cultural setting

Dedijer (*ibid*) rightly claims that successful technology transfer depends on first class intelligence. The following guidelines can be recommended (**Box 2.5**):

### **Box 2.5 Intelligence guidelines related to technology transfer**

- Use intelligence to hunt down sources of information about problems encountered with previous technology transfers
- Do not hire foreign 'business intelligence consultants;' through indigenous intelligence work it will be possible to emulate their work at far less cost
- Use evaluation procedures to improve intelligence operations with respect to technology transfer to raise its capability
- Obtain as much information as possible from domestic and foreign sources about possible partners for technology transfer before selecting a specific partner
- Acquire the know-how at the best possible price and under advantageous terms
- Understand how access to world markets will be enhanced by the technology transfer
- Estimate the effect of the technology transfer on domestic research and development
- Assess the influence the technology transfer may have on the capabilities of domestic manpower and the extent to which it will accelerate learning in the recipient country
- All technology transfer comes with conditions attached; intelligence should provide insights into how these conditions may be weakened or dissolved with time
- Use good technology transfer intelligence to minimize corruption

In addition, anticipatory intelligence needs to ask the following questions in preparation for any technology transfer programme that is embarked upon:

- What kind of global developments could be harmful and what kind beneficial?
- How soon may these developments occur?



- What might be the first signs that these developments are happening?
- Where and how might the leading indicators of impending change be seen?
- Who is in a position anywhere to observe these indicators?
- What is it worth to minimise the extent of surprise introduced by these indicators?
- Who needs to know about these impending changes?

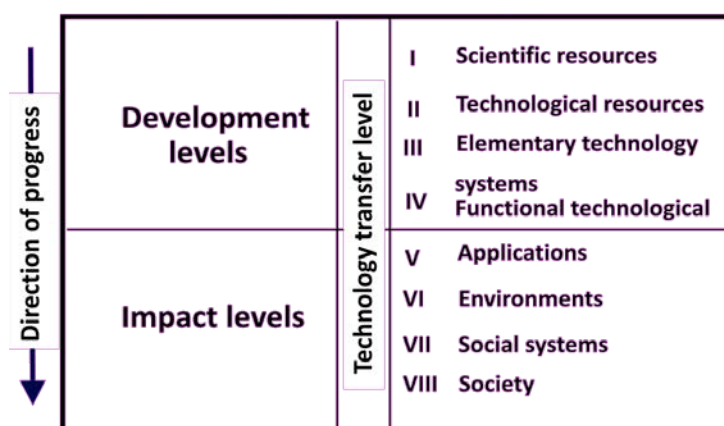
In this context, foresight has an important role to play in indicating what and what not to do and when, and when not to embark on technology transfer. It is also vital in all technology transfer programmes to ask three further fundamental questions:

- What is possible within the current limits of known science?
- What is feasible technologically within those limits?
- What is desirable technologically in the socio-cultural setting?

Transgression of any of these three questions will make technology transfer ineffective or even useless.

In his classic review for OECD, Jantsch identified eight steps in the technology transfer process; these have already been illustrated in **Fig. 2.1**, which is repeated here. Jantsch explains the table in the following way:

**Fig. 2.1 Steps in technology transfer**



“Technology transfer ... Takes place in a vertical as well as in a horizontal direction. Whereas a vertical transfer leads from fundamental science to technology, and further to systems (products, processes, etc.) and their impact on different levels, horizontal transfer in this flow scheme, represents, for example: empirical postulation of a scientific theory (Level I), fructification of other fundamental technological research (Level II), merger of discrete technologies (Level III), diffusion of existent technology (Level IV), demand for auxiliary or support systems (Level V), 'invasion' of other industrial sectors (Level VI), technical aid programmes for developing countries (Level VII) and ethical constraints on social goals (Level VIII).”

Many of the important aspects of technology transfer have already been dealt with in the discussion of the practicalities of licensing: they will not be repeated here. The

single most important point for anyone to remember in technology transfer is that it **must** involve access to the people in whom the 'know-how' for making the technology usable resides. No set of formal documents can ever convey the entirety of what is needed to make a technology transfer successful. The transferor will require both payment and conditions limiting such access, but it is right to negotiate long and hard for this access which cannot be indefinite, but **must not be** peripheral. It is better to have no deal than one that fails through lack of attention to this issue.

The last important issue regarding technology transfer and innovation is that of its obstruction. Innovation is not always resisted, but its possibility should always be anticipated and planned for. There are many anecdotal lists of ways that have been used to resist technology transfer and innovation; these range from the declaration that it is not company or organisation policy to more obscure matters. Bright gives an indicative but not definitive list of reasons for resistance that include those shown in **Box 2.6**.

#### **Box 2.6 Reasons for Resisting Innovation**

1. To protect social status or prerogative
2. To Protect an existing way of life
3. To prevent devaluation of capital invested in an existing facility or in a supporting facility or service
4. To prevent reduction of livelihood because the innovation would devalue currently required knowledge or skill
5. To prevent the elimination of a job or profession
6. To avoid the cost of replacing existing equipment or upgrading existing systems to accommodate or compete with the innovation
7. The innovation opposes social norms, fashions and tastes and everyday habits
8. The innovation conflicts with existing laws
9. Inherent rigidity of large bureaucratic organisations stifles innovation and change
10. Personality, habit, fear, personal relationships or those between institutions, status and similar social and psychological considerations stifle innovation
11. Tendency of organized groups to force conformity on members
12. Reluctance of any individual or group to disturb social equilibrium or the business culture

Ways of overcoming the barriers to innovation are and will always be specific to the individual organisation and will depend on a good understanding within the organisation of how the barriers can be overcome; general recommendations are not likely to be helpful.

## 2.12 Technology commercialisation and transfer centres

Innovation is one step after the extreme uncertainties of invention, but technology transfer should not be left to chance. In the post 1939-45 war years there have been many different ways of encouraging both invention and innovation; some of these approaches are described in the ensuing sections. In the industrial countries, the phenomenon of the very creative area around Boston, Massachusetts, (known as Route 128) and 'Silicon Valley' in California, coupled with the growth of venture capital funds there, have been prime examples that have been imitated elsewhere. From the late 1970s onwards, locally based organisations in the UK, known as 'enterprise trusts', were the starting point for the development of many businesses. Developments of these kinds will be used and referred to the context of the developing countries, as far as that is possible.

All exploitation routes are underlain by different modes of finance without which nothing would happen. The first route, incubators and science parks, depend crucially on location in or near to a vibrant university as their main, but not sole purpose, is to take near market research (not fundamental research) or invention into the first stages of innovation and subsequently into full scale commercialisation. However, the requirement for the proximity of a vibrant university or other form of research institution should not be forgotten, nor should 'science parks' be confused with the plethora of 'business parks' that have sprung up following the evolution of the 'enterprise trusts.'

### 2.12.1 Technology Incubators; their uses and abuses

For both technology incubators and science parks it is always necessary to ask 'what's in the name?' In theory the division comes in the size of the business, its stage of development and, crucially, its funding requirements. Technology incubators are almost entirely restricted to university campuses and their purpose is to provide facilities for academic researchers to take what are believed to be marketable research ideas out of the laboratory and into a first stage of innovation. At this point the funding requirement is *relatively* low, the risks are highest and the entrepreneurs need is for transitional facilities that cannot be created in a normal laboratory. The main characteristic of an incubator is then of a continual flow through of ideas and entrepreneurs: without that flow the atmosphere of the incubator will stagnate. The time any entrepreneur is allowed to stay in an incubator is then a key factor in its success. It seems unlikely that the period can be much less than a year, but if an idea is not showing promise after two years questions need to be asked, with the intention of requiring the entrepreneur to move out. Incubators can provide general facilities or the special ones needed by technologies that are particularly hazardous, such as biotechnology, where there are legal safety requirements to be met. Incubators also have a second function; to provide a place where entrepreneurs can meet providers of funds and possibly companies that will be interested in their ideas. It is also important to endeavour to create a 'critical' mass of activity within an incubator to prevent it developing a stagnant feeling with empty space.

It is unlikely that incubators will be greatly concerned about technology transfer, but that possibility should always be in mind as some companies may be prepared to secure rights to the outcome of an entrepreneur's work at a very early stage. However, at that point the deal is likely to be carefully hedged committing the interested company to as small a financial outlay as possible for the maximum rights, while termination clauses will also figure strongly in the deal. Incubators are aimed essentially at advanced technologies: their use in the developing countries needs to carry forward all the requirements as found in the Developed Countries. The incubator's benefits to a national economy are, needless to say, in the long term and are almost entirely 'potential' with market forecasts and other such estimates being highly uncertain and prepared more for the quest for funding than any substantive purpose. The success rate for incubator 'companies' are likely to be significantly lower (probably 1 to 5%) than that expected by venture capitalists (10 to 20%).

### **2.12.2 Science Parks; the reality of their role**

Science parks are probably the most direct European equivalent of the 'Route 128' and Silicon Valley phenomena. There are three major differences between a science park and an incubator; these are:

- Science parks are firmly expected to contribute to the local economy and to provide growth opportunities for that economy in the chosen advanced technology field or fields
- To enable entrepreneurs to move up from the small scale development to the size where the company can expect to be floated through an Initial Public Offering (IPO)
- The scale of finance required is an order of magnitude bigger and carries commensurate risks and rewards

There is a continuing debate about whether a science park is really a property company rather than a company to promote small, advanced technology growth businesses. The difference in mind set is considerable. It is clear that the successful development of a science park depends not only on its location, but also on setting clear objectives, deciding on the resources to be provided and the markets it wishes to address through the resources provided. It is essential for the founders (and funding agencies) to resolve these three considerations unambiguously otherwise the chances of success will decrease.

Science parks have to be concerned with a balance between indigenous and incoming companies. Because their scale is so much larger than that of an incubator, the multiple-occupancy, small unit principle can no longer apply. Special purpose buildings are needed and market focus for the science park founders then becomes an important issue. The balance between the indigenous and incoming businesses is problematic, but for the founders of the park their concern has to be for a mix that secures their future profits. Occupancy will inevitably be for longer periods, but the extent to which the flow principle of the incubator should be abandoned is one that needs careful consideration. Too static a population can lead to an 'industrial estate'

mentality that may not meet the founder's objectives as 'perpetual' occupants' businesses mature and become more bureaucratic with increasing size. Technology transfer at this stage of a company's development may be either through multiple licensing as a licensor or outright sale of technology or by being acquired by a predator company or in an IPO. Technology transfer is likely to be a feature of business management in companies based in science parks.

For the developing countries, the idea of the science park has to be appropriated in their local circumstances. They will also need to take note of the important factor of location. Other important factors are clear as are realisable objectives at that location. The latter needs to include what the science park has to offer to entrepreneurs, who have near market businesses to take forward to a larger stage: funds and facilities, and market access are essential elements here. Ambitions for floatation may not be appropriate, because of the lack of a stock market, but growth possibilities are necessary with expectations of success at least as good as those of the venture capitalist.

### **2.12.3 Technology Advisory Centres**

There is little to say about technology advisory centres; they are what they claim to be - information providers. As such they should have a natural link to technology watch and foresight programmes to enable the distribution of future oriented information concerning products, processes and markets. They should also be able to provide advice on how to acquire technology by technology transfer and from where technologies might be acquired. For the developing countries, the need for a technological intelligence organisation is or should be noted.

### **2.12.4 Rural and Small scale commercialisation centres**

In the industrial countries small scale centres are most likely paralleled by the work of enterprise trusts and business links, which have the objectives of finding small scale workshops and other facilities for *any kind of business*. The latter point is a distinct departure from the objectives of either incubators or science parks. Enterprise trusts (or other agencies) are 'finders' of facilities and funding; they do not provide finance at even the smallest scale. They play an essential role in bringing together the various providers at a very small scale, but unlike the incubator their interest is directly in promoting the local economy and in job creation. Similar activities take place under a number of other guises.

Workshops of the kind described here already abound in the developing countries: one such situation forms the basis of one of the case studies set out in **chapter 4**. It is unclear whether the organising principles of small-scale activity in the industrial countries, has much to offer to the developing countries where the socio-cultural patterns can be very different.

### 2.13 Financing

Financing of technology transfer from the Developed Countries to and between the developing countries, poses formidable problems. There is a real need for innovation and Ingenuity to complete financing itself and also to cope with the staggering range of situations that present themselves. However, since the 1999 edition of the Toolkit there has been financial innovation by the developing countries themselves for funding technology transfer and development. One of the most recent typifies these developments as follows (**Box 2.7** below)

#### **Box 2.7 The India-Brazil-South Africa (Ibsa) Fund for Poverty and Hunger Alleviation**

Ibsa is a fund set up by India, Brazil and South Africa to support projects in low-income countries 'without imposing conditions,' hence the claim that it is a 'South-South funding with no strings attached'. The fund provides an opportunity to showcase a viable, even if limited, South-South development approach. It also provides a chance for new players to test their abilities in the 'driver's seat'. The reason for wanting to distance themselves from Developed Country aid lies in the frequent (cyclic) crises in them and doubts in the developing countries about the long-term sustainability of recovery in the Developed Countries, many of which are facing ageing and shrinking populations that require state support. The developing countries then argue that future growth in the global economy will depend on an increasing number of funds like Ibsa.

Discussions to form Ibsa started in 2003 with the idea of building cooperation between India, Brazil and South Africa. Trade flows between the three countries increased subsequently. The Ibsa fund was created formally in 2004, with each contributing \$1m per annum. The money is used to support development projects in low-income countries. The fund is administered by the United Nations Development Programme (UNDP). Flagship projects are in Guinea-Bissau to improve agricultural practices and in Haiti to bring together members of conflicting factions in the violence-prone Carrefour Feuilles zone through a joint solid waste collection project. Support from the Ibsa fund is a 'donation': repayment is not expected. As emerging economies that still have their own development requirements, the Ibsa members are determined to distance themselves as far as possible from traditional donor-recipient relationships. In 2008 alone India spent \$547m on aid-related activities, either directly or indirectly linked to Ibsa. In the same year India also extended \$2.96m in lines of credit, mostly to sub-Saharan Africa showing that India is becoming an important player in development aid.

Other evidence of how finance for development projects in the developing countries is changing is found in the formation of the Grameen Bank and more recently the Grameen Foundation: these are described in **Box 2.8** below.

**Box 2.8 The Grameen Bank**

The Grameen Bank Project began in the village of Jobra, Bangladesh, in 1976<sup>8</sup>. It became a formal bank in 1983 when a law was passed specifically for its creation. It is owned by the poor borrowers of the bank, who are mostly women and it works exclusively for them. The borrowers of the Grameen Bank at present own 95% of the total equity of the bank. The remaining 5% is owned by the government of Bangladesh. The bank is an extremely successful initiative and in the last quarter of 2010 had 8.33 million borrowers, 97% of whom were women.<sup>9</sup>

The Grameen bank was established with a set of objectives that aim to alleviate poverty. The main purpose was to design a system of credit delivery to provide banking services for the rural poor in Bangladesh who have under utilised skills. This would eliminate the exploitation of the poor by money lenders and create opportunities for self employment for the large number of unemployed people in the country. The Bank provides an organisation that has a system of credit which can be managed and understood by disadvantaged people, predominantly the women from the poorest households. It aims to reverse the age-old vicious circle of *low income, low saving & low investment*, into a virtuous circle of *low income, injection of credit, investment, more income, more savings, more investment, more income*.

The bank makes small loans (microcredit) to borrowers but does not require any collateral. It does not take defaulters to court and does not require borrowers to sign legal documents. Each borrower must belong to a five member group but the group is not required to give any guarantee for a loan to its member. Repayment responsibility solely rests on the individual borrower, while the group and the centre oversee that everyone behaves in a responsible way and none falls into repayment difficulties. There is no form of joint liability and the group members are not responsible to pay on behalf of a defaulting member. Rather this is a group based credit approach which utilises peer pressure within the group to ensure the borrowers do not default, but do use caution in conducting their financial affairs responsibly, ensuring repayment eventually and developing good credit standing. To supplement the lending the Bank requires the borrowing members to save very small amounts regularly in a number of funds including an emergency fund and a group fund. These savings help serve as an insurance against contingencies.

The bank funding is drawn from different sources and the main contributors have shifted over time. In the initial years, donor agencies provided the bulk of capital at cheap rates. In the mid-1990s, the bank started to acquire most of its funding from the central bank of Bangladesh. More recently, Grameen has started bond sales as a source of finance. The bonds are implicitly subsidised as they are guaranteed by the Government of Bangladesh and still they are sold above the bank rate.

<sup>8</sup> The bank began as a research project by Dr Muhammad Yunus and the Rural Economics Project at Bangladesh's University of Chittagong to test his method for providing credit and banking services to the rural poor

<sup>9</sup> <http://www.grameen-info.org>

### **Why is the formation of the Grameen Bank good for developing countries?**

The Grameen bank is focused primarily on women as borrowers. Women's access to microcredit empowers them through greater access to resources and control over decision making. Grameen claims that more than half of its borrowers in Bangladesh (close to 50 million) have risen out of acute poverty thanks to their loan, as measured by such standards as having all children of school age in school, all household members eating three meals a day, a sanitary toilet, a rainproof house, clean drinking water and the ability to repay a 300 taka-a-week (around \$4 US) loan.

Inspired by the work of Grameen Bank in Bangladesh, the Grameen Foundation was created in 1996 by Muhammad Yunus to help share the Grameen philosophy and help alleviate poverty among the world's poorest people<sup>10</sup>. The Grameen Foundation, supports microfinance institutions worldwide with loan guarantees, training, and technology transfer. It helps the world's poorest, especially women, improve their lives and escape poverty by providing them with access to small loans, essential information and viable business opportunities, through use of two of the most effective tools available, those of microfinance and technology.

Among many different applications of microcredit by the Foundation, one is the Village Phone program, through which, predominantly female, entrepreneurs can start a business providing a wireless payphone service in rural areas. Rural entrepreneurs from countries such as Bangladesh, Rwanda, and Uganda are using microcredit loans to provide their neighbours with something that is often taken for granted in the developed world — the ability to make a telephone call. The Grameen Foundation provides all the tools and support systems necessary to set up an inexpensive public mobile phone that is durable, including the antenna, cables, signage, business cards, and training. The 'Village Phone kit' includes flashlights and a car battery charger to run the telephone in those areas of Africa, Asia, and Latin America still without electricity. The program is considered to be highly successful and has improved the livelihoods of farmers and others who are provided with access to critical market information and lifeline communications previously unattainable in rural villages in developing countries. The Village Phone initiative was a successful development initiative that has improved the social status of women and the productivity of rural communities. The model has subsequently been employed in Uganda, Rwanda, Cameroon, and the Philippines. The application of this technology in an innovative way has provided a sustainable business opportunity for improved self-



**Marie-Claire Ayurwanda, one of the first Village Phone Operators in Rwanda**  
*Photo: Grameen Foundation*

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<sup>10</sup> Grameen Foundation Annual Report 2009-10  
<http://grameenfoundation.org/sites/default/files/GrameenFoundation2009-2010AnnualReport.pdf>



sufficiency in rural communities. In 2001, the Foundation established the Grameen Technology Center, now based in Seattle, Washington, to help provide the financial and technological assistance needed to advance microfinance throughout the developing world.

While Aid programmes have been available to developing countries for many decades the conditions attached to them have often constrained their usefulness. Often major projects have followed patterns of development inappropriate for the countries involved. Since 1999 there has been a shift toward programmes such as the Ibsa funds and the Grameen Bank. Major philanthropic organisations are now making their presence felt, one of which, the Bill & Melinda Gates Foundation, is described briefly in **Box 2.9** below.

#### **Box 2.9 The Bill & Melinda Gates Foundation**

The Foundation was formed in 1994 and in 1999 was changed to its present form under the title The Bill & Melinda Gates Foundation. The Foundation merged with the Gates Learning Foundation in 2000 and over subsequent years its funds have grown to \$2 billion. In 2006 the Foundation's funding was further augmented when Warren Buffet pledged to give the foundation approximately US\$30 billion, in Berkshire Hathaway shares, spread over multiple years through annual contributions and under tight conditions concerning the way the funds could be used.

The Foundation's programme is made up of several parts in three grant-making programs:

- Global Health
- Global Development
- United States

The global health and global development programmes are the two of interest to the developing countries though it is far from clear how much of the funding goes directly to organisations paralleling the Ibsa fund. Nevertheless the financial muscle of the Foundation may make financing projects in the developing countries easier.

The variation in the HDI, which has an economic component, reflects the staggering differences between developing countries. Variations within countries, for example Brazil, are immense as very poor people, probably with incomes of only a few dollars per day, live in 'shanty' towns 'cheek by jowl' with immensely wealthy cities. The methods of financing used in the industrial world, such as venture capital, Venture Capital Trusts and so on, are for the most part absent in the developing countries. Most of the traditional funding has come from large organisations such as the World Bank, banks of various kinds, UN organisations and from aid agencies at the opposite end of the scale. Innovation in this field, to enable technology transfer, often of inexpensive but very effective technologies, is a prime need.

The recent global financial crisis has done little to change the situation. The cause of the crisis was itself due to the invention of financial instruments that very quickly became global innovations creating a debt 'bubble' that threatened, and to some extent still does, the global banking system. The effect of the very recent major earthquake and tsunami off Japan, shows how natural events, over which humanity has no control, can have deep influences on the world's money markets. Similar effects have arisen from speculation in the world's food markets that are affecting food grains in particular: these are causing instability in vital markets that physically become obvious as high food prices that create hunger amongst the Developing Country populations.

## **2.14 Tailpiece**

Knowledge, the acknowledgement of ignorance, either explicitly or tacitly, and money are fundamental throughout the whole process of invention, innovation, technology transfer and commercialization. The developing countries need to become participants in matters characterized by the work of the EPO and WIPO, and in comparable activities influencing the money world where the belief is incorrectly that developing countries default on their loans or other financial instruments more frequently than their Developed Country counterparts. As the situation now in 2011 makes clear, many European countries and the USA struggle with immense indebtedness (recent research by Reinhart and Rogoff, published in 2009 is valuable in this respect) and rescheduling of debt repayments (a form of default) looks like becoming a feature of the money world. To quote Obstfeld (2009) 'Despite an abundance of cross-section, panel, and event studies, there is strikingly little convincing documentation of direct positive impacts of financial opening on the economic welfare levels or growth rates of developing countries ..... The reforms developing countries need to institute to make their economies safe for international asset trade are the same ones they need so as to curtail the power of entrenched economic interests and liberate the economy's productive potential.' Obstfeld's views will be strongly influenced by his IMF background but whether they 'shake hands' with the mindsets growing in the developing countries is another matter, particularly now that China's interests, however selective they may be, are growing in Africa and other developing countries.

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## Chapter 3 Implementation - policy and strategy for action

The text in this chapter is of necessity based on Western World experience and patterns of behaviour. In the very different cultures of other Developed and developing countries, with their different political systems, the ideas presented here will need careful examination to assess the extent to which they can be adopted, adapted or discarded. As before there is a clear distinction between invention, as a pseudo-random event, and innovation as a socio-economic process leading to widespread adoption of an artefact otherwise recognised as commercialization.

### 3.1 Introduction

Invention is the precursor to innovation providing the basis for artefacts that through innovation may reach widespread use. Innovation programmes then require considerable effort and expense; it is not advisable to embark on one without clear objectives. How to go about innovation (implementation) should then be a major consideration during the programme's preparation, where the sponsors and potential users need to be deeply involved. Implementation is also likely to be an iterative process, as learning about the 'nut and bolts' of the innovation programme and technology transfer develops (it is a never ending process as the difficult steps always lie in the detail). In this context there are two broad themes that lie behind successful innovation:

- Successful innovation programmes necessarily take several years. In as much as government support, if needed in whatever form it takes, needs to be consistent through a defined period of the project. Consistency in government policy for national science and technology, or social programmes, in as much as they support inventions and their transfer into innovation depending on the programme's objectives. Capricious shifts in government policy can be tolerated but they are generally unhelpful
- Concrete outcomes for companies and organisations, large and small in all sectors. They take the form of the identification of inventions that are likely to lead to successful technology transfer and innovation opportunities to facilitate the development of business and the country's economy in all its aspects.

In many respects these two expectations are interdependent giving rise to a third outcome, the *improvement* of the interaction between all those parties likely to be influenced by and involved in an innovation programme and its purposes. The latter point re-emphasises the importance of the early involvement of the parties likely to be involved initially and mechanisms that allow others to become involved as necessary with the passage of time. For the third outcome the emphasis is rightly on the *improvement* of existing patterns of interaction and the development of new ones.

However, it is also hard to imagine that the management of innovation involving a dynamic network of partners will be anything other than idiosyncratic and designed to suit the purposes of the sponsors in their country. There cannot be firm and

universal recommendations that particular forms of management of innovation and technology transfer will suit all circumstances and all countries. Perhaps there are two rules worthy of universal acceptance, namely that management of all innovations should strive for:

- Clarity
- Simplicity

Complicated and convoluted procedures need to be avoided. In the developing countries, prioritisation of resources between innovations and technology transfer is inevitable as scarce resources will need to make their purpose appropriate and the outcome appropriable. Prioritisation is a bridge between the world of practicalities and the political world of the policy maker, while the implementation of an innovation or technology transfer is that further step from the political world into the wider world of the national society. Complicated forecasts are not the stuff politicians work with: complicated programmes will not be readily accepted socio-culturally.

### **3.2 What does policy mean in:**

#### **Developed countries**

The notions of policy are fragmented and much argued over. It is usually an activity reserved for the higher echelons of management though its execution is very much at 'street level' where the original intentions may have undergone several mutations in their transmission from higher to lower levels. Definitions of 'policy' take up a whole column in the Oxford English dictionary which is little wonder in the general mayhem that surrounds the activity the word describes. The most descriptive definition offered in the Oxford dictionary is:

"A course of action adopted and pursued by a government, party, ruler, statesman; any course of action adopted as advantageous or expedient"

#### **Developing countries**

There is no difference in the purposes of policy between the Developed and developing countries. The cultural setting will bring differences in the context and content that will depend on the geographic location of the country concerned and its level of development, particularly relating to governance.

#### **Effects of differing forms of governance**

The form of governance is a key matter that may seem to be the province of the country concerned, but it will be influenced by pressures and events running throughout the international community. International relations and diplomacy play a part that varies from the obvious neo-Clauswitzian to more subtle and discreet forces. Foresight (anticipation and adaptation) plays an important part remembering that the Oxford dictionary defines foresight as 'care or provision for the future' with the

alternative of 'the muzzle sight of a gun.' Mark Twain put the point differently saying that 'soap [health] and education are not as sudden as massacre, but they are more deadly in the long run' which is where policy 'ought to be' focussed.

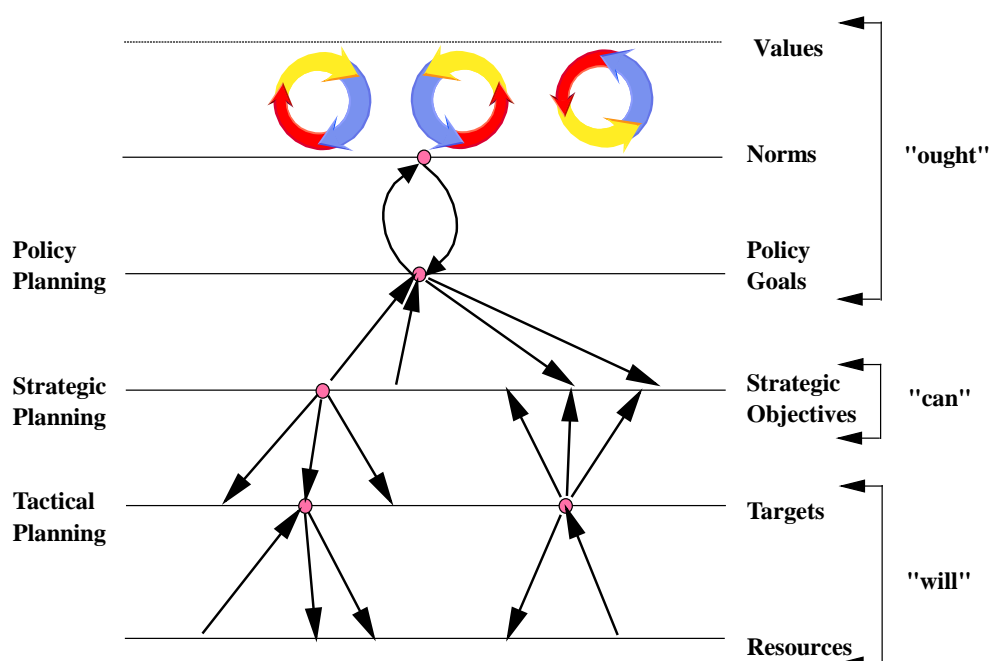
Policy is often surrounded by mystique and contradictions about what it is and what it is not. The explanation offered here is homogeneous in that it traces a pattern from policy through to tactics ('street level') where resources are allocated (and used) in detail. It is not claimed to be definitive nor to be universally accepted. If the approach seems academic then no apology is made for that; it is simply the outcome of trying to set out a common framework.

### 3.3 What policy is

#### 3.3.1 The notion of limits related to capability

Whether it be in the political sphere or in its business counterpart, policy can be conceived as a set of limits, some of which are constraining and others that are enabling. Fashioning these limits is a delicate and uncertain business. It depends on the existence of visions of the future that are disciplined to the extent that they are not daydream. Disciplined visions depend on foresight, but that dependence should not be construed as implying that until foresight programmes came into existence policies and the visions they depended on were undisciplined; nothing could be further from the truth. Foresight is an inevitable human activity and has always been used, by individuals or groups, in policy making with results that often cannot be differentiated in their visionary excellence. The advent of formal foresight, innovation and technology transfer programmes has simply opened the policy process to influences that are wider than in the past, but how much wider is a debatable question. The elements of the 'policy hierarchy' are illustrated in **Fig. 3.1**

**Fig. 3.1 Elements of a policy hierarchy**



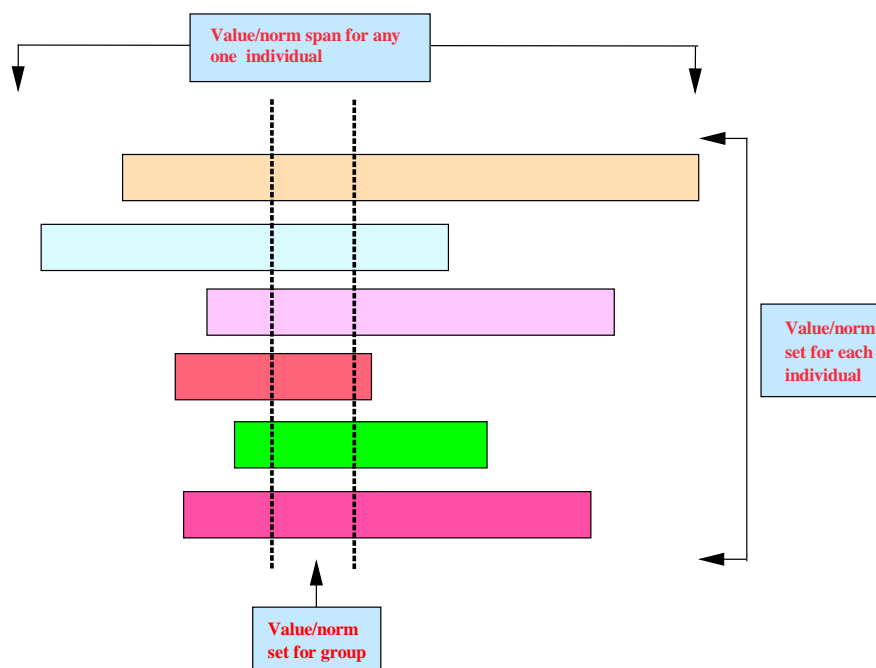


### 3.3.2 The policy “ought” as a statement of stretching and confining limits

The hierarchy needs to be interpreted in the following way:

- (i) Policy is concerned with sensing the *expectations* of the polity or a chosen subset of it. Expectations concern individual values and norms, and the way they aggregate is illustrated in **Fig. 3.2** below.

**Fig. 3.2 Aggregation of individual value/norm sets**



There is, then, a continual search to sense the intense activity that takes place between values and norms (the uppermost level in **Fig. 3.1**). It is the aggregation of this upper level activity (illustrated in **Fig. 3.2**) that ultimately represents the organised society's (polity's) expectations and is taken account of in policy planning either by passively acknowledging their implications for policy or to formulate policy to influence (or less likely, shape) the value - norm interaction in a particular direction (this is a highly uncertain process). Politicians and sponsors of programmes engage in this activity when sensing the need for a foresight or an innovation and technology transfer programme. If the need is accepted by the polity (or a selected audience) further sensing takes place, during the formative stages of a programme, to define its purposes and the way the outcome will need to be implemented. For sponsors, two important issues emerge from **Fig. 3.2**:

- The aggregate value - norm set for the audience may be the 'lowest common denominator' since the aggregate set is shared by all (the narrow vertical slice shown in **Fig. 3.2**)
- Particularly powerful or charismatic individuals may impose distortions onto the aggregate value - norm set that others acquiesce to but do not support

By accepting the lowest common denominator, sponsors may tacitly be setting an unadventurous tone for their programmes; this may lead to an equally mundane outcome. By contrast, the acquiescence of many individuals to impositions from particular individuals may facilitate a more adventurous programme (it may not) at the expense of later bringing disharmony.

(ii) As a result of (i) the sponsor sets out a policy for a programme by defining a set of enabling and constraining limits that *ought to* form its boundaries. These limits include the components of the STEEPV<sup>11</sup> set that will be represented. The combined foresight, innovation and technology transfer programme may have an explicit social dimension or it may focus primarily on technology. Both have an equally powerful influence on implementation of the outcome. Following from the formulation of the limits, to facilitate what the conduct of the programme *ought to* conform to, instruments of policy can be identified under three headings

- Those matters that can be under complete control during the programme
- Those where control is indifferent; some control can be exercised, but it is not complete and unexpected events, and outcomes are likely to occur (this is almost certain to be the case in innovation programmes)
- Those matters where control cannot be exercised and unexpected events and outcomes will be inevitable (for example in the use and commercialisation of the outcome, changes in power structures in sponsors causing changes in support)

These instruments then form the basis of the strategy for conducting the programme, where the concern is for the general disposition of resources at the appropriate time during the programme; those dispositions for implementation need to be formulated during the early stages of the programme along with appropriate contingencies.

(iii) At the lowest level in **Fig. 3.1**, the tactical level where the operational word is 'will,' lies the detailed allocation of resources to day-by-day management of the programme to complete it on time and within budget, whilst achieving the detailed schedule of programme milestones.

### 3.4 From policy to strategy

If policy is a set of enabling and constraining limits, the question becomes 'limits to what?' Policy formulations depend on visions of the future, where the plural is used deliberately to indicate that there is never a single vision of the future. Where then do foresight, innovation and technology transfer enter the policy process?

A model of the future is *someone's vision of the future*. To a starving man or woman a vision of bread is their model of the future, while to a NASA technologist it may be a

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<sup>11</sup>Social, Technological, Economic, Ecological, Political & Values and Norm

space station. The basis of models may range from records of *dreams* to *formal processes* such as simulation using special *languages*, including systems dynamics or econometrics, through to *interactive visual representations*, as used in flight trainers or in virtual reality. Models of the future begin as mental constructs; they are conceptual and later perceptual often taking on or expressing some form of ideology, using that word in its broadest sense; they are not *value free*. Models of the future draw strongly on their creator's subjective expectations of the future. The expression of a model in perceptual space, and later in physical space, can encompass an enormous diversity of ideas. Despite this diversity, models of the future continue to be created and to influence the future of the polity through communication of their content and synthetic capabilities. The phrase *synthetic capabilities* is complex, since any model of the future will *be synthetic* and will also have the capability of *synthesizing* many different, but possible futures.

### 3.4.1 Instruments of policy as tools for strategy

In policy making, the role invention, innovation and technology transfer *ought to* play in the process of transition, is set out as a set of limits that will be related to what is appropriate and appropriable within either the company or national setting. These limits are based on a sensing of what company and national expectations are regarding the future. They will be broad and will need to be brought into focus by identifying the instruments that the company or country has at its disposal to work toward the limits defined by policy. Innovation and technology transfer, based on foresight and its related intelligence gathering, are two important instruments in this context. While invention cannot necessarily be planned, innovation can be and is planned in companies. Consequently, areas where invention and innovation are needed certainly can be identified within the limits of policy (this is not an entirely controllable process in the terms identified earlier). Technology transfer is more controllable in the sense that once the source has been identified, success depends on following the processes as outlined earlier. However, the primary step has to be the recognition of technologies that are both appropriate and appropriable within the socio-cultural setting. An illustration of this is given in **Box 3.1**

#### **Box 3.1 Illustration of Policy limits and Instruments**

In the Western Europe there is currently much unease over food safety following a series of 'scares' in which various technological innovations in food production have, in retrospect, been perceived to have been undesirable by significant percentages of the population. The latest debate concerns genetically modified (GM) food, particularly soya, oilseed rape and tomato paste. National policies have hitherto been for benign encouragement of companies to produce GM foods. Some major companies decided to move into the production of GM foods, or more precisely seed, some 20 years ago to enhance food production, largely by preventing crop damage. The twin questions of the need for greater food production (as opposed to mal-distribution) and whether GM foods would be acceptable to the public may not have been asked. It was probably assumed that public opinion would follow the traditional pattern of passive acceptance (at that time science was in high standing; it no longer

enjoys that respect) since conventional plant breeding had always been accepted. GM foods were perceived not to be the same as conventional plant breeding, so that despite a regulatory framework, public acceptance of GM food has not been passive, while food stores have sensed that the introduction of GM foods is not appropriate and the technology is not appropriable.

### **3.4.2 The notion of levers that can be controlled completely or partially or not at all**

The instruments of policy (innovation and technology transfer are two such instruments) can be likened to a set of levers in a railway signal box. When the levers that control the points are pulled there is a controllable outcome - the train changes direction (there are exceptions when the mechanism fails but for the purpose of this illustration that is assumed not to occur). Levers that set the signals have an intended outcome which is not entirely controllable; the train driver may ignore the signal or the automatic braking mechanism may fail with unpredictable consequences. However, weather conditions, that may interfere with the safe operation of the train (snow, ice, thunderstorms, hurricanes, and so on), are entirely beyond the control of the signalman whatever his actions may be. While this set of circumstances may seem mechanical it is broadly reflected in the case studies in **Chapter 4** where each concerns an invention cum innovation, mostly in a social context, through a technology transfer. In each case the controllable lever is the recognition that an innovation can be attempted through a technology transfer. However, the outcome and the technology transfer itself are only partly under the control of the sponsor since the individuals involved may do things that were not expected. Lastly, each case study has elements that are not controllable by the sponsors; mostly these come from external influences that were either not recognised or if they were recognised the potential influences were not thought to be important.

Throughout the case studies (Chapter 4), there is a clear disposition of resources over time in order to achieve the desired outcome; this is the equivalent to 'winning the war' and not to be focussing only on the immediate battle which is the purpose of tactical allocation of resources.

### **3.4.3 From strategy to tactics: use and allocation of resources**

Once the policy to create a national infrastructure of communications, where only a fragmented one existed before, has been decided upon, and the policy instruments and strategy for doing so have been identified and formulated, the day to day tasks can begin. How these are done with the resources at hand is the province of tactical planning. It is here that all the formal methods of project planning can be used if they are both appropriate and appropriable. If that is otherwise, then less effective methods, that amount to reacting to the situation as it develops or fire fighting, have to be used. There is always an element of fire-fighting in any project, the purpose of formal planning tools is to minimise this kind of activity which is often the cause of project overruns in both time and cost.

### 3.5 Purpose of policy planning

Interpretation of industrial country experience and procedures into ideas that are appropriate and appropriable in the developing countries, is always fraught with risk and too often an overbearing manner by those people involved from the industrial countries. For that reason, this section must be hedged around with many caveats that simply question whether what is said is relevant to the enormous differences that characterize the developing countries. Underlying everything that will be said is the simple notion that policy, strategy and tactics are concerned with the satisfaction of human expectations in society wherever that is located. Jorge Ahumada, of Chile and Venezuela, made the point that:

'Economic development is not an *economic* problem. It is a problem of mind-set concerning a transformation of an indigenous socio-economic system from one state to another; as such it involves all those institutions, administrative, legal and political arrangements that ultimately are the visible representation of the underlying cultural values and norms.'

The developing countries cannot be replicates of those that have already gone through their own individual path of modernisation or industrialisation. Ideas concerning innovation and technology transfer can only provide guideposts to ways of doing things and in particular, how to expect the purveyors of technology and innovations from the industrial world to view, or go about processes, such as licensing and other ways of transferring technology. To quote Lauterbach '.... There is no one pattern or model of modernisation ..... [a] nation must or can follow; beyond a certain technical point, it will inevitably be left to its own devices.' In as much as innovation and technology transfer are part of modernisation, they can only be complementary to the indigenous effort; there has been much confusion and acrimony surrounding this point. Innovations take time to be accepted and often need cultural adjustments that cannot happen overnight. However, awareness of this issue means that it should be possible for the developing countries to avoid the destructive aspects of earlier paths to modernisation, but this in itself requires recognition. Familiar as this point may now be (it was not so familiar in 1974 when these matters were first being discussed) it bears repetition.

Policy planning for innovation is then about;

- (i) Assessing the role of innovation and technology transfer within the national context
- (ii) Identifying where innovation is needed and the technologies required
- (iii) Identifying the sources of those innovations and technologies

Of these three tasks, the first two have already been discussed. Given an identified need for innovation and new technology, a choice has to be made whether to:

- (i) Develop the technology internally (invention)
- (ii) Sponsor external development

- (iii) Acquire the technology from an external source or reverse engineer it
- (iv) Collaborate with one or more industrial partners to develop the technology

Which of the above options is selected and where responsibility for acquiring a new technology is vested will depend on a number of influencing factors, including the:

- (i) Size of the economy, its structure and diversity, and its products and services
- (ii) National culture and the level to which strategic and business planning is devolved
- (iii) National policy for technology acquisition
- (iv) Type of business regarded as being appropriate to the national interest and capable of being appropriable with national capability: these may be either in the “ASSEMBLY” or “WHOLE PRODUCT” categories of industrial activity
- (v) Relationship of the required technology to national capabilities and other technologies
- (vi) Urgency with which new technology must be acquired
- (vii) Availability of necessary internal skills and physical resources
- (viii) Availability of ways of funding for the internal development or external acquisition of technology
- (ix) Previous history of national development and growth by the acquisition of technology externally and by internal growth: this point reflects Lauterbach’s contention quoted earlier

Identifying the sources of innovations and technologies for acquisition largely falls into the intelligence field, but there are some tests that need to be applied to each possible source; these are set out in **Box 3.2**.

**Box 3.2 Test to apply to sources of technology for technology transfer**

Some important factors which require assessment in the evaluation of a source of technology are:

- The number of acknowledged specialists possessed by the source
- Who the key people are and how long they have been at the source
- The R&D infrastructure at the source
- The number and quality of publications by the key people
- The number and strength of patents filed by the source
- The long term reliability and stability, including financial stability, of the source (this again, is a matter of due diligence)
- Confidentiality and the source’s reputation in this respect
- The goodness of fit between the two parties, which can be assessed from any previous relationships between the country and the source, and between the source and other countries with whom it has business connections.
- Most of the responses to the above factors are judgmental and subjective opinion. For that reason some appreciation of the nature of expert opinion, as described by Amara and Lipinski, may be helpful.

### 3.6 Tailpiece

For all the arduous work that goes into policy making, implementation regularly fails more or less quickly. Often this is taken to imply failure of the process and of thought levels. However, in a paradoxical way policy failure is success through its inevitability. The most frequent cause of that inevitable failure is the mindset of the policy making community. The notions of science with its formulation of problems for solutions within constrained silos is a paradox of the real world. Conducted within this mindset, failure is inevitable and only a matter of how quickly. The dynamism of the real world with its make up of highly interdependent systems of activity means that a problem formulated at a fixed point in time has changed, possibly to something radically different, before a policy for its solution has even begun to be formulated. For this reason it is more appropriate to regard the real world as a cascade of interconnected situations in which amelioration is the appropriate intention of policy, not the solution.

### Chapter 3 References

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## Chapter 4 Case studies of Innovations

### 4.1 General Preface

It is timely to reiterate at this point that innovation is essentially a practical matter in which problems are identified and solutions to them are found. It is also timely to reiterate, as will be done in each case study in a more particular way, that innovation is not a matter of technology alone, but of technology in the service of the social setting, where the social need and the need for social innovation, may mean that the technological element is very much the minor one.

It is also often the case that innovation, through being associated with problem solving, is seen to be associated with what in the past has been called 'creativity training'; this too is a mistake, though many of the processes used in creativity training can be helpful when making innovations. In the industrialised countries, there is much concern for the systematisation of innovation arising from the need to obtain the maximum benefit from both public and private investment in research and development. In many senses, this wish to systematise innovation arises from the increasing complication and difficulty of research and development programmes in the industrial countries, since they are concerned with ever more esoteric branches of science and technology. In addition, public reaction to science and technology in the industrial countries is no longer one of simple acceptance, since the more complicated and interdependent nature of many developments means that their presentation can become bogged down with conflicting statements and claims. For the developing countries there are lessons to learn from these dilemmas, but for the poorest the importance of innovation lies in solving the problems of creating underlying infrastructures to raise the quality of life in their populations in general.

In this chapter the practicalities of innovation will be demonstrated through a number of case studies that relate to the fundamental need to create a modern infrastructure where none exists currently. For that reason the case studies concern:

Case study 1	Appropriate Technology – Building Materials
Case study 2	Appropriate Technology – Cooking Stoves
Case study 3	Solar Power: Communications Infrastructure
Case study 4	Solar Power: Refrigeration and Lighting
Case study 5	Solar Power: Rural Electrification
Case study 6	Irrigation using Solar Powered Water Pumping Systems
Case study 7	Alternative Energy Technologies Electrification: Wind Power
Case study 8	Orphan Drugs

Case studies demonstrating innovations that have emerged from the developing world

Case study 9	Cuban biotechnology
Case study 10	Cataract Surgery



As the case studies progress so the nature of the technological solution changes towards what might be regarded as advanced technology. However, each is underlain by two deeply embedded notions, those of sustainability and appropriability in the manner discussed by Lauterbach. Modernisation cannot in the end proceed unless the local population are deeply involved in the process, whatever it involves. There is also a third factor that underlies the case studies; all of them concern raising the quality of life in the regions where they have been applied.

It is now time to turn to the case studies themselves. In each case, material has been freely supplied by companies ranging from the largest (BP Amoco) to the smallest (J.P.M. Parry and Associates) and charitable institutions such as the Christian Blindness Mission and the International Centre for Eye Health. In this field, company or organisation size has little to do with the effectiveness of the solutions to the problems of modernisation.

#### **4.1.1 Introduction**

Innovation is making use of knowledge that is already in existence and assimilating that knowledge in a new way to solve technical or management problems. It is important to remember that innovation is not related solely to technology. Innovation is about good design for a specific function, whether it is a service, a product or simply a means of communication.

Innovation is necessary because world and social conditions evolve constantly and human resources must meet those needs by a process of adaptation in which innovation is an essential part of the equation. Innovation is a means of introducing new practical solutions and applying new tools to accommodate current needs, and greater societal expectations. Innovation may range from high technology to manual simplicity and it is important that it is not judged on its complexity, but on its effectiveness for the task at hand.

#### **4.2 Developing Countries – Appropriate technology**

Appropriate Technology (AT) has an image problem. Too often it is equated with second rate technologies abandoned by wealthier countries. In practice, the beauty of AT is that it responds to the current economic climate that prevails in a country at any given time. An Appropriate Technology is an Affordable Technology.

##### **4.2.1 How does Appropriate Technology differ from Intermediate Technology?**

AT is the big picture; it is the recognized choice to solve a given problem. In the course of its practical application it may need tweaking or major surgery. Intermediate Technology is the thought and commercialisation of AT to arrive at the original goal.

#### **4.2.2 What is Intermediate Technology?**

Intermediate Technology (IT) is a means to answering questions of what is most appropriate to development; it is made credible by action in the field, where expectations are maintained at realistic, achievable levels. IT contributes to upgrading indigenous capacities, utilizing local knowledge and experience, benefiting from collaboration, and exchange within a network of IT centres. Examples include the low-cost Oil Palm Mill Project in Sierra Leone and the Hand Dug Water Wells project in West Africa (Danert, 2006).

#### **4.2.3 Developing Local Expertise**

The problems facing those who wish to initiate these schemes appear universal and include:

- Unfamiliarity with basic concepts of technology,
- An unwillingness to accept anything remotely innovative due to feelings of inadequacy and, most obviously,
- A language barrier, both social and technical

Other cultural differences might include:

- The lack of ability to plan ahead or
- A more leisurely approach to health and safety

Intermediate Technology involves self-help, as indicated by Lauterbach. It relies on improvisation and adaptation, which depends on the willingness of the local population to accept outside support and training, but which they can then implement for themselves. IT workshops operate within the boundaries of a non-profit making organization; any surplus income is ploughed back into further development and innovation.

### **4.3 Case study 1 - Building materials**

#### **4.3.1 About this Case Study**

The production of building materials in developing countries is well established; this case study focuses on the small-scale production of affordable roofing tiles as an alternative to traditional or inappropriate roofing materials. It is an Appropriate Technology that emerged from an innovation by a UK company based in Birmingham. The company, J.P.M. Parry & Associates<sup>12</sup>, sells the technology, but they have a recurring concern of ensuring that any technological development does not require continuous outside support. Parry's objective is to produce a technology, which enables local people to become self-sufficient.

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<sup>12</sup> <http://www.parryassociates.com/>

### 4.3.2 How the Innovation Came About<sup>13</sup>

Corrugated iron is often the most sought after material for roofing in the developing countries. Customers like it and manufacturers like to sell it. It is light in weight, portable, durable and irresistible to its clientele. Furthermore it is very adaptable. It can accommodate the most irregular of roof structures, a property that allows it to be resold time and time again. Initial innovations sought to replicate the obvious properties of corrugated iron. However, when this thinking was applied locally, obvious shortcomings became clear.

- Raw materials used in corrugated iron were not available, and
- Local manufacturers used technology designed for the use of Portland cement when producing roofing materials, a commodity widely available and ideal for small-scale production

Attempts were made to copy the large scale manufacture of corrugated iron using Portland cement combined with fibre; this effectively formed a concrete sheet that could be produced manually. Providing great care was taken in the quality of the raw materials, the maintenance of the equipment and the production process, the manufacture of large-scale cement fibre roofing sheets was perfectly feasible. However, production was initially in a controlled experimental environment supervised by qualified and experienced technicians, used to handling the raw materials, familiar with the technology and with the manufacturing process. These skills were transferred wholesale to the local operatives, where the thoroughness and rigour of the manufacture were impressed upon them. However, it was after manufacture, in the general handling and transportation of the sheets, where this product failed. The method of fixing the sheets to roofs often caused them to break in two. It was this fault that led to the first design change which was to halve the length of the sheets. An improvement in the moulds followed and with additional mechanical innovations, including a vibrator, which was thought to operate effectively when covering only a small area, the roofing *sheet* was transformed into a more practical and more manageable roofing *tile*.

### 4.3.3 Those involved in the Innovation – State Provision/Partnerships<sup>14</sup>

The desperate plight of people in developing countries led to a sizable rethink about the role of state provision in improving the quality of their lives. Until the Habitat Conference in Vancouver in 1976, state thinking focused on rural and agricultural communities. In the early 1980's, aid and development analysts finally recognized urban poverty, which was being created, in part, by the migration of the rural populations to the cities in their search for a better way of life. The Habitat II Conference, held in Rio de Janeiro, was asked to accommodate new thinking and to redefine the role of the state beyond the year 2000. Does the state have a duty to provide? Do human rights extend to housing? What does enablement mean?

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<sup>13</sup> Parry News (1998) *Feature article*, May, p.7

<sup>14</sup> Alternative Technology (1996)

One of the key observations has been the need of the state to focus on *people* rather than systems. Appropriate language aids understanding and the choice of vocabulary can be hugely influential and beneficial in the general understanding of the problem. For example, people replace *populations*; homes replace *habitat*; jobs replace *employment*. Thinking has shifted away from the impersonal, large-scale model, towards a more manageable and smaller, human scale.

The interests of local communities are not viewed as practically compatible with market forces in the long-term, but as a short-term answer for guaranteed capital return. Global markets too often dominate thinking, pushing smaller, sustainable economies onto the sidelines. However, these smaller-scale initiatives are generating jobs, operating local utilities and building sustainable settlements.

It is the people who make up the local communities whose interests should be put first. This can be achieved by recognizing the unique skills that individuals contribute to a community and exploiting them in the best possible sense. Small-scale economies are self-serving, self-regulating and self-sufficient.

The manufacture of roofing tiles is an example of a small, localized business. In a poorer country, one of the shortcomings of this type of enterprise has been the reliance upon imported manufacturing equipment. What Parry Associates offer is adequate training in equipment maintenance so that local communities can operate independently, without feeling dependent on outside help.

#### **4.3.4 When did the innovation happen?**

For a time, when energy was cheap, it made economic sense for industrialized countries to think big. In practice this meant centralized mass production to produce goods and services at the expense of smaller more localized businesses. While the highly industrialized countries have a wealth of skilled labour, developing technologies and resources, the developing countries do not. The downside of 'think big' philosophy has been great concern over:

- Increased pollution
- The wider social, and human cost of overproduction, and
- Sustaining populations that demand vast quantities of energy

In the 1970s, cheap energy became 'a thing of the past,' and in the developing countries smaller community-based businesses restored local employment, producing individual goods without the need for transport. When applied to a range of goods and services, a marked decrease in waste, pollution and road transport is evident; the only obvious increase is in community employment.

Unemployment and a lack of foreign exchange make it almost impossible for developing countries to adopt the established industrialised nations' prodigious development schemes. Equally, the highly technical and technological advances that are in evidence in centralised mass production remain out of reach. An alternative

was sought to accommodate local needs. The only model available, and one favoured by the industrialised countries was the regeneration of small local businesses. Small scale, low-cost technologies were regarded as the norm and 'appropriate', not secondhand or second-rate.

#### **4.3.5 Background to the Roofing Tiles project – Reasons for the Innovation**

Climate and readily available natural resources often dictate the choice of building materials in a given country. The roof tile developed in the 1970s had to be resistant to high winds, fire and insect infestation. Indigenous materials, notably straw and leaves, might provide adequate protection, but only for a short period of time. Galvanized roofing sheets had proved a costly alternative. So an effort was made to reproduce the obvious effectiveness of the galvanized roofing sheet but more cheaply. The development of a corrugated cement reinforced sheet using natural fibres such as sisal or coir produced a solution. Here was the development of a roofing sheet, which could be made commercially in a developing country on a scale appropriate to the needs of its construction industry. The method of production was simple enough, but problems arose within a few years as the sheets cracked and the fibres decayed. These sheets, once seen as a panacea for many developing countries, were slowly abandoned. But the very nature of it is further development.

**Fig. 4.1 Demonstration roof assembly**

The fibre-reinforced concrete roofing (FCR) tile was developed as a result of the failed roofing sheet. It was smaller (500x250x6 or 8mm) and less dependent on the fibres as reinforcement. So as the tiles decayed, they were less likely to crack. A further development was the addition of a tile vibrator in the production process, which has the effect of removing air bubbles that might otherwise cause weakness in the finished tile. The result is a stronger, more durable product than the roofing sheet.



**Figure 4.2 Roof during assembly**

Micro-concrete roofing (MCR) tiles have been the most recent development, made without any fibre at all. Greater care is required in their production as they are more fragile, and the raw materials should be of a superior quality, a vibrator is also used in the production process.



**Figure 4.3 A Completed Building**

Choosing one type of roofing tile over another would depend on the local conditions, the resources available and the experience and skill of the local people. It was critical to develop equipment and production techniques on a scale small enough to be sustainable. The technology developed has succeeded because of Parry's willingness to learn how to accommodate local needs and to overcome each setback by a process of continuing development and innovation, both of which are inherent in IT. The type of roofing tile developed is now widely produced by small businesses throughout Africa, South and Central America and Asia.



## **Labour**

The size of the workforce is an important consideration in the workshop process and establishes a realistic projection of the volume of tiles that can be produced in any one day. For example, the output that can be expected from a standard 'Super Roman' tile plant with two workers is approximately 100 tiles per shift. Add extra workers for handling the tile moulds and far higher outputs can be achieved.

## **Equipment**

The accessories and equipment needed to produce the tiles are inclusive within the package. Once the training workshops have been completed, the local community must be able to manage and maintain the equipment without outside help. So it is in the interests of the trainers and the trainees to participate fully by communicating their needs and resources honestly.

A successful roofing plant comes complete with six essential pieces of equipment suitable for the production of both the FCR and the MCR tiles. The plants cater for manually powered production for remote places where electricity is not available and battery power, which could be charged with solar power, has to be used. Every eventuality is catered for. Safety is a key factor too. The electricity supply is DC and only 12 volts. The equipment is designed to work underwater. It is safe and easy to repair machinery. Finally, a 'How to use' manual is supplied with every plant. The six essential items are:

- 1        - a tile vibrator
- 2        - moulds
- 3        - plastic sheets
- 4        - batching boxes
- 5        - a water curing tank
- 6        - a table to work on

The tile vibrator is an essential item in the production of MCR tiles, which contain no fibre to bind the concrete mix together. Vibration helps to consolidate the concrete mix, removing air bubbles that would considerably weaken the finished tile. The vibrator unit consists of a suspended flat metal plate to which is attached a rotating eccentric cam. The rotation of the cam translates into the up-and-down motion of the plate. A hinged metal frame fits onto the plate defining the sides of the tile. The vibrator can be driven manually, electrically with a battery, or run off mains electricity.

The moulds used in tile plants are self-stacking and self-sealing. It is critical that MCR tiles cure in a damp environment to ensure that during the first 24 hours, the products do not dry out. The plastic moulds envelop the tile mix completely and stack one on top of the other. Each batch of 200 moulds should contain 10 ridge moulds for making the specially shaped tiles for the ridge of the roof.

There should be one plastic sheet per mould. The concrete mix is moulded on the plastic sheet before both are transferred and repositioned on the mould. Plastic sheets do wear out and extra sheets are supplied with each plant.

Two batching boxes per tile are required, one to measure accurately the correct amount of sand and the other to measure the cement.

A water tank is needed for curing the tiles after the first 24 hours. A tank large enough to hold 1000 tiles is recommended, (8 metres long, 0.8 metres wide, 0.6 metres high), although it is not unusual to find a number of smaller tanks in use. The water should be clean and where possible, free of sulphates. As a rule of thumb, if it is used regularly for human consumption, it is good enough.

An easy, self-assembly steel framework unit supports the vibrating unit and accommodates the complete production process.

## **Quality Control**

### **Materials**

*Quality control* is important in the selection of the three basic materials and in the mixture composition. Stringent procedures should be applied especially for MCR tile production. If this cannot be guaranteed and large numbers of damaged tiles are being manufactured, then producers are advised to cease production immediately and seriously consider alternative methods. Sand, cement and water are used for both FCR and MCR tiles. Pigments are optional. In addition, FCR tiles are reinforced with natural fibres and MCR tiles contain 50% fine aggregate (gravel).

*Sand* needs to be graded. Tiles of different thickness require different sized grains. Sieves are used to size the grain providing further evidence of quality control in a very simple but effective way. FCR tiles contain 75% sand and MCR tiles 25% sand. Sand can be dug out of a river.

*Ordinary Portland Cement* is recommended. FCR tiles and MCR tiles; each contain 25% cement.

*Natural fibres like sisal or coir* are used. Bagged fibre is relatively cheap and consists of polypropylene. Sisal behaves the same way as the polypropylene, as a crack stopper. When the concrete mortar sets, fine cracks are evident. Sisal works not by reinforcing the concrete mortar but by holding it together in its wet state.

*Water* should be clean and free from significant quantities of dissolved salts. Drinking water is perfectly acceptable.

### **The Production Process**

The process of making a tile is easy to grasp after very little practice, providing all rules regarding quality control are observed and understood. The method is the same for both FCR and MCR tile production. For the FCR tile, the cement mortar is a mixture of sand, cement, 0.5% fibre and water. For an MCR tile, the cement mortar is a mixture of sand, cement, fine aggregate (gravel) and water. Pigment is optional in both cases.





**Figure 4.4 Mixing the mortar and assembling the table and mould**

A plastic sheet is fixed to the table frame to which the vibrator is attached. A measured scoop of mortar mix is spread onto the plastic sheet. The vibrator is switched on and the operator trowels the mortar flat. The vibration drains out some of the air and water, giving the concrete more strength. The tile has a 'nib' and as this is formed a wire loop is inserted. The procedure is strong and consistent (the nib will hang from the roof held in place by a wire loop placed through the nib. A nail secures the loop).

**Figure 4.5 The frame is removed. The wet mortar is dragged onto the tile mould**



The frame is removed and the wet mortar is dragged onto the mould, still on its plastic sheet. The mortar takes the shape of the tile mould. The mould is then carefully added to a stack of newly made tiles. For the next 24 hours, the mortar hardens in the sealed, humid environment of the mould. They are carefully removed after that time and placed in water-curing tanks for up to two weeks or placed in solar curing areas for 3 to 4 days. If rapid curing is required, a third option is the use of a

humid chamber, which can be constructed on site. Mobile high humidity curing bins can also be used.

**Figure 4.6 The tile mould is removed and added to a stack of newly made tiles**



#### **4.3.6 What the Innovation has achieved**

Such innovation achieves greater self-sufficiency within small communities, along with the creation of high quality-roofing tiles, which can be manufactured locally by unskilled labour using local raw materials. Innovators like Parry Associates have established the production of the roofing tile as a legitimate small scale manufacturing business, with the potential to employ thousands of local people. All manner of buildings have been roofed with these tiles allowing the likes of schools and clinics to operate successfully without falling into unnecessary disrepair.

#### **4.3.7 Further Development**

Parry Associates have gone beyond simple tile production and have already a range of roofing tile equipment. The inventions and development of small scale roofing tiles are now only one part of a range of other products. The machinery and expertise has expanded. Now, potential customers are encouraged to think big; they are asked to consider building concrete products factories rather than simply assembling a tile machine. A 'factory' might comprise of a number of processing machines that have been adapted to make concrete blocks and floor slabs. The same rules apply regarding availability of raw materials and affordability of production. To accommodate evolving local conditions, existing customers are continually encouraged to diversify.

#### **4.4 Case Study No. 2 Appropriate Technology - Cooking Stoves**

Mass production of fuel efficient wood-burning stoves. Manufacturing location Zhejiang province, China

##### **4.4.1 Why the need for innovation?**

Around 3 billion people worldwide eat food cooked on fires that burn wood, charcoal, dung, coal and straw. But the traditional cooking stove has proven lethal to the health of some of the world's most vulnerable groups. Women and children in particular suffer the effects of pollution from smoke and gas inhalation, in particular carbon monoxide. It is estimated that around 1.6 million people die every year as a result. Of these, around a million children under the age of five die of childhood pneumonia. In addition, the use of wood as fuel in the cooking process has contributed to deforestation and climate change. The wood is often collected by women, which is tiring and time-consuming. The design of more fuel efficient cooking stoves can tackle the health problems of more traditional cooking fires, reduce the impact on climate change and herald a range of social benefits.

##### **4.4.2 The organisations behind the technology**

Aprovecho Research Center (ARC) is a non-profit organisation that has been designing stoves since 1976 working with various partners along the way. In 2007, ARC, based in the USA, formed a partnership with Shengzhou Stove Manufacturer (SSM), a private company, based in Zhejiang province, China, to develop and produce stoves. Together, they set up a factory scale production of inexpensive and efficient wood and charcoal stoves, ARC was responsible for the design and marketing of the stoves and SSM their production and sales. Their main customer is Envirofit International which markets the stoves in India supported by the Shell Foundation. Other markets include South Africa, Tanzania, South America and India. During the 1980s and early 1990s, China itself introduced over a 180 million improved cooking stoves. It is now trying to introduce even newer models to its population.

##### **4.4.3 The technology**

In consultation with the end-users, three main models, all portable, were designed. The 'rocket' combustion chamber uses an internal chimney in the stove. This directs air through burning wood, encouraging the mixing of flame and gases above the burning biomass.

**Figure 4.7 Cutting the opening in a clay combustion chamber, Shengzhou Stove Manufacturer, China. Photo: Martin Wright/Ashden Awards for Sustainable Energy**



The internal dimensions of the stove are critical in achieving high combustion efficiency and transferring the heat efficiently to the cooking pot. In addition, the material of the combustion chamber itself must have a low density and thermal mass. This provides good insulation and ensures carbon monoxide emissions are kept to a minimum.

The most popular model burns only wood and has a single door for adding the fuel. A second model can burn either wood or charcoal. This has two doors, a lower one for controlling air flow and a second, upper door for adding the fuel. All designs should last between 3-5 years.

ARC relies on customer feedback for its continuous product development. For example, an inexpensive all-ceramic stove was developed in direct response to feedback from GTZ, the German Development Agency working in Southern Africa. In this instance, the stove was supplied without metal parts so that the product could be finished in the country where it was to be used.

#### **4.4.4 Manufacturing and maintenance**

The stoves are manufactured by SSM. To ensure their manufacture met internationally approved efficiency and emissions standards, a laboratory was built at the factory. Product durability is another essential test i.e. how the stoves perform in the field and quality assurance checks are made on every batch.

**Figure 4.8 Emissions testing. Loading wood into a stove, Shengzhou Stove Manufacturer, China. Photo: Martin Wright/Ashden Awards for Sustainable Energy.**



#### **4.4.5 Cost to the customer**

Depending on the size of the model, a complete metal-clad stove costs (before shipping and distribution) in the region of US\$7 to US\$12 and the all-ceramic stove, even less, at around US\$3.50. A few stoves are sold to individuals, but generally, most go to distributors that include companies, NGOs and government programmes. The distributors pay SSM directly and various financial arrangements are then made with the end-users to supply the stoves.

#### **4.4.6 Social benefits**

There are many benefits associated with the introduction of these improved cooking stoves. In terms of a person's health, less smoke means less air pollution and a reduction in respiratory and eye diseases. Also the risk of fires and burns are much less. Because of the efficiency of the stove, they heat up more quickly, so the cooking time is reduced. Less wood is required, which means less time collecting it and for those who spent a large part of their income on the purchase of fuel, they save money.

#### **4.4.7 Environmental benefits**

Measurement and survey data suggests that compared to a cooking fire, the stove can save between 40% - 50% of fuel wood and reduce carbon monoxide emissions by 50 to 60% and particle emissions by 50 to 70%. The fuel wood saving helps reduce local deforestation.

#### **4.4.8 Future developments**

By 2009, SSM had sold over 60,000 stoves. In partnership with ARC, SSM are successfully manufacturing and mass-producing a durable, affordable and efficient fuelwood cooking stove. Moreover, with around half the world's population using fires or less efficient stoves, the market potential is very promising. ARC and SSM are currently developing a fan-assisted stove which they hope will reduce greenhouse emissions.

#### **4.4.9 The Cookstove Programme in the Millennium Development Villages (MDV)<sup>15</sup>** Location, Senegal, Africa

#### **4.4.10 Reasons for implementation**

The motivation behind the Millennium Village Project (MVP) which sought to introduce biomass cooking stoves across rural Africa, was to identify appropriate technologies that would serve two purposes. Firstly, by providing efficient combustion, the impact on the environment would be greatly reduced. Secondly, doing so in such a way that traditional cooking practices would be accommodated. It was necessary that establishing a cooking stove in the field would save between 35-40% in locally sourced fuelwood and that the village community were willing to participate in the project.

Cookstove vendors were recruited from women's groups, youth groups and shopkeepers and trained in the technical, financial and practical aspects of the cooking stoves, as well as the project itself. It is the vendors who are responsible for selling stoves to the community.

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<sup>15</sup> <http://modi.mech.columbia.edu/category/energy/cook-stoves/>



#### 4.4.11 Sustainability

The sustainability of the project depends very much on the investment by all those involved. The importance of commercial partners in extending the programme beyond the Millennium Villages to other parts of the country and the need to capture the carbon revenue potential of the cooking stoves that can then be used to subsidise their use by others, increasing their affordability along the way.

#### 4.4.12 Important considerations for successful implementation

Several lessons have been learned since the implementation of the Millennium Village Project.

- *The availability of wood.* Where wood is plentiful, some villagers find stoves less attractive. Whereas those villagers who have to forage for wood in dangerous areas may be more willing to adopt an improved stove.
- *Training.* Giving adequate support and training in basic accounting and record keeping is equally important as the training in the practicalities of cooking stove use, especially for monitoring and evaluating programmes.
- *Reliable vendors.* Have family members, for example, vouch for the vendor. Involving a community leader from the outset of the programme can help in the event of a vendor defaulting.
- *Technical assistance.* Site team support ensures that strong connections are created between distributors, local co-operatives and vendors limiting the support needed for the project in the future.
- *Partnerships.* Creating links, sharing knowledge and good practice with other organisations who share the same objectives can make the programmes more financially viable.
- *Size of stove.* MVP staff identified the size of the stove as a reason for its rejection in some instances. The villagers found the stoves to be too small for their various pot sizes and for the number of people they were cooking for, typically ten or more people for every meal.
- *Local capacity to manufacture.* Making stoves locally can seriously reduce costs and increase sustainability of improved cooking stoves and is to be welcomed. However, strict manufacturing specifications need to be adhered to. So encouraging local manufacturers to partner with an established stove manufacturer, where design, manufacturing and training is strictly controlled, will ensure the continuity of a quality product.
- *Locally made stoves.* These vary in size, construction, durability and efficiency and do not necessarily have the uniformity or fuel saving capacity as those manufactured industrially.
- *Testing under local conditions.* Local foods, cooking practices and fuel wood vary within and across countries and so it is important to test stoves in the field. Stove testing is also a very useful PR exercise for promoting the product in the community.

- *Trial test period.* The MVP, ‘Try before you buy’ model allows women to use the stove confidently for two weeks with the option to buy at the end of the trial period.
- *Affordable market.* It is important to gauge a community’s willingness to pay for a stove and prices should reflect that. MVP price the cooking stove at US\$10-US\$16 and subsidises the remaining cost. MVP expects that this subsidy will be covered by carbon financing through the voluntary market in the future.
- *Seasonal impact.* Demand for stoves is very often seasonal. In the rainy season demand is higher because dry wood is harder to gather and purchasing wood is more expensive at the local markets.<sup>16</sup>

#### 4.4.13 Barriers to their use

It would appear that the majority of customers who use the improved cooking stoves prefer them to cooking on fires or on less efficient stoves. The benefits, as we have learned, are manifold – social, financial and environmental. However, occasionally there are pockets of resistance and often for very practical reasons. For example, most women may dislike the smoke from the older less efficient models but for others it is a valuable aid because the smoke drives away malaria-carrying mosquitoes and kills bugs that lie in their thatched rooves. In another instance, women knew the benefits of the new stoves but were cautious about adopting them without the approval of their husbands or community leaders.<sup>17</sup>

### 4.5 Case studies based on Innovations in the infrastructure underpinned by solar power

The following case studies involve the use of solar power to create an improved infrastructure in the following ways:

- In **communications**, by providing power for wireless based communications networks that will cover remote rural and city regions
- In **public health**, by providing power for refrigeration used in vaccine storage in remote areas
- In **food production**, by providing power for water pumps for irrigation systems

Each innovation depends crucially on innovations in solar power arrays. The basis of solar arrays is described first. After that there is a brief summary of the places where applications of the kinds listed are known to be in use. The list does not claim to be exhaustive and has been taken from various sources including BP Solar Ltd and MIT’s Media Laboratory’s cooperative work with the Costa Rican Foundation for Sustainable Development. The individual applications are then described indicating their importance to the process of modernisation.

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<sup>16</sup> <http://modi.mech.columbia.edu/category/energy/cook-stoves/>

<sup>17</sup> [http://www.ashdenawards.org/files/pdfs/reports/Cookstove\\_report\\_final.pdf](http://www.ashdenawards.org/files/pdfs/reports/Cookstove_report_final.pdf)

#### 4.5.1 Solar Energy

Sunlight, or solar energy, is the most abundant renewable energy source on Earth. The Earth receives  $\sim 1.2 \times 10^{17}$  W of solar radiation power. The current worldwide rate of energy consumption is about  $\sim 10,000$  times smaller at  $\sim 1.3 \times 10^{13}$  W. (US Department of Energy, 2005). Thus, the amount of energy that comes to the Earth that can be captured and transformed into useable energy is several hundred times greater than the annual energy consumption of the planet. In short, the Earth receives more solar energy in an hour than the total energy it consumes in a year.

Solar energy alone has the capacity to meet all the Earth's needs for the foreseeable future (Tao, 2008). Solar energy is available anywhere on the surface of the Earth, though the amount varies with latitude, the season of the year and other more complicated factors including the diurnal variation, the tilt of the Earth's axis and annual variation due to the elliptical orbit of the Earth about the Sun. There are other variations due to clouds, atmospheric pollution, dust or haze. Over time in a given location the annual amount of solar energy received is relatively constant, with a greater abundance in the equatorial regions.

This section is concerned with Solar electric systems which convert the sun's radiant energy directly into electrical energy, which can then be used in appropriately designed appliances that are in common use. The main challenge to designers is to make a device that will capture the solar radiation effectively and convert it reliably into electricity at as high an efficiency as possible. The amount of energy falling on a flat level surface one-meter square over the course of one day is roughly 5 kWh, an average over 24 hours of about  $0.2 \text{ kWh/m}^2$ . When compared to other modern energy sources, this is not very concentrated. For example a 100-Watt light bulb at its surface has an intensity of about  $12 \text{ kW/m}^2$  and an electric stove (500W burner) has an intensity of about  $25 \text{ kW/m}^2$ . Thus solar energy systems need to have collectors with a relatively large area compared to other energy sources we are familiar with. However, were 0.16% of the Earth's surface to be covered with 10% efficient solar cells, they would provide  $\sim 2 \times 10^{13}$  W of electricity, which is more than the current total energy demand of the planet. (US Department of Energy, 2005)

There are different types of solar energy systems currently in use. These include solar hot water, solar pool heating, solar chimneys and solar power towers. But the two most common are passive solar heating, mainly used for home heating and small, stand-alone solar electric systems based on photovoltaics (pv).

#### 4.5.2 Solar cells

Solar - or photovoltaic - cells convert solar energy into electricity. When single photovoltaic cells are connected together electrically into a series or parallel circuits, they form a photovoltaic module. Modules, assembled together form a photovoltaic panel. A solar photovoltaic array consists of any number of these panels arranged to create one interconnected generating system. If a single panel is not sufficient to



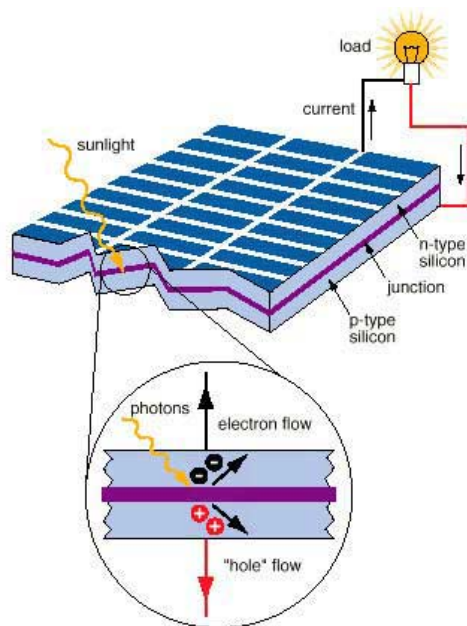
supply power to an application, then individual panels can be linked together and configured into wireless networks to supply power that is needed.

The current (and power) output of a photovoltaic cell depends on its efficiency and size (surface area) and is proportional to the intensity of sunlight striking the cell's surface [Florida Solar Energy Center]. These are some of the factors that determine the successful application of solar arrays in remote rural areas and are some of the challenges facing designers of solar energy systems.

#### 4.5.3 Composition of a Photovoltaic Cell

Solar cells are devices that convert solar energy into electricity directly via the photovoltaic effect. The photovoltaic or solar cell is made up of two different layers of silicon pressed together, forming a semi-conductor device, which produces a photovoltage between the layers. A photon from the sun excites an electron within the photovoltaic cell into a mobile state. Light hitting one layer results in a buildup of a negative charge and for the other layer a positive charge. If the charges have nowhere to go they will not do anything useful so a wire grid is attached to the front of the cell to act as a negative contact. A metal plate is added to the back of the cell to act as a positive contact. When wires are attached to these two contacts, an electric current flows.

**Fig. 4.9 How a Photovoltaic Cell Works<sup>18</sup>**



The materials used in photovoltaic cells are generally silicon-based. In general, photovoltaic materials are categorised as either thick crystalline sliced from single crystals of silicon or thin film deposited in thin layers on a substrate in either polycrystalline or amorphous form. The type of material and technologies used in the construction of photovoltaic cells has a major influence on the conversion efficiency of the cell.

In today's market, commercially available silicon solar cells have light-to-electricity efficiency conversion rates that exceed 15% and can be manufactured at a fraction of

the cost of 30 years ago. Photovoltaic conversion is a simple and dependable technology that can be used on any scale from milliwatts to megawatts. It is environmentally friendly, silent and emission free.

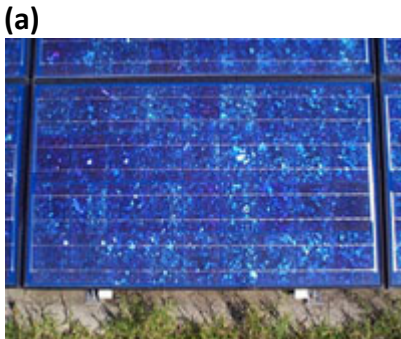
<sup>18</sup> Murdoch University, School of Engineering and Energy, Australia.

Today's solar cells can be manufactured in many different materials including cadmium telluride, gallium arsenide and copper indium diselenide. The practical production of silicon solar cells is also varied ie polycrystalline, ribbon, amorphous, single crystal and thick film.

**Figure 4.10 Different types of silicon solar cells.**<sup>19</sup>



**a) Single crystal solar cells in panel**



**b) Polycrystalline solar panel**



**c) Amorphous silicon solar panel**

**(c)**

A single photovoltaic cell on its own cannot produce much power. However, put a few hundred together and they can generate enough electricity to power a satellite's cameras, radios and computers. When the sun is especially bright, enough excess energy is stored to recharge a satellite's back-up batteries. These batteries are then drained when the sun is behind clouds or as day turns to night.

Today, the majority of photovoltaic arrays are used for electricity generation connected to a network. However, a smaller, but growing market for off-grid power applications includes remote homes, boats, electric cars, parking meters, emergency telephones and road signs.

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<sup>19</sup> Image Source: Murdoch University, School of Engineering and Energy, Australia.



**Figure 4.11**  
**Typical solar array**

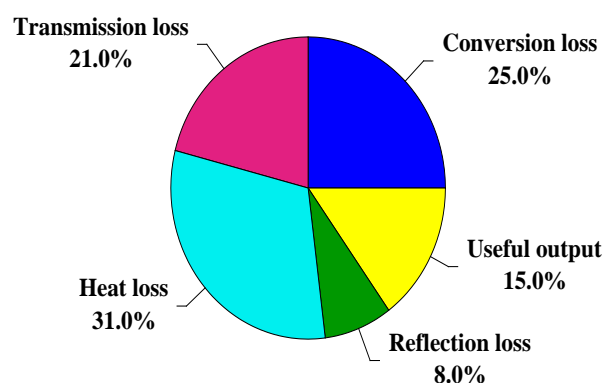
#### 4.5.4 What are the limitations to Solar Power?

Like all power generation systems solar power has its limitations. There are some negative environmental impacts arising from their production and destruction and from the aesthetics of the installations. The manufacture of panels and batteries use Lead, sulphuric acid and cadmium telluride, all toxic materials, so the safe disposal of these products at the end of their useful life is important. Solar installation requires a large area for a system to be efficient and large solar arrays can be unsightly. However, the major current limitation is the relatively low conversion efficiency of photovoltaic systems. Of the light energy hitting a solar panel per day the photovoltaic cells currently convert between 13-16% into electricity. However, current developments, using newer photovoltaic materials, are raising the potential for greater efficiency to as much as 30%, nearly twice as efficient as they are now.<sup>20</sup>

**Fig. 4.12 Typical Performance of a Photovoltaic Cell**

To produce the required amount of electricity for a particular installation, many solar panels may be needed; this is simply one of the design parameters that influences the final cost of the system. Typically, the current cost of a panel producing 45 watts of power is \$150-\$200 (the average lamp uses 90 watts). As the use of photovoltaic arrays

has increased the real price of a photovoltaic module has decreased and will continue to do so as production volumes rise. In addition there are relatively high costs associated with the maintenance of solar panels mainly due to the need to bring in



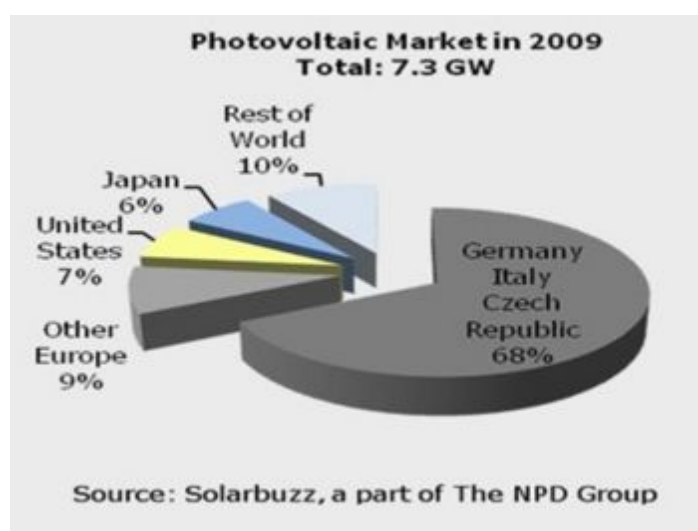
<sup>20</sup> Research Institute for Sustainable Energy (RISE), Murdoch University, Australia

very skilled technicians to remote areas to install and repair the equipment. Even if the failure rate is low, maintenance in remote areas remains difficult and expensive.<sup>21</sup>

#### 4.5.5 Uses of solar power

Many of the developments during the last 40 years have originated from space research as solar power arrays are used extensively in satellite power systems. Photovoltaic devices now have widespread uses ranging from tiny cells for watches and calculators to power systems for yachts and large scale rural power applications. In 1992, while still small at only 50 MW of sales world wide, the solar industry was expanding at a rate of 20% per year.

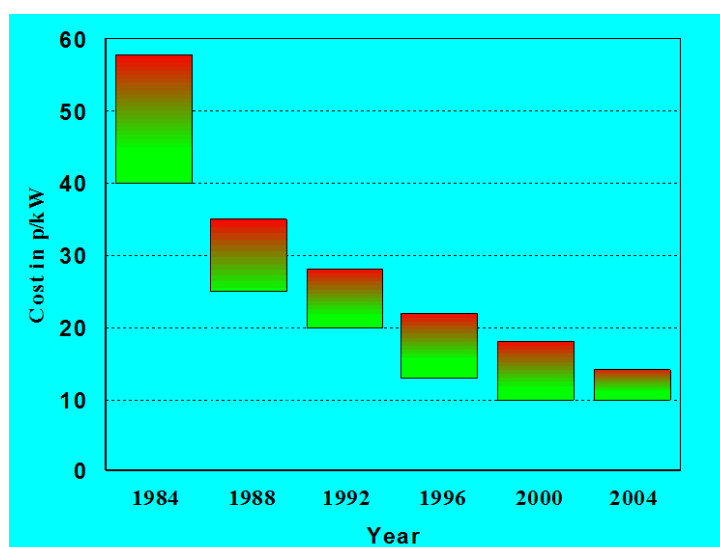
**Figure 4.13 Photovoltaic Market in 2009<sup>22</sup>**



In 2009, photovoltaic installations grew by 20% compared to 2008, with over 7.3GW of installations globally (**Fig. 4.13**). Demand for solar energy has grown at 30% annually over the past 15 years.<sup>23</sup>

**Fig. 4.14 Decline in Cost of Electricity Generated by Photovoltaics**

Growth at this rate, with its concomitant rate of innovation and the falling costs of solar electricity generation (**Fig. 4.14**), are promising signals that solar power is increasing its potential as an important energy industry player.



<sup>21</sup> WHO fact sheet – “Solar Energy and Rural Health Care 23/06/99,” Fact Sheet N132 September 1996

<sup>22</sup> Solarbuzz Marketbuzz (registered trademark) 2011

<sup>23</sup> <http://register.solarbuzz.com/our-research/reports/marketbuzz>

#### **4.5.6 Applications of Photovoltaic Systems in Rural Areas**

The World Bank estimates that some 2 billion people are without the basic amenities in life, including electricity and drinking water. The low power consumption in rural communities and their distance to the nearest electricity supply point, makes extension of the conventional grid supply unjustifiable from an economic point of view. In these situations, the needs of rural communities are best met by stand-alone power systems (see Case Study 3 on communications infrastructure) that are long lasting, reliable, robust and relatively simple to maintain. Photovoltaic generating systems fulfill the first three of these conditions but do require skilled people for their maintenance and repair in the event of failure. Happily, failures do not occur very frequently, but it is important for the indigenous population to grow local repair competence, in line with Lauterbach's principle of self sufficiency.

Photovoltaic technology has been widely used in remote standalone electricity applications and is now established as an appropriate and appropriable technology for use in developing countries with demonstrated developmental benefits when used successfully. Photovoltaic technology has also demonstrated how industries can cooperate at global and local levels to respond to real local needs as will be demonstrated in the following brief case studies.

#### **4.6 Case Study 3 – Developed and Rural Areas in Developed Countries - Communications infrastructure**

An effective communications infrastructure is an important plank in developing a strong social and economic infrastructure. However, for rural areas a conventional cable based network is inappropriate. The case study outlines how a wireless based communications infrastructure can be created using self-contained photovoltaic systems as the source of electricity.

##### **4.6.1 History of Solar cell innovation**

The first tentative steps towards using photovoltaic arrays in providing power for rural communications systems goes back to the mid-1950's. But the scientific investigation of the photovoltaic (PV) effect began much earlier in 1839 with Henri Becquerel. The French physicist discovered that an electric current could be produced by shining a light onto some chemical solutions. It was observed in 1877 in metal selenium, a solid material used in light meters. It was not until the insights of Einstein and Schottky into a better understanding of scientific principles in 1905 and 1930 respectively, that more efficient solar cells could be made. Since then the theory and the manufacture of photovoltaic devices has advanced considerably. In 1954, Chapin, Pearson & Fuller developed a silicon solar cell which converted 6% of sunlight falling onto it into electricity. The applications for this type of cell were specialised e.g. orbiting space satellites from 1958<sup>24</sup>.

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<sup>24</sup> [www.rise.org.au](http://www.rise.org.au)

In 1961, the UN organized a conference on 'Solar Energy in the Developing World' but it is not clear whether communications systems featured in it. The first positive event came in 1972 when the French installed a Cadmium Sulphide photovoltaic system in a village school in Niger, to run an educational TV. From 1976 through to 1985 and from 1992 to 1995, the NASA Lewis Research Center project office installed 83 photovoltaic power systems covering every continent except Australia. These systems provided electricity for diverse applications including many already described and telecommunications and classroom television.

From 1983 onwards the pace quickened with photovoltaic systems being installed in remote medical clinics in Kibwezi, Kenya; Ikutha, and Chikwakwa, Zimbabwe. These systems provided, in Keyna, power for radio communication. In 1984 the NASA Lewis Research Centre supported the development and installation of 17 photovoltaic power systems in four villages in Gabon, to include TV/VCR and other facilities. In 1985 a system was installed near Wawatobe, Sulawesi, Indonesia, to power a satellite transmit/receive earth station and classroom equipment as part of a US AID project for distributed education throughout Indonesia. The photovoltaic power system was designed and installed by NASA Lewis Research Center and their contractor, Hughes Aerospace, Long Beach, CA.

Since the mid-1980s major companies, including BP and Shell, have become involved in installing solar power systems for communications networks in rural areas. For example, BP report having manufactured systems for use in Africa (Algeria, Botswana, Sierra Leone and Zambia), Asia (Bangladesh and India), Australasia (Papua New Guinea and Tuvalu), Latin America (Argentina, Chile, Colombia, Costa Rica, Panama, Peru and Venezuela) and South East Asia (China, Indonesia, Malaysia, the Philippines, Thailand and Vietnam).

There have been many developments since the earliest scientific investigation in 1839 and the more recent developments of the 1950's. Further innovation and application in the 1970's has meant that the photovoltaic cell has become 40% more effective in collecting sunlight<sup>25</sup>. It is now appropriate to turn to the current state of the art in system design.

#### **4.6.2 Communication system components and design**

##### **Photovoltaic arrays**

Their very simplicity – with a total absence of moving parts – and not dependent on a fuel supply like diesel or kerosene, make them particularly suitable for power generation in remote areas. Applications in these areas require only small amounts of power and the ease with which photovoltaic arrays can be designed to meet these specific power demands makes them ideal for the purpose.

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<sup>25</sup> [www.scienceclarified.com/scitech/Energy-Alternatives/Solar-Power](http://www.scienceclarified.com/scitech/Energy-Alternatives/Solar-Power)

In common with most photovoltaic generators those for communication systems will have these components:

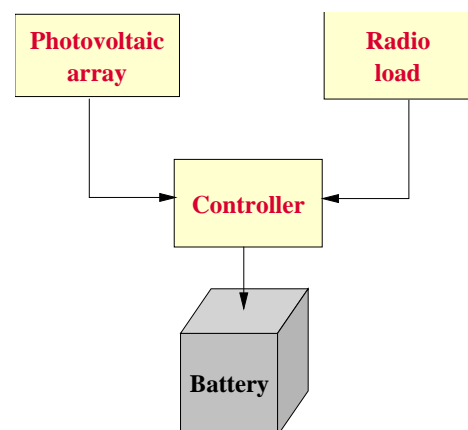
- A photovoltaic array of appropriate output (ranging from two to several hundred panels)
- A power storage system, often a battery, or generator (not one that requires fuel) to supply power during the hours of darkness or other periods when the array is not available (e.g. during rain fading)
- A power control unit (to regulate power from the panels)
- An inverter for converting the DC (direct current) to AC (alternating current) power

It is possible to nearly double the output of an array by using 'trackers' which are used to keep the panels directly facing the sun. However there would need to be a cost analysis of the benefits of including a tracker with the added cost and mechanical complexity it would entail.

The communications node is completed by a mast. The components for both the node and customer stations might be arranged roughly as shown in **Fig. 4.15** and **Fig. 4.16**.

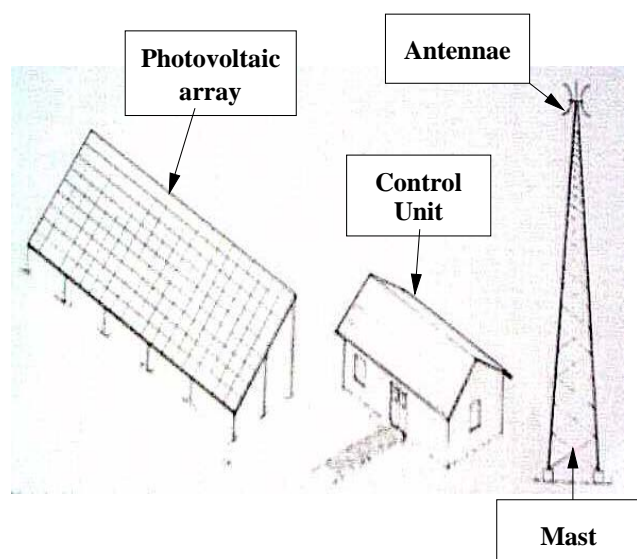
**Fig. 4.15 Notional connection of Customer and Node Equipment**

One such node would be able to serve several hundred 'customers' located within a 20 mile radius. The individual customer handsets would probably require about 10 watts of power (about 1 m<sup>2</sup> of photovoltaic array), while the node would probably need a panel of about 2 m<sup>2</sup>. The system would be digital and designed for multi-access. The node would connect to a trunk network based on microwave radio or cable (preferably fibre optic) installed, perhaps, along a road or railway.



**Fig. 4.16 Notional Layout of Customer and Node Equipment**

These systems are deceptively simple but are not simple to design requiring much detailed information about solar insolation at the latitude and longitude of the node site and those events that will influence the effectiveness of the array. For example, the influence of 'rain fading' which affects the power margins needed and hence the radius of local network i.e. from the central mast.





Backup power supplies must be provided for the hours of darkness and those occasions when the weather will 'blackout' the solar power source. Alternatives are the use of the array's spare capacity to trickle charge batteries or, as in MIT's Costa Rican scheme, pedal driven generators could be used. Better still the surplus power could be used to drive a water pump to fill a reservoir to feed a small water turbine to drive a small generator. One of the main functions of the control unit is to maintain the standby batteries in the highest state of charge possible.

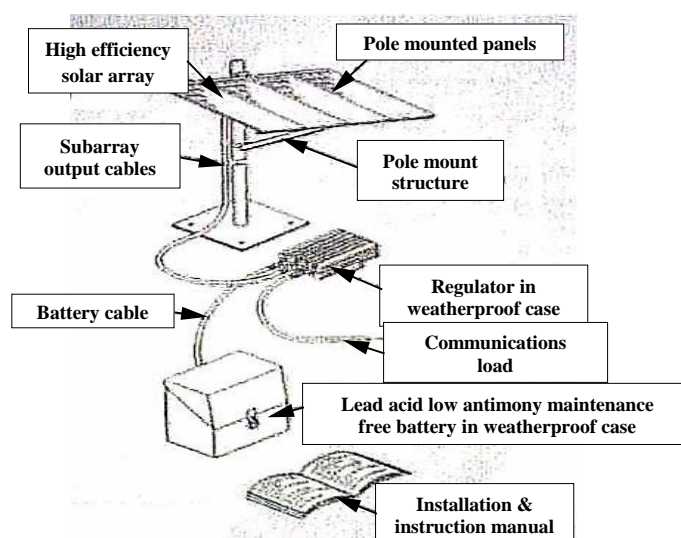
Now that major companies have become involved in the development and manufacture of photovoltaic arrays, packaged systems have been developed that are suitable for rural areas and for the developing countries; **Fig. 4.17** illustrates a notional package.

**Fig. 4.17 Typical Solar Array Package**

As the efficiency of photovoltaic cells rises, it seems more likely that power systems based on them will become the dominant way of powering communication systems in remote and rural areas, particularly in the developing countries. It is now time to look at operational experience.

#### 4.6.3 In-use experience

Operational experience takes three forms (i) the reliability of the system (ii) the appropriability of the technology and (iii) user experience.



- (i) The reliability of photovoltaic systems themselves break down into the reliability of the photovoltaic array and of the other components, specifically the regulator/control unit and the battery. Reports show that solar arrays are reliable with performance that has been entirely satisfactory. There is no reason to suppose that the claims for long and reliable life will not be borne out in practice<sup>26</sup>. In this context photovoltaic arrays are seen as the most dependable way of generating electricity in rural areas, especially in those that are also remote. Experience with the regulator cum control unit and the battery have been less satisfactory. The crucial role played by these components in providing a reliable source of electricity throughout the day is often overlooked. From the beginning the control units used in small scale installations performed better than those used in larger installations. However, recent innovations have produced improvements so that the earlier experience (Amara & Lipinski, 1983),

<sup>26</sup> Zeiton, T. & Chamberlain, H. And Chandler, S.A.G. Have independently reported to this effect in 1989 and 1990 respectively. Similar claims are made by manufacturers.



- when the performance of the entire system left much to be desired, has changed. Their independence from scarce and expensive fuel supplies is particularly important.
- (ii) Another aspect of reliability is the appropriability of the technology - the extent to which local people can maintain and repair the equipment in the event of breakdowns. The situation seems mixed, with training being more effective in some locations than others. In all locations proper regard needs to be paid to the cultural hierarchy since this can determine who it is acceptable to train and to maintain equipment that may be located in places that are not accessible to everyone.
  - (iii) User experience has two parts (a) the acceptability of the design and its economic effectiveness and (b) whether the system has fulfilled user expectations.
- (a) As has already been said, the design of a solar power system is a far from simple matter despite their apparent simplicity. The complications of system design (solar insolation data for the latitude and longitude, tower shading, rain fading, regulator cum control unit and battery system design, batteries themselves, the need for security fencing, etc.) have now been appreciated with consequent improvements in operating experience.
  - (b) Whether the systems have fulfilled user expectations is more difficult to establish. Communication systems did not always come at the forefront of rural development and the lack of reliable power supply systems also restricted their installation. Now that this last obstacle is being removed the very obvious need for communication systems has seen an increase in the number being installed. As the systems become available and begin to be used, so user expectations will change, just as the availability of TV has begun to raise social expectations. Equally, the technologies used have meant that the original CB radio based systems are tending to be replaced by more modern equipment that is inherently more powerful and adaptable, while permitting multiple access locally and connection to 'trunk' networks giving access to the wider world.

When all aspects of the operating costs are taken into account over the expected lifetime of the equipment, solar installations based on photovoltaic arrays can already be shown to be more cost effective than competing systems. As PV manufacturing processes and conversion efficiencies continue to improve, so the cost of the systems will decrease. However it is unlikely there will be a dramatic reduction in cost in the near future<sup>27</sup>.

Today, PV modules are guaranteed by manufacturers from between 10 to 20 years although most will likely last for 30 years. A well-designed PV system operates unattended and requires minimal maintenance.<sup>28</sup>

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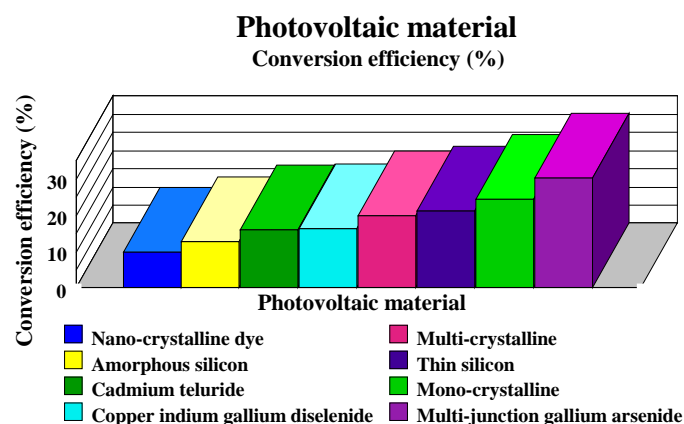
<sup>27</sup> El Paso Solar Energy Association, 2007

<sup>28</sup> Research Institute for Sustainable Energy (RISE), Murdoch University, Australia

#### 4.6.4 Likely future developments

Most developments are clear. Photovoltaic cells will continue to become more efficient. It was shown earlier that efficiencies are now typically about 15%, but experimental designs are already working at twice that level. The pace of development is illustrated in **Fig. 4.18**.

**Fig. 4.18 Pace of development of photovoltaic cell efficiency**



The services that can now be accessed from even the most remote areas have, thanks to new technologies, changed out of all recognition and will in a relatively short space of time include all those that can be accessed in the developed countries. These include all the Internet based services.

Projects that are aimed at realising this potential are now being put together; perhaps the most well established is the joint venture between the Costa Rican Foundation for Sustainable Development and the MIT Media Laboratory's Center for Future Health. Together they created the LINCOS project.

The LINCOS project<sup>29</sup> or 'Little Intelligent Communities' (or Small Project Smart Communities) is based on community centres that use digital technology to provide access to many different kinds of services including those based on the Internet. The project as a whole has received financial and technical support from companies such as Hewlett Packard, Intel, Microsoft, LCSI and CISCO. Organisations including Discovery Channel Global Education Fund, FLORA Foundation, Avina Foundation and CRUSA are also involved. The project is creating links between other academic establishments in Costa Rica and those further afield in Germany and Florida (US).

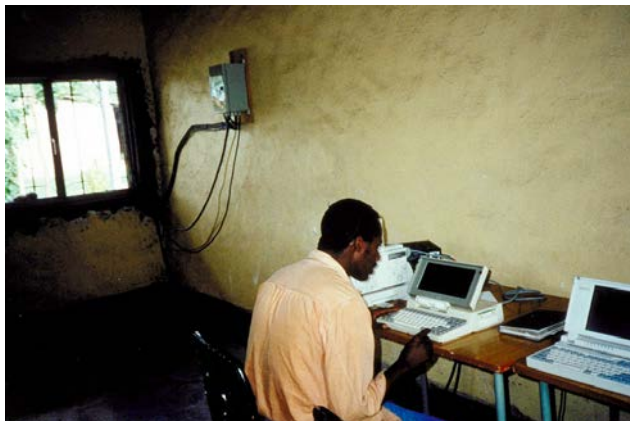
Community Development LINCOS is based on sustainable human development and working in an inter-disciplinary way with the latest technological advances. Since 2003, a further development has been SECOND GENERATION LINCOS, a new model designed to build capacity and train new entrepreneurs.

The LINCOS project currently has 20 operating units through out Costa Rica and the Dominican Republic and hopes to expand its scope to South America and Mexico. Similar schemes have already been developed elsewhere as illustrated in **Fig. 4.19**.

<sup>29</sup> [www.lincos.net](http://www.lincos.net)

In all, the use of solar powered communication systems is accelerating rural development in all parts of the infrastructure, with beneficial outcomes for the indigenous people. That is what these case studies have attempted to demonstrate.

**Fig. 4.19 Use of solar powered lighting in a rural setting**



#### **Latest developments**

Stand-alone Power Systems (SAPS or SPS), also known as Remote Area Power Supply (RAPS) is an off-grid electricity system for locations that are without an electricity distribution system. Typically, SAPS systems include one or more methods of electricity generation, energy storage and regulation.<sup>30</sup>

They are considered the next step involving renewable energy sources such as the sun, batteries for energy storage and a diesel generator for back-up power and battery charging. Diesel generators, as we have learned, pollute in terms of noise and spillage. However in this instance, in the hybrid SAPS system, the generator is limited to a supporting role of charging the battery. Newly designed lead-acid batteries have a longer life and require less maintenance. This enables them to operate at their most efficient and for less time. The PV solar panels and batteries supply the power silently 24 hours a day. The running time of the generator is reduced, meaning less maintenance, less fuel use and pollution from emissions.

SAPS systems were designed for remote, difficult applications, but they are actually complex power plants. This means they require various electronic controls to collect, direct and monitor power production and distribution throughout a village. This enables data collection which can be monitored by satellite from remote management/service centres.<sup>31</sup>

### **4.7 Case Study 4 Developing Country - Rural Health Clinics - Vaccine Refrigeration and Lighting**

There are currently two main applications of solar energy, which directly support health care activities in developing countries; these are vaccine refrigeration, blood products and to a lesser extent the lighting of the health care centres. The technology of photovoltaic refrigerators is mature and fully commercialized with more than 6,000 installed worldwide<sup>32</sup> The case study is concerned with work carried out by BP Solar and Apex-BP Solar in Zambia, Africa.

<sup>30</sup>[http://en.wikipedia.org/wiki/Stand-alone\\_power\\_system](http://en.wikipedia.org/wiki/Stand-alone_power_system)

<sup>31</sup>[www.ilzrorapsperu.org/pubs/poster.PDF](http://www.ilzrorapsperu.org/pubs/poster.PDF)

<sup>32</sup>[www.madegood.org/practical-action-solar-photovoltaic-refrigeration-of-vaccines/#two](http://www.madegood.org/practical-action-solar-photovoltaic-refrigeration-of-vaccines/#two)

**Figure 4.20 Zambia**

Source: Causetinnitus.net

Between 1994 and 1997 BP Solar was involved in a rural development programme to upgrade and improve medical facilities in 200 health clinics throughout Zambia. The development programme made use of solar energy to provide a reliable power source for medical refrigerators and lighting kits in remote rural areas, which did not have an existing electricity grid.

#### 4.7.1 Refrigeration - How the innovation came about

For many years the WHO and UNICEF have been carrying out a world wide expanded programme of immunization (EPI). Immunization is the most effective tool in the fight against transmittable diseases such as tuberculosis, whooping cough, yellow fever, polio, tetanus and measles. The safe provision of vaccines requires that the vaccines themselves are kept cool and in controlled temperature conditions from production to time of use, for example 0°C to 8°C for vaccines for Hepatitis B, TT, DT, DTP, IPV and Hib, -15°C to -25°C for Oral polio and Yellow Fever. The transportation and storage of refrigerated vaccines is known as the *cold chain*. All vaccines are to some degree unstable and their potency, and therefore the protection they give against disease, decreases over time. The higher the temperature to which the vaccine is exposed, the more quickly this decrease occurs. Freezing may damage some vaccines, whereas others must be kept in a frozen state in central stores.

The *cold chain* is a network of fridges, freezers and cold boxes, organized and maintained by teams of workers throughout the world. The system ensures that the vaccine is kept at the right temperature to retain its potency from the moment it leaves the vaccine manufacturer until the moment it is dispensed. The recommended equipment for storage and transport has to comply with a set of performance standards defined by WHO and UNICEF. Cold rooms, refrigerators, freezers, cold boxes and vaccine carriers in the *cold chain* have to meet the standards set down. Stock management procedures are also in place to ensure that vaccines are not stored longer than necessary at the central, regional and district levels of the *cold chain*.

In rural areas, before the introduction of photovoltaic power systems, bottled gas or kerosene typically powered refrigerators in which the vaccines were stored at the correct temperature. These methods of powering the refrigerators were unreliable and the equipment needed much maintenance and had a short life span. There were also problems in obtaining the fuel to operate the refrigerators.

The expanded programme of immunisation is to employ the more reliable power source of solar energy. Not only are photovoltaic systems more reliable, but they require less maintenance, have a longer life span and lower operating costs. Operating the *cold chain* to run on solar power is more effective and is sustainable. Although more expensive initially to implement, throughout its life span a solar powered refrigerator offers favourable economics in terms of the number of vaccine doses per dollar of outlay.<sup>33</sup>

### The Key Stakeholders

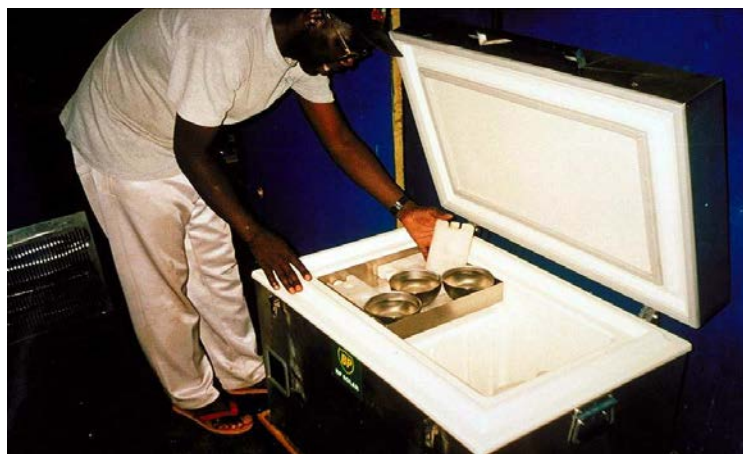
As part of the Zambian Ministry of Health's countrywide rural health rehabilitation programme, the EU, via the EDF, provided financial support to supply and install 200 solar powered vaccine refrigeration systems (**Fig. 4.21**) at separate locations throughout Zambia.

The project team involved in the rural health clinics project consisted of the Zambian Ministry of Health who were the contracting authority. Sub-contractors were BP Solar, BP Zambia, the World Health Organisation, who carried out the bid evaluation, and a UK company IT Power, who are an installation agency. The project began in 1994 and was successfully completed during 1997. Ensuring the *cold chain* in Zambia is a challenge in that the highest average temperature is 40°C.

**Figure 4.21 Vaccine Storage for a Rural Area**

#### 4.7.2 What the development programme achieved

The *cold chain* project equipped 200 health centres in Zambia with solar powered refrigerators and lighting and greatly helped the immunization programmes against diseases such as polio, yellow fever and tuberculosis.



At each of the 200 sites a refrigerator system and lighting kit was installed. Each refrigeration system consisted of:

- A VR50 cabinet providing 45 litres of vaccine storage capacity and a 2.4 kg ice pack freezing capability complete with an integral control unit
- A 225 Wp array including the support structure
- A 360 Ah battery complete with lockable box
- Essential interconnecting cables and hardware (Harford, 1998)

<sup>33</sup> BP Solar information leaflet on *Photovoltaic Projects: Zambian Rural Health Clinics*.

The view of the World Health Organisation is that continued development and use of solar refrigeration is indispensable as new vaccines and programmes of large-scale immunization increase. Solar refrigerators allow longer storage of vaccines and these can be passed more rapidly down through the distribution system relieving pressure on higher level storage facilities. Vaccines can be stored closer to the point of use. These benefits are sufficiently important to outweigh the differences in the cost of purchase and maintenance if the cost burden can be shared with other applications sharing the same photovoltaic power source and a local maintenance infrastructure can be established.

**Fig. 4.22 Vaccine Use Enabled by the 'Cold chain'**



### **4.7.3 Recent Developments**

In 2005 it was announced that a further 121 community-based organisations and 9 schools in rural areas of Zambia will be getting BP Solar panels to generate electricity for refrigeration, lighting, radio and television. Apex-BP Solar, a subsidiary of BP France, has been awarded a contract through the distributor Electrical Maintenance Lusaka Ltd (EML) by the Zambia Social Investment Fund. Apex-BP Solar will supply the panels – designed to customer specifications – EML will deliver and install them and also train their users in various health centres and schools in Zambia. It is expected that the project will produce a peak power of around 250 kWp.<sup>34</sup>

### **4.7.4 Vaccine Refrigeration**

Location: Nigeria, Africa

Immunisation programme in rural North East Nigeria using solar powered vaccine refrigerators. This case study is concerned with work carried out by KXN Nigeria Ltd. It is a private company established in 1999 distributing, assembling, installing and maintaining PV systems in Nigeria.

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<sup>34</sup> [www.bpsolar.com](http://www.bpsolar.com)

Vaccines deteriorate rapidly in heat which is why those for polio, diphtheria and tuberculosis need to be kept cool (around 3 degrees C). Standard refrigerators are heavily dependent on either a reliable mains electricity supply or diesel supply which cannot be guaranteed in remote areas. According to Nigeria 2006/7 statistics (UNDP), 54% of people lacked grid electricity. KXN provide solar powered vaccine refrigerators for this purpose.

#### **4.7.5 How the technology works**

The KXN system consists of a freezer, vaccine refrigerator, photovoltaic (PV) modules, charge controller, batteries and cabling. The PV modules connect to the battery via the charge controller, providing a constant DC operating voltage for the refrigerator. The refrigerators are heavily insulated so remain cool in high temperatures and require little power to function. 240 Wp of PV modules generate the electricity and keep batteries charged for 24 hour cooling.

#### **Cost of provision**

The cost of installation is expensive. Each system costs approximately US\$10,800 (1.4 million NGN (Nigeria Naira)). However, a typical refrigeration system holds over US\$5,400 worth of vaccines making the investment worthwhile and sustainable.

The majority of systems installed by KXN were paid for by the National Programme for Immunisation and installed free in remote health centres as part of the national campaign to eradicate polio. The remaining systems were funded by the Rotary International Nigeria PolioPlus.

#### **Maintenance**

KXN worked with the University of Maiduguri in Borno State and with BP Solar to train technicians to install and maintain the PV systems and ensure that health centre staff knew how to use them.

#### **Benefits**

A single vaccine refrigerator will serve a population of approximately 6000 people. Between 2002 and 2004, 189 vaccine refrigeration systems were installed in 90 villages across north east Nigeria, giving almost 1.1 million people access to vaccination. More recently, in 2009, installations had significantly increased to a total of 767, enabling immunisation services for approximately 4.6 million people.

#### **Benefits of solar systems over other systems**

Solar PV systems are more reliable in remote areas according to the World Health Organisation (WHO) and are less polluting in terms of noise, fumes and spills than diesel or kerosene powered generators.

#### **Social and health benefits**

The introduction of the PV vaccine refrigeration system was to enable a programme of polio vaccination in remote areas where the disease still prevailed. The programme also includes immunisation against diphtheria, whooping cough and tuberculosis.



### **Employment benefits**

Here is an opportunity for people to be trained as solar technicians to install and maintain the refrigeration systems. By 2005, 12 people had been trained. With support from KXN, it is possible for these installers to gain further experience and become 'solar entrepreneurs'. This would allow them to generate extra income by selling additional commercial PV services e.g. battery charging, water pumping and solar home systems (SHS). However, it has not always proven easy for local people to develop these businesses. Local people may also be employed on a casual basis for assembling the systems, in warehousing or in an administrative capacity.



**Figure 4.23 Training the technicians in solar pv in Maiduguri, Northern Nigeria.**  
*Photo: David Fulford/Ashden Awards for Sustainable Energy*

### **4.7.6 2011 Nigeria update**

As part of Nigeria's national 'cold chain' rehabilitation programme, and with the support of UNICEF and the Japanese government, the provision of vaccine cold-chain stores serving up to 3 million children and pregnant women will be provided in Lagos and the south west states. The Japanese government has been one of the main donors, through UNICEF, of Nigeria's polio immunisation and eradication programme since 2000.

In northern Nigeria, again supported by UNICEF and Japan, the polio immunisation campaign aims to reach a total of 14.5 million children under the age of five.<sup>35</sup>

### **4.7.7 Solar Lanterns**

#### **Background to the innovation**

There are currently 1.6 billion people worldwide without access to electricity<sup>36</sup> (2010) and they rely instead on fuel based sources for lighting such as kerosene. But

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<sup>35</sup> [www.unicef.org](http://www.unicef.org)



kerosene, as we have learned, is expensive (using as much as 65% of a household's income) a fire hazard and pollutes the air. With this in mind, solar rechargeable LED lanterns have been developed which provide clean, affordable and bright alternatives to candles and kerosene lanterns.

### **When did the innovation begin**

A company called D.light, with its HQ in Hong Kong, and offices in India, China, Tanzania and the US, began in 2007 to design and sell affordable solar lanterns in developing countries. It sells the lanterns through local dealers, networks and distributors in 32 countries, the majority of sales being in India and East Africa. D.light Design, Inc., is a social enterprise, registered in the US, prioritising social benefits over profits. The company is funded by Indian venture capitalists and Silicon Valley.

### **The technology behind the solar lantern**

There are currently three basic models of solar lantern, the Nova, the Solata and the Kiran. Launched in 2008, the Nova (the largest lantern) and the Solata both have detachable photovoltaic modules, 1.0 or 1.3Wp and 0.625Wp respectively, and an outdoor cable. The Kiran, launched in 2009, is the smallest and least expensive lantern, with an integrated 0.3Wp photovoltaic module.

Each of these lanterns includes a rechargeable battery and charge controller. A photovoltaic module has a life expectation of at least 10 years, the battery has a 1-2 year lifespan before it needs changing and the LED light can operate for 50,000 hours. The wear and tear of all other parts is very much dependent on use and care of the lantern.

The Nova lantern has a handle for carrying or hanging and some versions include a mobile phone charger. One days charging will run the lantern for 4 hours on its brightest setting or 100 hours as a nightlight. The Solata is a desk lamp providing between 4 and 15 hours of light from one days charging. The Kiran has to stand in the sun to charge and will run from 4 to 8 hours. All models have different brightness settings.

### **Cost of solar lanterns**

A Nova lantern will cost in the region of US\$45 (2,250 Indian Rupees (Rs)) and a Kiran lantern US\$10 (499 Rs). Most customers in India pay for their lanterns up front with a local dealer. Some employers have bought the lanterns in bulk and sold them to their employees via salary deductions.

### **Manufacture**

The solar lanterns are developed, designed and tested in Hong Kong and manufactured and assembled in China. Initial fieldwork is conducted in the countries that intend to use the products to ensure it matches the needs of the end-users. The

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<sup>36</sup> [www.ashdenawards.org/winners/Dlight10](http://www.ashdenawards.org/winners/Dlight10)

lanterns are marketed directly to rural customers through dealers, networks and 'rural entrepreneurs' (REs).

REs, as we have learned, are local entrepreneurs who buy a few lanterns and re-sell at a profit to their own village. They are responsible for explaining the social, health and financial benefits of the lights and stage demonstrations for their villages and may offer customers a trial period, before payment. They also make use of the internet as a marketing tool.

**Figure 4.24 Demonstrating a D.Light Nova lantern at a stall in Chamieyani, India.**

*Photo: Martin Wright/Ashden Awards for Sustainable Energy*



**Maintenance**

Each solar lantern has a six month warranty. A warranty card and a serial number carries the dealer's stamp and the mobile number of the local RE. Within the six month period, a faulty lantern will be replaced free of charge. After that period, the RE or dealer orders spare parts as necessary.

**Benefits/achievements of the technology**

By May 2010, over 220,000 solar lanterns had been sold in 32 countries by the D.light company. That benefits over 1.1 billion people, assuming a household of five people.

**Social benefits**

Solar lanterns do not emit any harmful or polluting fumes in contrast to kerosene which contributes to indoor air pollution, killing 1.6 million people each year. Kerosene lamps also lead to fires that cause severe burns and deaths.

A solar lantern, fully charged, can provide enough light so that people can stay up late after dark, improving their social life and the lives of others in their community. Perhaps the greatest benefit so far has been the improved studying environment they can create. End-users have reported that children have been able to increase their study time with the help of the more dependable, brighter and clearer solar lantern. (Govindasamy Agoramoorthy & Minna J. Hsu, 2009)

**Figure 4.25 A mother of three with her D.light Kiran lantern** Photo: *Martin Wright/Ashden Awards for Sustainable Energy*



#### **Environmental benefits**

The use of solar lanterns in place of kerosene lamps is reducing carbon emissions. According to D.Light, a typical kerosene lamp, used daily emits 0.2 tonnes/year of CO<sub>2</sub>. The 220,000 solar lanterns sold to date (May 2010), have made a saving of at least 17 million litres/year of kerosene and reduced CO<sub>2</sub> emissions by at least 44,000 tonnes/year. These figures may be on the low side because often one solar lantern replaces several kerosene lamps.

#### **Economic benefits**

The financial cost to a household can be considerably reduced by the ownership of a solar lantern and not having to purchase kerosene. It is hoped that a Kiran lamp, the smallest, can pay for itself within a few months and the more expensive Nova lantern, within two years. Coupled with that is the potential for further income generating activities such as extended shop hours.

**Figure 4.26 A shop owner, working with a Nova lantern, Bara.** Photo: *Martin Wright/Ashden Awards for Sustainable Energy*



#### **Employment benefits**

According to D.Light, there are approximately 420 REs selling their products, over 100 distributors and nearly 400 dealers. D.Light itself employs over 70 people across its five offices.

#### **Future developments**

With the number of people without electricity running into the billions, the product has enormous potential. The company D.Light has managed to produce high quality lanterns at low cost. It is hoped that carbon finance could help to reduce the cost even further. D.Light has been given approval by the UNFCCC for a carbon offset project in India. The company's mission is to become a market leader in off-grid consumer electronic products.<sup>37</sup>

<sup>37</sup> [www.ashdenawards.org/winners/Dlight10](http://www.ashdenawards.org/winners/Dlight10)

#### 4.8 Case Study 5 – Developed and Developing country - Rural Electrification

Rural electrification is important because, when implemented, it stimulates development. One of three recognised options for electrifying rural areas is Solar Home Systems (SHSs), electrification without the extension of the domestic electricity network or a decentralized local grid. The stand-alone system is defined as one that provides power for single household (typically between four and five people) use. An SHS system comes complete with a single photovoltaic solar panel, a rechargeable battery, a battery charge controller, a power outlet, one or more lights and other powered appliances (dependent on the size and power of the panel). Its limited power supply ensures its use is strictly domestic.

Rural electrification is a thriving market for photovoltaic technology. Yet barriers to the successful application of SHS's do exist. Two are seen as particularly detrimental. Firstly, the need for stable financing schemes and secondly, poor system delivery. SHS's require a substantial advance capital investment corresponding to a fifteen to twenty year period. Where rural applications are concerned, short-term schemes are more likely to succeed; long-term investment is not looked upon very favourably. It is estimated that 10% of all developing countries' households can afford SHS's, a percentage that could rise considerably if appropriate credit mechanisms were in place. Where commercial photovoltaic applications have succeeded their customer base has been the better off as in the World Bank's Indonesian SHS project.

The implementation of SHS's suffers if not enough time is given to correct installation and maintenance. Adequate training and after-sales service should be robust. A certain level of technical expertise needs to be maintained. Very often banks need credit guarantees to part with their money. The creation of government agencies ensures performance standards of SHS equipment are regulated and upheld. When the rural area is not only remote but also inaccessible, the installation and maintenance of photovoltaic SHS's is a massive investment of human resources over a long period of time; this helps to explain the low commercial diffusion of SHS's in highly dispersed rural areas. Ways of overcoming these problems include public sector intervention which encourages greater growth in photovoltaic applications.

The Solar Development Group (SDG) was created in 1996 as an organisation whose main function was to stimulate the photovoltaic market in developing countries by courting the private sector. It was created with the specific aim of increasing the delivery of SHS's to rural households in developing countries. The SDG initiative ended in 2004 and during its 8 year operation, dispersed \$2.85 million to solar photovoltaic projects in over 20 countries. However, more might have been achieved had the organisation developed more strategic alliances with, for example, the World Bank – an influential organisation – that could promote local government support by creating an 'enabling market environment' i.e. supportive regulatory and policy environment, availability of end-user finance and knowledge and awareness of solar photovoltaics,

and also a lack of co-ordination with other groups involved in solar initiatives like, for example, the United Nations.<sup>38</sup>

#### **4.8.1 Rural Electrification**

Location: Western & North Western China

#### **4.8.2 The case for Solar Home Systems (SHS)**

Almost 97% of Chinese households have access to electricity and yet there are still 30 million people without it. Western and North Western China has some of the poorest, most remote and rural regions in the country. Few have access to grid electricity and lighting is provided by mainly candles, butter lamps and kerosene. Two programmes were introduced, one an international initiative, the second a national initiative to address this issue.<sup>39</sup>

The international initiative, The Brightness Programme, was designed to bring electricity to rural areas. China implemented this programme in 1998 with the aim of providing electricity for 23 million people in remote areas by 2010 using renewable energy technologies. The initiative focused on Inner Mongolia, Gansu and Tibet. Initial targets included establishing stable financial schemes, technical capacity and training systems and access to electricity for 8 million people, which included 2000 non-electrified villages.

In 2001, China's State Development and Planning Commission (since renamed NDRC) launched a two-tier renewable energy based rural electrification programme. The first tier focused on townships and the second on villages. The Village Electrification Program was targeted for 2005-2010 and would electrify 20,000 villages, with capacity building an important component, combining international and local agencies to develop and implement a training programme for national and local engineers and technicians – the training certification system an integral part of The Brightness Programme and the sustainability of rural electrification initiatives<sup>40</sup>.

The Renewable Energy Development Project (REDP) as part of the NDRC, has boosted the use of SHS's in off-grid areas in western China. REDP has installed over 402,000 systems between 2003 and 2008, with a total capacity of 11.1MWp. If a household is estimated as four people, a total of 1.61 million people have benefitted directly and more continue to benefit from the network of suppliers that has been set up by the programme. This has been achieved through the support to the industry through continued improvement to photovoltaic components, technical and managerial support to local installers and subsidies to sales. The REDP acted as wholesalers to supply systems to local retailers. Local retailers could make local arrangements to help

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<sup>38</sup>

[www.ifc.org/ifcext/enviro.nsf/AttachmentsByTitle/p\\_SellingSolar\\_PartTwo\\_CaseStudies3/\\$File/PartTwo\\_CaseStudies3.pdf](http://www.ifc.org/ifcext/enviro.nsf/AttachmentsByTitle/p_SellingSolar_PartTwo_CaseStudies3/$File/PartTwo_CaseStudies3.pdf)

<sup>39</sup> NREL International Programs. [www.nrel.gov/international](http://www.nrel.gov/international)

<sup>40</sup> NREL International Programs. [www.nrel.gov/international](http://www.nrel.gov/international)

people finance the systems. The model of market-driven incentives has been a key factor enabling the programme to work effectively and this model is now being replicated in other donor-funded programmes in China. Since the REDP ended in 2008, its role of supporting the PV industry has been replaced by the China Photovoltaic Industry Association.<sup>41</sup>

#### 4.8.3 Solar Home System (SHS) technology

In the REDP programme, a typical SHS consists of a single 20Wp PV module; a charge controller; a 12V, 40Ah battery; one or more 7W to 9W dc lamps; a dc socket for a mobile phone charger or radio. A larger system, 75Wp to 100Wp, may include inverters to provide as power for DVD players and televisions. A metal carry case is also available to make the system portable. When the programme started, most systems were in the 10Wp to 20Wp range, reflecting the low demand for electrical appliances and the need for a semi nomadic lifestyle for many of the population. As the programme progressed, larger systems became more popular. The solar modules are guaranteed for 10 years and warranties issued for all other components.

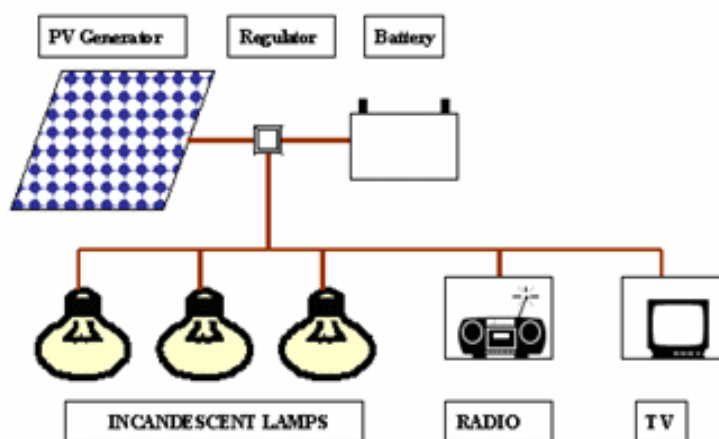


Figure 4.27 Solar home system components.<sup>42</sup>

#### 4.8.4 Cost of provision

According to the World Bank, the average sale price of a SHS in the REDP programme was Y1,221 (China Yuan) or £88 in 2007. A 20Wp system typically sold for Y900 – Y1000 (£65-£72). A 75Wp -90Wp system typically sold for Y4,000 (£290) excluding television or other accessories.

These prices compare very favourably with the rest of the world. This is partly due to the low cost of the solar module in China, between Y20 – Y35 (£1.40-£2.50) per Wp and also due to the REDP subsidy on offer to participating companies during the course of the initiative. Prices have risen about 20% since the REDP subsidy ended in 2007.

<sup>41</sup> [www.ashdenawards.org/files/reports/redp\\_china\\_case\\_study\\_2008\\_0.pdf](http://www.ashdenawards.org/files/reports/redp_china_case_study_2008_0.pdf)

<sup>42</sup> Source: HEDON Household Energy Network. [www.hedon.info](http://www.hedon.info)

#### 4.8.5 Social, Health & Financial benefits

The nine provinces in Western and North Western China are very cold, around 4000 metres above sea level and most of the small population live off the land, living in tents for part or all of the year. Access to goods and services is poor. The introduction of SHSs means communities feeling less isolated. The reduced pollution from the burning candles and butter lamps and the burning and spillage of kerosene, has meant improved health. SHS have meant brighter, cleaner lighting for work, study and recreation for children and adults. In addition SHS's make it easier for people to enjoy evening activities which helps to strengthen community networks and increases their sense of safety.

**Figure 4.28. Solar tent.** *Photo: Martin Wright/Ashden Awards for Sustainable Energy*



According to the World Bank, 58% of the SHS output is used for lighting, 38% to power radios and all other appliances account for 4% SHS output.

**Figure 4.29. Boys and solar module.**  
*Photo: Martin Wright/Ashden Awards for Sustainable Energy*



#### 4.8.6 Economic benefits

The programme has had some impact on employment and income in the rural areas. Village shops with SHSs can generate additional income because they are able to stay open longer. Greater impact has been observed in the companies participating in the programme with up to 1500 permanent jobs and 3000 temporary jobs created. By 2006, over 50% of these company sales were outside the REDP, showing that the programme has stimulated a wider market. The environmental impact with the use of SHSs is helping reduce greenhouse gas emissions by replacing kerosene and candles.

#### **4.8.7 Future Developments**

By setting targets for renewable energy, China has acknowledged the impact of energy use on air pollution and climate change. It hopes to double its renewable energy capacity by 2020 as it faces a deficit of up to 15% between generating capacity and electricity demand. In regard to rural electrification in particular, the government has set a target of 300 MWp of rural pv (both off-grid home systems and local pv grids) by 2020.

The REDP has supported some PV village systems providing electricity to public facilities such as schools, health centres, Buddhist temples and satellite telephones.

The REDP model of using market driven forces to improve system quality and reduce costs has greatly expanded the market for SHSs and supported the growth of suppliers and retailer networks. This model is being replicated by the World bank on projects in other developing countries.



## 4.9 Case Study 6 Developing Country - Irrigation using Solar Powered Water Pumping Systems<sup>43</sup>

Rural areas are heavily dependent on agriculture. A successfully installed photovoltaic powered irrigation system can increase income and greatly improve productivity.

### 4.9.1 Why the need for Solar Water Pumps?

In rural areas, heavily dependent on agriculture, irrigation is essential, while plentiful water for livestock as well as potable water for the local population is desirable. Solar Water pumping systems, based on photovoltaic power systems, are ideally suited to rural areas. Hence the development of water pumping systems powered by photovoltaic energy sources.

**Fig 4.30 A Solar Pump at Work**



In the 1980s around 1.8 thousand million people were living in the rural areas of the developing world. Of these, only 1 in 5 had access to clean water. A total of 590 million children under 15 years of age (over 40%) did not have access to clean water. One hospital patient in 4 suffered from an illness caused by polluted water.<sup>44</sup> It was the overriding aim of The United Nations

International Drinking Water Decade, 1981-1990 to ensure that half the world's population was adequately supplied with water and sanitation by 1990. The development of alternative and appropriate technologies introduced Solar power into the equation. The high demand for small-scale water pumping systems for irrigation and water supply in rural areas was an enormous consideration. In 1979, the United Nations embarked on a worldwide programme of field-testing in association with the Intermediate Technology Development Group, experts in small-scale solar powered pump demonstrations. The World Bank were instrumental in its inception and in return were to be advised on the way in which this technology could be fully utilized, economically and appropriately.

<sup>43</sup> Alternative Technology (1987) 14 (1), June

<sup>44</sup> [www.gdrc.org/uem/water/decade\\_05-15/first-decade](http://www.gdrc.org/uem/water/decade_05-15/first-decade)

**Figure. 4.31. Provision of local water supply**



By 1981 the first phase of the field trials were complete. Twelve systems - 11 photovoltaic and 1 solar-thermodynamic - had been installed across the Sudan, Mali and the Philippines in collaboration with higher technical institutes or research organisations. In 1982-3, laboratory testing of commercial photovoltaic water pumping systems was

undertaken, in response to a tender specification issued in 1981. Technical and economic data were collected in order to assess the appropriateness and viability of the many different types of systems. As a result, the data enabled the development of small photovoltaic pumps able to perform to the highest technical specifications and end-user requirements, for introduction on a large scale.

The manufacture of photovoltaic pumps is now commercial. It is estimated that over 3000 pumps have been used in demonstrations around the world. As a result of the solar pumping initiative, begun in 1979, and the publication of its handbook in 1985, considerable improvements in the performance, efficiency and the costs of solar water pumps continues.

#### **4.9.2 Achievements of the Water Decade**

By the end of the decade over 1.2 billion people had access to water and almost 770 million access to sanitation. However there were limitations to this success. Rapid urbanisation and low public awareness about health has reduced countries' abilities to keep on top of need. As a consequence, there are still around 1.2 billion people with inadequate access to water and 2.4 billion without appropriate sanitation.<sup>45</sup>

#### **4.9.3 Areas that Benefit from Solar Powered Water Pumps**

The market for solar water pumps can be found in predominantly two areas. First, in agriculture for irrigation and watering livestock and surrounding game. Second, for use in rural water supply schemes which might include subsistence watering for remote communities and use in rural schools, and health clinics.

<sup>45</sup> [www.gdrc.org/uem/water/decade\\_05-15/first-decade](http://www.gdrc.org/uem/water/decade_05-15/first-decade)

#### 4.9.4 Solar Water Pump Design

Commercially available photovoltaic pumps come in many shapes and sizes. There are five principal configurations of pump currently available:

- Submerged motor/pump unit with centrifugal pump
- Submerged centrifugal pump driven by a shaft from a motor mounted at ground level
- Submerged reciprocating positive displacement pump
- Floating motor/pump unit with centrifugal pump
- Surface-mounted motor/pump unit, with a self priming tank

The key criteria for the end user is the volume of water delivered per day. The size and configuration of the pump is less important than the performance they can expect from the solar input. The capacity of the pump is very much determined by the daily volume of water delivered at the design head and how the photovoltaic array is designed to make best use of the daily solar irradiation.

In theory, photovoltaic pumps can be designed to meet any output, but what maintains their status in appropriate technology is that they are stand-alone, robust, economic and simple. These designs are intended for small communities, where affordability and easy maintenance, their prime trademarks, are of paramount importance.

#### 4.9.5 Installation and Performance<sup>46</sup>

One of the main criteria behind small-scale production of electricity by photovoltaic arrays is that equipment maintenance is manageable and kept to a minimum. The measured performance of some of the earlier installations was not comprehensive. Some of the most valuable data has been collected in Mali where, during 1978 and 1997, over 300 sites had been equipped with solar water powered pumps.<sup>47</sup>

Ancillary component failure has been the overriding problem in contrast to the photovoltaic array which has fared much better. An established methodology has arisen as a direct result of so many system failures. It appears that surface-mounted motors fare worse than their submersible motor counterparts. Consequently this reappraisal has overcome a potentially disruptive design flaw.

Since 1982, as suppliers and manufactures of pumps become more experienced in the application of the equipment to accommodate local needs, the reliability of the product has increased. Failures have also sprung from the level or lack of technical expertise available on site.

It is not surprising that areas that have low rainfall and arid conditions, might also experience a low water-table; this is something that must, wherever possible, be

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<sup>46</sup> Alternative Technology, 14(1) June 1987

<sup>47</sup> [www.ared.org/country/mali/mali.pdf](http://www.ared.org/country/mali/mali.pdf)

taken into consideration. It is not unusual for 'dry running' to occur, where the peak pump output at noon can be greater than the bore hole yield or recovery rate. The result, where the water table has dropped, and 'dry running' has occurred, is a burnt-out motor. Furthermore, water storage needs to be built into the system to accommodate days that are cloudy.

What has emerged from practical experience, is that accurate solar insolation and water resource data can improve the performance of a given system enormously. The misapplication of erroneous data has also resulted in the poor performance of individual systems. Inaccurate information regarding the depth of the water-table and the seasonal variations can have disastrous consequences. As the solar and water resource information continues to build in a particular region, so the mechanics of photovoltaic water pump systems become better understood.

There are common factors in the successful application of photovoltaic pumps. The full involvement of the end user and the availability of technical support are key. Lack of knowledge and experience are all that seriously hamper the running of a system. So training, as in all small scale productions, is the lynch-pin of the management and maintenance of photovoltaic water pumping systems.

#### **4.9.6 Future developments**

Since the end of the Water Decade, hopes for further improvement are centred on the World Water Assessment Programme. This is a joint effort of the UN system and its member states. It is hoped that the launch of a second International Decade for Action – Water for Life, 2005-2015, will provide fresh impetus for the assessment programme. The resolution called for a 'greater focus on water-related issues and for actions to ensure the participation of women (as managers of water) in water-related development efforts'. It also recommitts countries to achieving the water-related goals of the 2000 Millenium Declaration.<sup>48</sup>

#### **Drip (or micro) Irrigation**

This is the most rapidly expanding type of irrigation in sub-Saharan Africa (Burney et al, 2010). Photovoltaic Drip Irrigation (PVDI) is an appropriate technology promoting food security and economic development in sub-Saharan Africa. These areas of Africa rely heavily on rain and producing sufficient food products to sustain local populations through the rainy season and into the dry season is not always possible. Providing the crop yield is good, and with careful management, this is achievable. But not every rainy season guarantees a healthy yield. In these instances, local populations need to supplement a poor yield with additional foods. Increased demand for supplementary foods inevitably means higher food prices.

It is expected that because of climate change, reliable food production will become harder as weather patterns adversely affect agriculture. Photovoltaic drip irrigation is

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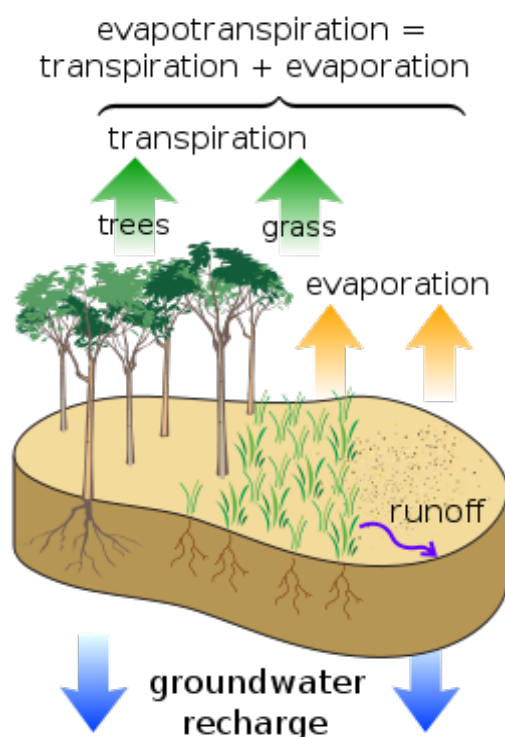
<sup>48</sup> [www.gdrc.org/uem/water/decade\\_05-15/index.html](http://www.gdrc.org/uem/water/decade_05-15/index.html)

considered a viable means to encourage stable food production, improve the health of local populations and help them adapt effectively to climate change.

### How the technology works

A photovoltaic array powers a pump that feeds water to a reservoir. The reservoir distributes water to a low pressure drip irrigation system. Water is fed directly to the roots of crops. The system is self regulating i.e. the volume of water pumped increases on hot clear days when plants need more water. The size of a PVDI system is dependent on the local water resource and local evapotranspiration (i.e. the sum of evaporation and plant transpiration).

**Figure. 4.32. How evapotranspiration works**<sup>49</sup>



### Installation and Maintenance of PVDI systems

For a PVDI system to be successful, there needs to be adequate access to management and technical support to ensure its sustainability in the long term. If the systems are to be adopted regionally it requires regional manufacture, links to larger markets and a local supply chain so that customers can confidently invest in PVDI systems. Until institutional support can be developed, the financing of these systems is reliant on PVDI project financing, providing the stable demand necessary for private sector investment.

<sup>49</sup> image source: wikipedia

### **Sustainability**

The PVDI system must accommodate local need and conditions if it is to be sustainable and at a village level this is determined by local water resources. Two types of systems may be used, one a surface water PVDI, the other a groundwater PVDI. The first is based around seasonal water flow and the latter on existing groundwater resources. PVDI systems are less polluting than fuel-based systems.

### **Economic and nutritional benefits**

With the aid of more reliable irrigation, produce is more plentiful and the income this generates enables the purchase of other staple foods to supplement their diet. This in turn improves the health of both adults and children.

In line with the Decade for Action – Water for Life, 2005-2015, ‘ensuring the participation of women’, the implementation of the small irrigation systems has been achieved in sub-Saharan Africa by approaching local women’s agricultural groups. Food access – through purchasing and home production – is increasing for these groups using the PVDI technology.

## **4.10 Case Study 7– Rural Electrification – The case for wind power**

(Information is reproduced with permission from the Ashden Awards)

### **4.10.1 How the innovation came about/why it is important for the developing world**

Although power has been extracted from wind for thousands of years, it is only in the last ten years that wind technology has developed in response to growing global concern over carbon emissions and climate change. Wind technology can provide renewable electricity and support remote areas with off-grid electrical and mechanical power. Modern wind turbines are the most mature renewable energy technologies available. The cost of electricity produced by wind turbines is competitive with fossil fuel generation, and the number of turbines being constructed across the world has been increasing rapidly for several years. There are also economic benefits (e.g. employment) especially when there is investment in local wind farms.

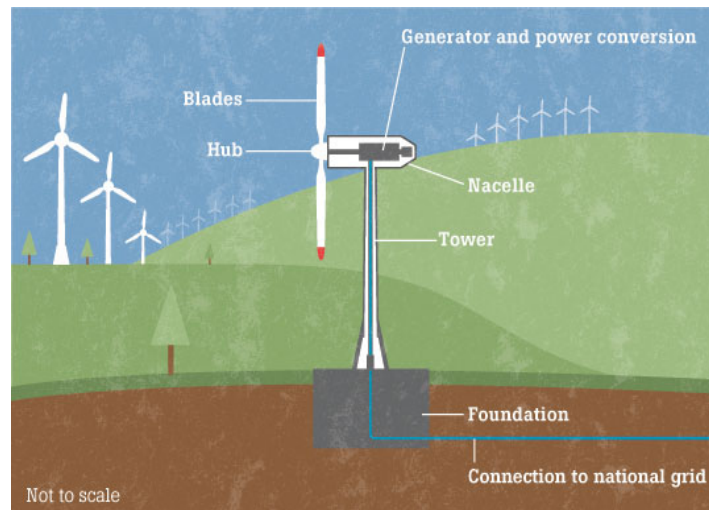
The electrical output of wind turbines is very much dependent on wind strength at a particular location which can vary over time. However, this can be minimised by linking turbines to a national or international electricity grid, and by combining them with other forms of renewable energy generation.

### **4.10.2 Wind Technology and how it works**

Wind turbines use rotor blades which are mounted on a shaft and are designed to convert the energy of wind movement into mechanical power. The force of the wind turns the rotor blades, converting the energy of the wind into mechanical energy of the rotating shaft. This shaft is then used to turn a generator to produce electricity, or

to operate a mechanical pump or grinding mill. In windmills this energy is used to pump water, drive machinery, or mill grains. The electricity that is generated can be used directly or stored in batteries. Most modern wind turbines are used for electricity generation.

**Figure 4.33 Components of a wind turbine.** Source: ©Ashden Awards for Sustainable Energy



### Wind Turbine components

- *Rotor blades.* Designed to spin in the wind and drive the turbine generator.
- *Generator and power conversion.* The rotating shaft is coupled either directly or by gears to a generator which generates power. Electricity is transferred using cables either to storage, direct use or exported to an electricity grid.
- *Directional system.* Turbines usually have a mechanism that orients them to produce the maximum output.
- *Protection system.* Most modern turbines are equipped with mechanisms to prevent damage in exceptionally high winds. Some large turbines adopt brakes to shut down power generation. Smaller turbines change the blades pitch reducing the speed of rotation.
- *Tower.* Turbines are built as tall as is economically possible to capture high wind speeds. They must be robust and have easy access for maintenance.

### Wind Turbines

Small wind turbines are used in off-grid systems, usually with rechargeable batteries so that the variable wind supply can be matched to the demand for the electricity. A wind turbine with a working capacity of less than 10kW is usually considered to be small-scale. These turbines can be connected to the grid but more often than not, they are used to generate electricity as part of a Stand-alone Power Supply (SAPS or SPS) or Remote Area Power Supply (RAPS) in regions where the electricity grid is unavailable or not viable.

### Windmills and Wind Pumps

Using windmills to pump water from under the ground can be observed in some rural areas. They operate at lower wind speeds than wind turbines for electricity generation. Windmills are able to store the energy they produce in water tanks so that water is available for irrigation or feeding livestock when there is no wind. Windmill water pumps have also been used for rural electrification using battery and low voltage systems. In SAPS or RAPS systems, a modern and efficient triple bladed rotor is used.

### Cost of installation

The range of wind turbines on the market varies enormously — from 50 W battery chargers with blades 0.25 m long, up to 6 MW turbines with 60 m long blades, for use in off-shore wind farms. The cost depends very much on how they are installed and where they are sited. For example, installing them on land can cost anywhere between US\$ 1200 to 2600 per kW.<sup>50</sup> Smaller turbines i.e. those under 100kW capacity, cost more, typically between US\$ 3000 to 5000 per kW. Most grid-connected wind turbines are installed in groups or 'wind farms'. Installing a large group of turbines reduces the average installation and operating cost.

#### 4.10.3 Environmental impact

There are concerns over their effects on wildlife, radar and aesthetics (they can be very visible in the landscape) and this has often limited the number of potential onshore locations. This in turn has led to the construction of offshore wind farms where the wind is often stronger and less variable over the sea. However installation and maintenance are more difficult and therefore the turbines are more costly to operate than their onshore counterparts. As a result an assessment of the environmental impact of a wind farm is usually required for planning permission to be given.

#### 4.10.4 Number of Wind turbines installed

The global installed capacity of wind turbines has risen from 93.8 GW (2007) to 120.6 GW (2008) to 157.9 GW in 2009. This is an increase of 58% over two years,<sup>51</sup>. Countries with a high growth rate in installed capacity are shown in the table below [Fig. 4.34]. China has been able to more than double its capacity in both 2008 and 2009.

<sup>50</sup> <http://www.eea.europa.eu/publications/europes-onshore-and-offshore-wind-energy-potential>

<sup>51</sup> Global installed wind power capacity (mw) – regional distribution, Global Wind Energy Council, 2009 Source 1 | Source 2



**Table 4.1 Increase in wind turbine capacity**

Country	Capacity at end of 2007	New capacity in 2008	New capacity in 2009
China	5.9	6.3	13.0
USA	16.8	8.4	9.9
Spain	15.0	1.6	2.5
Germany	22.2	1.7	1.9
India	7.8	1.8	1.3

**Source: GW of installed wind power in selected countries. Ashden Awards for Sustainable Energy – data from Global Wind Energy Council**

#### **4.10.5 Wind Power distribution**

Asia has seen the most dynamic progress of wind power, followed by North America. For the first time, Europe accounted for less than half of the total capacity. Five years ago Europe dominated the world market for wind turbines with 70.7% of the new capacity. Since 2009 however, new installations accounted for only 27.3% of the market whereas Asia accounted for 40.4%. Both Latin America and Africa accounted for only minor shares in total capacity. But both increased their new installations by 1.5% (2008, 0.4%) and 0.4% (2008, 0.3%) respectively.

#### **4.10.6 Achievements to date - Installation in Africa**

Africa's growth rate of 28% was below the global average of 31.6%. However more African governments are aware of the potential of wind power and are keen to start setting up the necessary frameworks. The introduction of the first feed-in tariff on the continent by NERSA (South African National Electricity Regulator) is a welcome breakthrough. With these new regulations, implemented in 2010, South Africa has the potential to take the lead in Sub-Saharan Africa and become the lead example for other countries on the continent.

Egypt and Morocco are also leading the way in new wind projects and new markets are opening up in Namibia, Tunisia, Ethiopia, Kenya and Cape Verde. In Egypt, installation of wind turbines has encouraged manufacturing industries. If these types of markets can be stabilised, it is more likely that the continent can establish domestic wind industries in several African countries.

It is expected that if this expansion is to continue, then SAPS or RAPS in combination with other renewable energies will play a pivotal role. In terms of rural electrification for Africa: deploying technologies is still in its early stages. Factors affecting its implementation and expansion include the lack of technological know-how and financing. Financing in particular could be helped in the future by the potential establishment of a Global Fund for Renewable Energy Investment and the outcome of UN climate change discussions.

#### 4.10.7 Future developments

A much larger proportion of global electricity could be generated by wind power. Currently, in 2009, the global energy generated by wind turbines was 340 TWh, or 2% of global electricity generation, and 0.26% of global primary energy use<sup>52</sup>. The total global wind resource is estimated at 278,000 TWh/year<sup>53</sup> and at least a third of this is economically exploitable within the next 20 years.

#### 4.11 Case study 8 Diseases of Poverty: Drug Development and Market Access by Dr Graciela Sainz de la Fuente

'Diseases of poverty' affect the world's poorest people: there are three main conditions addressed in the sixth Millennium Development Goal (HIV, Malaria and Tuberculosis), as well as other infectious conditions nominated as Neglected Tropical Diseases (NTDs). The 13 NTDs are major disabling conditions and are amongst the most common infections amongst 2.7 billion people who live on less than \$2 per day. By prevalence these diseases are: Ascariasis, Trichuriasis, Hookworm infection, Schistosomiasis, Lymphatic filariasis, Trachoma, Onchocerciasis, Leishmaniasis, Chagas' disease, Leprosy, Human African trypanosomiasis, Dracunculiasis and Buruli Ulcer (Hotez, Molyneux et al. 2007).

The Millennium Development Goals called for a dramatic reduction in poverty and a marked improvement in the health of the poor. Simultaneously, the World Health Organisation (WHO) advocated an increase in basic and applied research aimed at specific diseases (WHO 2001). These institutional commitments were followed by public initiatives and public/private collaborations, aimed at improving the treatment of diseases in developing countries that cause and are consequences of poverty. The Millennium Development Goals highlighted the need for more basic and applied research aimed at HIV/Aids, Tuberculosis, Malaria and other infectious diseases in developing countries (WHO 2001). Since then, other international organisations, publicly funded initiatives and public-private partnerships have embarked on technological development to combat these diseases (Hotez, Molyneux et al. 2007). However, there are hurdles to be overcome as there is a:

1. "Drug gap": less than ten percent of the global health research spending is dedicated to diseases that primarily afflict the poorest ninety percent of the world's population (Oxfam International 2008)
2. "Knowledge gap": research for diseases of poverty is under-funded
3. "Policy gap": public health initiatives have not been able to tackle the problem of access to medicines in the developing world (Trouiller, Olliaro et al. 2002). The Doha Declaration reaffirmed some flexibility in the World Trade Organisation (WTO) Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), enabling the possibility of compulsory patent licenses

<sup>52</sup> World Wind Energy Report 2009, World Wind Energy Association, 2010

<sup>53</sup> [http://www.wbgu.de/wbgu\\_jg2003\\_engl.html](http://www.wbgu.de/wbgu_jg2003_engl.html)

for medicines in cases of national emergency, but access to pharmaceuticals in the developing world is still challenging

As a result of these hurdles there is not yet an effective production and delivery model to which poverty-related diseases could adhere.

#### **4.11.1 The Drug Gap**

To create a new medicine in the Developed Countries the basic principles are:

- Basic and applied research to identify new drug targets
- Development of potential drug candidates
- Clinical trials that prove safety and efficacy
- Regulatory approval mechanisms that guarantee market access
- Compliance with reimbursement policies that assure market demand.

These steps, and those discussed below, are derived from Developed Country practice: they are lengthy and costly (Di Masi, Hansen et al. 2003).

In the Developed Countries, for one drug to be approved by the US Food and Drug Administration (FDA), a firm typically screens 5,000-10,000 compounds. From these; an average of 250 survive pre-clinical testing; only five reach clinical testing and only one gains FDA approval. The average time required to take a product from the start of clinical testing to regulatory approval is 7.2 years (Kaitin and DiMasi 2011). The associated, basic research on health conditions is funded by the public sector, while clinical testing and drug development are financed by the private sector. Globally, of the total investment in R&D, governments contribute about 44% of the total development cost; the pharmaceutical industry contributes about 48% and non-profit, and university funds make up the remaining 8% (Pécoul, Chirac et al. 1999)

#### **4.11.2 The Global Drug Gap**

Less than ten percent of the spending on health research globally is dedicated to poverty related diseases that afflict the poorest ninety percent of the world's population (Oxfam International, 2008) (\$6 billion of a total of \$100 billion annually). The 10/90 gap is the consequence of a number of market and government failures as well as huge income differences (Reich 2000): both lead to important deficiencies in the knowledge needed to foster technological developments in vector control; early diagnosis; disease surveillance; preventive chemotherapy; drug treatments and vaccine development. Commercial investments in R&D are heavily influenced by the size of the market. From the 1,223 new drugs brought to market between 1975 and 1997, only 13 (less than 1%) were targeted at tropical diseases; of these, only 4 were the result of direct R&D investment from the pharmaceutical industry (Global Forum for Health Research 2004).

### 4.11.3 Public-Private Partnerships

In the developing countries philanthropic organisations have been a great source of funding for research into tropical diseases. However, their funding cannot cover the costs of the whole process of bringing a new drug to market along with the development of manufacturing capacity (Levine, Kremer et al. 2005). Private companies, are strengthening their R&D effort into tropical diseases using open innovation approaches (Kar 2010) but so far this reorientation of R&D effort has not yet been sufficient for the magnitude of the problem.

In the 1990s, the Product Development Public-Private Partnership concept (PDP) emerged as a way to channel philanthropic funding. The WHO defines these public-private partnerships as “a wide variety of ventures involving a diversity of arrangements, varying from small, single-product collaborations with industry to large entities hosted in United Nations agencies or private not-for-profit organisations” (WHO 2011a). PDPs now occupy an important place in the global R&D landscape for poverty related diseases (Moran, Guzman et al. 2010). The field of neglected tropical diseases is also starting to create PDPs aimed at accelerating the development of drugs, diagnostics and vaccines targeted at these diseases. The Rockefeller Foundation and the Bill & Melinda Gates Foundation have been instrumental in the development of the PDP concept and its implementation (Levine, Kremer et al. 2005). In 2007, the Bill & Melinda Gates Foundation provided 49.3% of PDP funding. The United States Agency for International Development (USAID), the UK Department for International Development (DfID), the Dutch Ministry of Foreign Affairs and Irish Aid completed the picture of the top five funders, each providing over US\$20 million to PDP organisations in that year. Together, these five funders accounted for 77.1% of the global funding of PDPs’. The ‘big three’ diseases (HIV/AIDS, TB and malaria) received the largest amounts of funding in 2007 (Moran, Guzman et al. 2010).

Other organisations that have also been crucial in fostering research and product development in diseases of poverty include:

- The Global Fund to Fight AIDS, Tuberculosis and Malaria (created in 2002) is a partnership between governments, civil society, the private sector and affected communities: it is a new approach to international health financing dedicated to attracting and disbursing additional resources to prevent and treat HIV/AIDS, tuberculosis and malaria. The Fund has become the dominant financier of programs to fight AIDS, tuberculosis and malaria, with approved funding of US\$ 21.7 billion for more than 600 programs in 150 countries (The Global Fund 2011).
- Drugs for Neglected Diseases Initiative (DNDi), established in 2003 by five public sector institutions – the Oswaldo Cruz Foundation from Brazil; the Indian Council for Medical Research; the Kenya Medical Research Institute; the Ministry of Health of Malaysia; France’s Pasteur Institute; Médecins sans Frontières (MSF); and the UNDP/World Bank/WHO’s Special Programme for Research and Training in Tropical Diseases (TDR). DNDi is a, patients’ needs-driven, collaborative non-profit drug research and development (R&D) organisation that is developing new

treatments for malaria, visceral leishmaniasis (VL), sleeping sickness (human African trypanosomiasis, HAT), and Chagas' disease (DNDi 2011)

- Task Force for Global Health is a non-profit, public health organisation created to serve as a Secretariat for a consortium of UNICEF; WHO; The Rockefeller Foundation; The United Nations Development Programme; and the World Bank. These organisations sought support for a collaborative effort to improve child wellness and survival strategies. Some of these collaborations are: the Centre for Global Health Collaboration; Children Without Worms; Global Polio Eradication; International Trachoma Initiative; Lymphatic Filariasis Support Centre; Mectizan Donation Program; Public Health Informatics Institute Training Programs in Epidemiology and Public Health Interventions Network.

Some of the main product development programmes in which pharmaceutical companies have been involved are:

- African Programme for Onchocerciasis Control (APOC)
- Onchocerciasis Elimination Program of the Americas (OEPA)
- Global Programme to Eliminate Lymphatic Filariasis (elephantiasis)
- International Trachoma Initiative
- Children Without Worms (CWW) Initiative
- WHO Programme to Eliminate Sleeping Sickness
- Schistosomiasis Control Initiative
- Leprosy Drug Donation
- African Malaria Partnership (AMP) Programme
- Chagas Disease Treatment
- Tuberculosis (TB) Treatment

An alternative to the establishment of PDPs is the generation of markets to encourage drug development. The creation of incentives for commercial investments in R&D, where donors commit to pay for a new medicine only if, and when, it is developed, are fostering the creation of markets for medicines targeted to the poor (Levine, Kremer et al. 2005). These commitments are characterised by:

1. Technical specification in terms of outputs
2. Minimum price guarantee, available up to a fixed number of treatments
3. Guaranteed co-payments of products meeting the specifications, paid by sponsors and permitting eligible countries to buy medicines at affordable prices
4. Inclusion of performance incentives both at the supply side and at the demand side (Eicher, Levine et al. 2009)

These proposals may have an impact on access to medicines in the context of the developing countries.

#### **4.11.4 Bridging the knowledge gap**

Multinational companies (MNCs) based in Africa focus mainly on the development of generic drugs or on drug reformulations. Some developing countries are more

advanced scientifically than others and are referred to as Innovative developing countries (IDCs). These countries are in favour of the development of pharmaceuticals for poverty related diseases. Health research in developing countries is close to the needs of the poor; it is conducted in the public sector and driven by public health goals. Some manufacturers in developing countries follow a business model based on high-volumes at low-margins, which leads to low-cost products, often with the goal of distributing them to developing country markets (drug exports from India and Brazil are 67% and 74% respectively go to other developing countries, 63% of Uganda's drug imports and 54% of Tanzania's come from other developing countries (Moran 2005).

In 2008, the African Network for Drugs and Diagnostics Innovation (ANDI) emerged with the intention to strengthen research and development capacity in Africa and to foster African-led innovation through the discovery and development of affordable tools (e.g. natural product drug formulations) for diseases prevalent in the continent. The rationale for ANDI is the creation of incentives for African entrepreneurs to address diseases that are unattractive at a global level (Tom Mboya-Okeyo 2009).

The South-South Initiative for infectious diseases of poverty (SSI), aims to promote research collaboration between investigators in Disease Endemic Countries (DECs) across Africa, Latin America and Asia, with an emphasis on infectious poverty related diseases while the Global Network for Neglected Tropical Diseases is an advocacy initiative led by the Sabin Institute and is dedicated to raising the awareness, political will, and funding necessary to control and eliminate the most common neglected tropical diseases. International research collaborations such as the Malaria Genomic Epidemiology Network, MalariaGEN are aimed at bringing together data and expertise from multiple investigators to achieve specific scientific objectives. Finally, in response to the need to identify drug targets, a number of parasite genome projects are in progress (El-Sayed, Myler et al. 2005; Morel, Acharya et al. 2005).

#### **4.11.5 The Policy Gap**

In 1994 the World Trade Organisation (WTO) created the TRIPS (Trade-Related aspects of Intellectual Property Rights) agreement, which obligated WTO-members to recognise pharmaceutical product patents under the threat of trade sanctions.<sup>54</sup>

Numerous factors can affect the decisions that determine the extent to which firms pursue and succeed in the development of drugs in various therapeutic areas. These include (Kaitin and DiMasi 2011):

- Potential development and approval times
- Estimates of the likelihood of approvals
- Development-related costs
- Potential market sizes

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<sup>54</sup> [http://www.wto.org/english/docs\\_e/legal\\_e/27-trips\\_01\\_e.htm](http://www.wto.org/english/docs_e/legal_e/27-trips_01_e.htm)

Large pharmaceutical companies use the ‘blockbuster’ business model and seek peak sales of a drug of around \$500 million per year to justify their investments (Moran 2005). These ‘blockbusters’ make use of the advances in knowledge that can support applied research and be used for commercialisation where profitable markets exist (Smith, Correa et al. 2009); this business model does not work for diseases that prevail in the developing world. Consequently, the global pharmaceutical market is highly polarised, with North America, Europe and Japan accounting for 75% of sales (Smith, Correa et al. 2009). While Developed Countries produce and export high-value patented pharmaceuticals, developing countries import these products and produce low-value generics. Malaria, for instance, is one of the world’s biggest killers and, an effective vaccine and/or treatment would have an enormous social value. However, few alternatives have been licensed over the past 20 years (Klausner and Alonso, 2004).

The implications of the TRIPS agreement for the developing countries led, in 2001, to the Doha Declaration (WTO ministerial declaration on the TRIPS agreement and public health). Under article 8, WTO-members could “adopt measures necessary to protect public health and nutrition”. TRIPS allowed licenses to be granted compulsorily to enable third parties to produce or sell a drug, against payment of a royalty to the patent owner, when drugs are not available in sufficient supply, or are not affordable. The principle of the Doha Declaration was ratified at the 61st World Health Assembly (WHA). Resolution WHA 61:21, secured an enhanced and sustainable basis for needs-driven essential health R&D relevant to diseases that disproportionately affect developing countries (Smith, Correa et al. 2009). However, issuing compulsory licenses has often been difficult because:

- (i) TRIPS allows companies to sue governments at the WTO
- (ii) Data-exclusivity provisions of the bilateral agreements restrict the use of bioequivalency for generic drugs because there are ethical problems in testing a generic equivalent drug versus placebo (Stiglitz 2009).

Essential drugs are defined by WHO as “those that satisfy the health care needs of the majority of the population and should be available at all times in adequate amounts and in appropriate dosage forms” (WHO 2010). However, developing countries often do not have access to essential medicines. Anti-retrovirals reach the market fastest in the US and Europe (twice as fast as other drugs) (Kaitin and DiMasi 2011) but despite the rate at which the FDA grants approval for HIV drugs, the 33 million people living with HIV (22 million in sub-Saharan Africa), ten million people are in urgent need of treatment (Medicines Patent Pool 2011). Because of inequalities in market access, WHO identified patent pools as one way to improve access to essential medicines in the developing countries. In the patent pool model, multiple patents are ‘pooled’ and licensed out by one entity in order to cut down on transaction costs for all the parties involved: this is particularly important in HIV treatments which comprise a number of drug combinations and allows more affordable drugs as well as speeding up the process of improving access to urgently-needed newer and improved HIV medicines

(UNITAID 2011)<sup>55</sup> Socially Responsible Licencing (SRL) is launching other projects, such as the FP7 Access to Pharmaceuticals (ATP) consortium, a project focused on the promotion of means to improve and ensure the availability of essential medicines in the developing countries.

Some of the policies adopted by the US and Europe in the field of rare diseases and orphan drugs (those are not economically feasible under the block buster model and are of little interest to the pharmaceutical industry because of too small a market), may be extrapolated to the developing countries. In 1983 the US Federal Government enacted new legislation that would allow the development of drugs for rare diseases. The Orphan Drug Act (ODA) provided a number of development incentives (Guarino 2009) including a:

1. Tax credit of 50% of the cost of conducting human clinical trials
2. Seven-year market exclusivity to sponsors or companies of approved orphan products
3. Federal research grants for clinical testing of new therapies

Through the Office for Orphan Products Development (OOPD), the FDA encourages clinical development of products for the treatment of rare diseases by:

1. Providing assistance for sponsors of drugs for rare diseases
2. Encouraging sponsors to carry out open protocols
3. Allowing patients to be added to ongoing studies to facilitate the availability of promising drugs to extremely ill patients as early as possible in the drug development programme

Companies developing orphan products are also exempt from the user drug application fees charged by the FDA and can also be eligible for a fast track review of their application.

### **Case studies which demonstrate the emergence of a new innovation in a developing country**

#### **4.12 Case Study 9 Biotechnology in the developing world the case of Cuban Biotechnology**

##### **4.12.1 Why is Biotech important to the developing world?**

Biotechnology is a powerful innovation in the struggle to improve the lives of people in developing countries. Biotechnology has a tremendous potential for developing countries. In the words of Dr. John Wafula, the head of biotechnology research at the Kenya Agricultural Research Institute (Kari): *"The need for biotechnology in Africa is very clear. The use of high-yielding, disease-resistant and pest-resistant crops would*

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<sup>55</sup> The Medicines Patent Pool aims to improve access to affordable and appropriate HIV medicines in developing countries.



*have a direct bearing on improved food security, poverty alleviation and environmental conservation in Africa.”*

Although the benefits of genomics and biotechnology are concentrated primarily in the industrialised world, this is not the whole picture and there is also a significant developing world biotechnology capacity, in Cuba. Over the past thirty years Cuba has established a prominent position in the biotechnology industry, which has become one of the most important driving forces of the country’s economy. Initially it was a significant gamble for the Cuban state to become involved in a new high-tech industry that was reliant on government investments and strategic involvement. The case of Cuba and in particular of its health system, is of special interest for the *Toolkit* because of its developed country health outcomes despite its developing country economy.

#### **4.12.2 How the Innovation came about?**

In the 1970s and early 1980s in order to distance its gross national product from complete dependency on more traditional commodities of sugar, nickel, tobacco, rum and the associated fluctuations in markets for these goods, Cuba decided to move into a scientifically advanced arena and to develop a major biotechnology sector. As a core component of its regional development, plans for a specific biotechnology sector were incorporated in the ‘Havana Master Plans’ and a dedicated biotechnology region was developed on the outskirts of Havana in an area now known as the Western Havana Scientific Pole. The Cuban experience is unusual because it occurred contemporaneously with the growth of biotechnology and biotech regions in the West.

Since the 1980s, Cuba has built up world-class expertise in the sector as part of a centralised strategy to boost international trade and to support domestic social development - particularly in areas such as public health and agriculture. During the period 1990-1996 the Cuban government invested 1 Billion US\$ in its Biotechnology industry. This proved to be a successful investment and by 2008 Cuba’s Science Pole, comprised some forty-two interlinked institutions and 14,000 scientists. Cuba now leads the world in many fields of specialist medical research. It is also one of only four countries to have been accredited by the World Health Organisation for the production of Hepatitis B vaccines.

#### **4.12.3 What has the innovation achieved?**

For Cuba itself the local production of 80% of finished pharmaceutical products is a significant benefit to the country. In addition the export earnings from Cuban biotech bring in over 100 million dollars a year in export earnings. Cuba has not only covered domestic demand for medicines, but has also led to the development of products that compete on the international market (Cárdenas, 2009).

#### 4.12.4 What is interesting about Cuban Biotech?

The case of Cuban biotech demonstrates that a concerted effort by a government to invest in a fledgling and high risk industry can achieve huge benefits for that country. This case is all the more remarkable in that it has been achieved by a country classed as part of the developing world.

#### 4.12.5 Statistics Cuban Biotechnology

The **table 4.2** below from UN Data<sup>56</sup> shows the exports of medicaments from Cuba 2004-06 rising from 138.3 to 218.4 billion dollars

HS code	4-digit heading of Harmonized System 2002	Value (million US\$)			Unit value			SITC code
		2004	2005	2006	2004	2005	2006	
	All Commodities.....	2332.1	2318.6	2980.2				
7501	Nickel mattes, nickel oxide sinters and other intermediate products.....	1062.3	1073.0	...	13.7	14.2		284
9999	Commodities not specified according to kind.....	...	0.0	1870.8				931
2402	Cigars, cheroots, cigarillos and cigarettes.....	206.3	232.6	216.1	127.7	124.7	118.3	122
3004	Medicaments (excluding goods of heading 30.02, 30.05 or 30.06).....	138.3	217.0	218.4	53.7	64.2	58.2	542
1701	Cane or beet sugar and pure sucrose, in solid form.....	267.8	164.9	...	0.1	0.2		061
0306	Crustaceans, whether in shell or not.....	84.3	76.8	58.0	14.8	12.3	8.9	036
7207	Semi-finished products of iron or non-alloy steel.....	30.6	46.3	42.7	0.3	0.4	0.3	672
2523	Portland cement, aluminous cement, slag cement.....	32.3	42.5	36.6	0.0	0.0	0.0	661
9018	Instruments and appliances used in medical, surgical, dental or veterinary.....	19.5	41.9	43.1				872
2009	Fruit juices (including grape must) and vegetable juices.....	62.9	28.4	9.9	0.9	0.8	0.7	059

Source: UN Comtrade

### 4.13 Case Study 10 Preventable blindness: an example of international partnership

#### 4.13.1 How the Innovation came about

The Millennium Goals of 2001 highlighted the need for improvement in the health of people in the developing countries, particularly the poorest: they also called for global partnerships for development, particularly in the field of health. An imaginative and innovative way of achieving this goal is to create links between institutions in the Developed Countries with their counterparts in the developing countries to enable skills to be transferred to underserved communities. Powerful and sustainable partnerships of mutual benefit can be created in the process. The VISION 2020 Links Programme (described briefly later) is just such a process that originated as part of the 'VISION 2020 - The Right to Sight' initiative that was established in 1999 by the World Health Organisation and the International Agency for Prevention of Blindness to eliminate avoidable blindness worldwide. Collaborative work on preventable blindness (described shortly) is a notable example of a global partnership that predated the Millennium Goals: this brief case study describes the partnership with a focus on two organisations the Christian Blind Mission (CBM) and the International Centre for Eye Health (ICEH).

<sup>56</sup> COMTRADE database of the United Nations Statistics Division

The notion of 'preventable blindness' in the developing countries has a long history of over 100 years. The CBM was formed by Pastor Ernst Jakob Christoffel in 1908 and carried out pioneering work initially in Turkey. Over time, its interests have extended from blind people to those with other disabilities providing access for them to basic healthcare. There are about 600 million persons with disabilities in the world most of whom live in the developing countries. About 2.5% of this global population of people with disabilities are covered by CBM's programmes. The ICEH was established by Professor Barrie Jones in 1980 at the Institute of Ophthalmology: it is now part of the Department of Clinical Research in the Faculty of Infectious & Tropical Diseases at the London School of Hygiene & Tropical Medicine (LSHTM): it is led by Professors Allen Foster and Clare Gilbert. Both CBM and ICEH work in co-operation with the World Health Organisation (WHO), Sightsavers, the International Agency for the Prevention of Blindness (IAPB) and other charitable organisations (IAPB is a coordinating organisation for mobilising resources for blindness prevention: it was set up in 1975 and aspires to link professional bodies, non-governmental organisations (NGOs), educational institutions, and interested individuals, with national programmes for the prevention of blindness). In 1999 'VISION 2020: The Right to Sight' programme was launched with the goal of the elimination of avoidable blindness, the promotion of good vision and improving the quality of life of people with visual impairment. ICEH supports the goals of VISION 2020. But what is preventable blindness?

There are four easily preventable causes of blindness. They are:

**Trachoma:** an infection of the eye by *Chlamydia trachomatis* a parasite passed from person to person or through flies. Repeated and prolonged infection causes eyelid deformities and eventually scratching of the cornea and blindness. The infection can be treated easily with Tetracycline antibiotic cream. Prevention focuses on simple hygiene measures and making clean water freely available.

**River Blindness (onchocerciasis):** is caused by infection of the skin and eyes by a parasitic worm. The worm is transferred through the bite of the black simulium fly. Prevention requires a single, yearly dose of the drug Mectizan, (donated by Merck Pharmaceuticals part of a worldwide elimination programme by Merck Pharmaceuticals).

**Refractive Errors and Low Vision:** Low vision is defined as being between 6/18 (what a normal person can see at 18m, the near-blind can only see at 6 metres) and 3/60 (what a normal person can see at 60m, the near-blind can only see at 3 metres). Below 3/60 the person is deemed to be blind. The causes of low vision include glaucoma and other diseases.

**Cataract:** In a cataract, the lens becomes opaque as the eye ages: it is prevalent in areas where environmental and disease factors (smoking and diabetes in particular) and diet contribute. Cataract is easily reversed with simple eye surgery.

Preventable blindness is a global situation though its distribution is skewed towards the developing countries, especially Africa as noted earlier. The emphasis is on cataract surgery in the later parts of this case study.

#### **4.13.2 The VISION 2020 Links Programme**

The programme embodies the following principles:

- It works with overseas partner institutions (primarily in Africa) to identify their main needs and priorities and then match those requirements with a suitable UK training eye unit
- It is an initiative to give teaching eye institutions in developing countries the skills and resources to develop high quality programmes (including training) for eye care professionals (doctors, nurses and paramedical staff)

#### **4.13.3 How the links process works**

The VISION 2020 Links Programme has a defined assessment process (set out below) to enable sustainable partnerships between teaching institutions in developing countries and partner eye hospitals in the UK.

Through the responses to the assessment process the VISION 2020 Links assessment programme will endeavour to:

- Help the overseas partners to identify their priority needs for eye care training
- Match them with the most appropriate UK institution and facilitate the process
- Look for 'seed money' for the needs assessment process
- Organise orientation visits by key members of staff, UK to Africa and Africa to UK
- Establish Steering Groups for both partners
- Facilitate joint discussion and agreement of the goals and objectives
- Monitor and report on the Links as they develop to the VISION 2020 Links Steering Committee

The International Centre for Eye Health (ICEH) promotes the development of links by acting as a resource and networking centre facilitating ophthalmic Links within NHS hospitals and by maintaining a database of interested UK ophthalmologists to aid the matching process.

**Table 4.3 Steps in the process**

<b>VISION 2020 Links</b>	<b>Outline of the Main Steps in Developing Links</b>
Step one	Ensure that there is a willingness in the eye department to develop a link
Step two	Needs Assessment process completed by overseas institution to identify priority needs for eye care training

<b>VISION 2020 Links</b>	<b>Outline of the Main Steps in Developing Links</b>
Step three	Appropriate match within UK from institutions registered with VISION 2020 Links
Step four	NHS Trust support for the link - management agreement needed - Steering Group formed
Step five	Orientation visit from the UK to the overseas hospital
Step six	Return visit from overseas hospital to UK hospital
Step seven	Joint discussion and agreement of goals and objectives. Memorandum of Understanding completed and signed
Step eight	Development of overall plan, annual activity and financial plans
Step nine	Monitoring and Evaluation plan in place
Step ten	Funding sought from sources such as the NHS Trust charitable arm, local foundations through involvement of the staff. The two 'link partners' who choose to work together look for long-term funding

#### **4.13.4 Benefits for the overseas institution**

1. Clinical skills transfer
2. Community focus
3. Management of information
4. Research

There are corresponding benefits for the participating Developed Country institutions through the Programme by offering staff development and job satisfaction through 'hands on' work in a developing country, improving teaching skills, and increasing the status of the UK partner as an instrument for change in global eye care.

#### **4.13.5 The Tropical Health and Education Trust (THET)**

*"Links are about changing the health of people rather than only professional-to-professional support. We need to constantly remind ourselves that the outcome of any link is to provide better services to more people."* Professor Allen Foster-ICEH

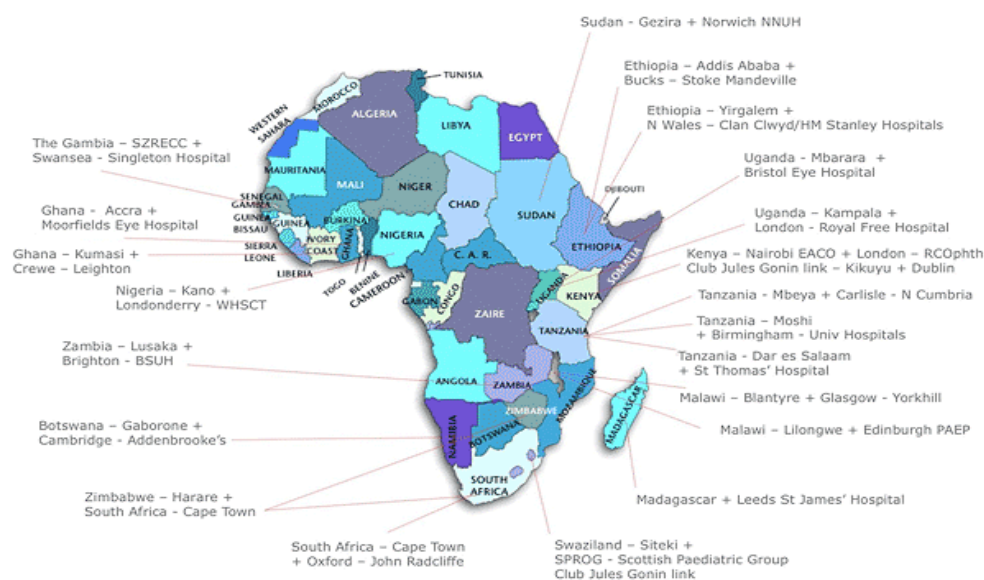
One of the strengths of the VISION 2020 Links Programme is the close association with THET, a long standing general health links programme that acts as an umbrella organisation to foster institutional links.

Since 1978 there has been a training scheme between the University Eye Hospital in Munich and the University of Nairobi Department of Ophthalmology through which trainee ophthalmologists undertake three month training placements in Germany, and vice versa. The existence of this long-term training link, plus the many health links under the Tropical Health Education Trust umbrella, led the VISION 2020 UK International Board to establish, at ICEH, the VISION 2020 Links Programme in 2004. Since then, the number of VISION 2020 links has grown to 25.

The VISION 2020 Links Programme addresses one of the key needs for eye care in Africa - strengthening training for eye care professionals in order to build capacity. Each VISION 2020 link is established to meet the priorities of the overseas partner and provides long-term training support to the whole eye care team (ophthalmologists, eye nurses, optometrists) and enhances their expertise in treating, for example, diabetic retinopathy, glaucoma, childhood cataract, adult cataract and trauma. This is achieved principally through training visits between partners, which provide much needed support and friendship as well as skills exchange.

The scope of the LINKS programme in Africa, together with the organisational innovations that enabled the widespread treatment of preventable blindness can best be judged from the map below.

**Figure 4.34 The scope of the VISION 2020 Links Programme in Africa**



#### 4.13.6 Cataract Surgery

There have been technical innovations in many fields but in this section the prime focus is on cataract surgery. There are three procedures for cataract surgery. The main focus of this case study are the phacoemulsification procedure as practiced in the Developed Countries (especially Europe and the USA) and the SICS procedure developed and used in Africa and widely in the developing countries. The latter includes organisation and operational procedures (role of nurses, etc.) as innovations copyable to and from Developed Countries.

In cataract surgery, small incision sutureless cataract surgery (SICS) is used extensively in Africa and elsewhere in the developing countries. The outcome is very similar to that of phacoemulsification used in Europe but the procedure is much cheaper and is

quicker. It is widely believed that, if the SICS procedure had been introduced in the UK before phacoemulsification, there would have been huge savings to the NHS. African surgeons are keen to learn the phacoemulsification procedure.

Organisational innovation is strong. For example, in Africa one or two people run an entire unit which is a whole new way of thinking about how to develop eye care services. This is what impresses most UK eye care professionals during a link training visit. ICEH's impression is that in the UK complex procedures are used while the procedures done in the developing countries are much simpler, less expensive, less time consuming and are no more invasive. For example, in Africa, nurses will do very simple procedures and in some places they will do cataract surgery. All oculoplastics are done by nurses, freeing up time for the ophthalmologists to do the major operations.

**Phacoemulsification** refers to cataract surgery in which the eye's internal lens is emulsified ultrasonically and aspirated from the eye. Aspirated fluids are replaced with irrigation of balanced salt solution, thus maintaining the anterior chamber. One or more incisions are made in the eye to allow the introduction of surgical instruments. The surgeon then removes the anterior face of the capsule that contains the lens inside the eye. Phacoemulsification involves the use of a machine, based on either a peristaltic or a venturi type of pump controlled by a microprocessor. The phaco probe sculpts and emulsifies the cataract while the pump aspirates particles. The cataract is usually broken into two or four pieces each of which is emulsified and aspirated out with suction. An intraocular lens implant (IOL), replaces the natural lens.

Manual **small incision cataract surgery** (SICS) offers advantages such as wider applicability, better safety, a shorter learning curve and lower cost. Manual SICS can be performed on almost all types of cataracts and time spent on nucleus delivery does not vary with the cataract. In SICS, however, the surgical skill and experience of the surgeon play a significant role in the results. Another advantage of manual SICS over other methods of cataract surgery is the shorter time taken, making it particularly applicable to high volume cataract surgery. Learning SICS is claimed to be 'easy' with a gentle learning curve and learning the procedure is consequently less expensive than for phacoemulsification.

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## Chapter 5 Evaluation of Innovation Activities

This chapter will cover two separate but related aspects of innovation in a developing economy; the management of innovation within firms and the evaluation of innovation activities from a public perspective.

### 5.1 Evaluation of Innovation Programmes and Projects

#### 5.1.2 Why are evaluations carried out?

Evaluation is a tool which is used to steer, manage and improve the activities of, and investments in, innovation activities. It is not an academic exercise but a practical process to improve current and future performance. In order to be effective there must be a feedback loop from past activities to future activities. Evaluation sits alongside performance measurement systems, monitoring and performance indicators which are commonly implemented for the management and control of innovation programmes and projects. Evaluation of innovation activities can be understood as being carried out at different stages or levels of activity.

Identified below are the various levels at which an evaluation can be conducted. For example, we may focus the evaluation on a programme of research *or* a specific project or projects of research. Evaluations may be conducted at different stages. They may be ex-ante, real-time, ex-post or historical.

#### Focus of analysis for evaluations

Technology Assessment  
National- macro-economy  
Regional Economy  
Industrial/Sectoral  
Firm  
Programme  
Project  
Institutional

Evaluation is distinct from project management. Evaluation of an innovation and technology transfer programme is an important step in 'closing the circle' in the learning process to enable such programmes to avoid past pitfalls and to improve the effectiveness of future programmes. While this simple dictum ought to apply in all organisations, it is particularly important in the public sphere to ensure that accountability is taken seriously. What follows is based on up-to-date experience in the field<sup>29</sup> but consideration must be taken to the earlier caveat that what fits one culture may not fit another.

The **table 5.1** below illustrates the relationship between the operational management of an innovation activity and its evaluation. It attempts to show by listing the main

elements of the two processes that they are not so distinct and that there is a blurring of the boundary between the two.

**Table 5.1 The relationship between the operational management of an innovation activity and its evaluation**

	Technology Management	Evaluation
OBJECTIVES	Operational Management	Strategic: Input to policy design
TIMESCALE	Day to Day control	Ex-ante; real time; ex-post
TECHNIQUES	Project management techniques: e.g. PERT, critical path analysis	Evaluation techniques
ACTIVITIES	Project definition, Project tasks, duration and timing	Definition of policy or programme objectives, assessment of performance against policy objectives (see box 5.2)
INDICATORS	Monitoring performance against plan, using milestones & deliverables	Gathering and analysis of quantitative and qualitative indicators of impacts (intended and unintended)
FEEDBACK	Remedial action	Policy advice, learning
PERSONNEL	Project Managers	Independent Evaluators

### 5.1.2 Management of Innovation activities

Within firms the management of innovation programmes can be formally identified in two types:-

- (i) To control and assess the progress of a formally initiated programme of innovation and technology transfer
- (ii) To observe the development of a technological field that has been identified as of interest to a current innovation programme or for a future programme

The first of these is a normal project management activity. It requires the preparation of a project plan setting out milestones of achievement, rates of expenditure, project budget and the completion date. While these matters sound simple enough, whether the procedures involved are compatible with the culture of many of the developing countries is less certain. For example, in the developed countries the foregoing procedures are often based on the use of the 'critical path analysis' (CPA) and the 'programme evaluation and review technique' (PERT) techniques. The CPA method uses 'flow charts' to identify the individual steps required to complete a programme and the time needed to complete each step, setting them out in such a way as to identify sets of steps that can run in parallel. The set that takes the longest is defined as the *critical path* and is always dependent on completion of all the other paths before it can be completed. **Monitoring** then takes place by checking the progress of work against the start and completion dates for each step in each path set. The method involves the notion of 'float', which represents the amount of time by which steps can be allowed to depart from the allocated time without affecting the

completion according to the critical path where float is generally taken as zero. The PERT technique is similarly characterised by the introduction of analysis of uncertain input data, such as the uncertainty in the completion time of a particular step, and the introduction of probability into the time for completion of the project as a whole. Both methods lend themselves to computer implementation and are most suited to large-scale projects. For the myriad of small innovations needed in the developing countries, simpler management of the achievement of milestones and rates of expenditure are needed and are probably more appropriate, and more appropriate.

The second monitoring activity, tracking the development of a chosen field of technology, should be a part of the remit of any intelligence gathering process. Some pointers to the nature of this activity are given in **Box 5.1**.

### **Box 5.1 Components of Technology Monitoring**

For the development of new products

- Improvement of products and processes
- Cost reduction
- Compliance with regulation
- To meet quality standards
- Radical changes in production processes, for environmentally friendly products, and for the reduction of waste
- Shortening of product life cycles
- Shortening time between (i) technological advancements and their commercialisation as products, processes and services and (ii) the time to the maturity, and early obsolescence, of the technologies on which these products, processes and services depend

Consequences of the above:

- Higher level of financial and non-financial resources, to develop and extend the boundaries of existing technologies and/or to develop or acquire new technologies
- The merging of technologies quickening the development of new products and widening the applications for both existing and new products
- Global trends toward products and services of improved quality and performance but marketed at lower price
- Purchasing, production and delivery processes that minimise stockholding and working capital, while meeting customers time schedules and quality requirements, etc.

Other activities to watch:

- Patent activity via access to public patent databases in major technology based countries (e.g. USA, Japan and the EU)

- Quality journal publications
- Company Websites
- Company exhibition stands at major exhibitions, trade fairs, etc.
- Academic publications, theses, etc.
- Activities of venture capital funds
- New company formations particularly on science parks and in innovation centres
- Quality journal Websites (e.g. Science, Nature, etc.)
- Outcomes of national foresight and other publicly available foresight programmes
- Publication of commissioned reports by reputable consultancies and other bureaux
- Content and outcome of EU Framework and other publicly accessible programmes
- Access to reports from publicly funded research (e.g. UK research councils, US National Institute of Health, etc.)
- Publications by UN agencies, the World Bank and the IMF
- Major investment movements by the major financial institutions
- Merger and acquisition activity since this may affect licensing possibilities
- Access to reports from publicly funded research (e.g. UK research councils, US National Institute of Health, etc.)
- standards

## 5.2 Evaluation procedures and their use<sup>57</sup>

To plan any evaluation clarity in terms of the purpose of the evaluation, of the scope of the activity to be evaluated and of the criteria to be employed are vital and are the minimal conditions for success (Bach and Georgiou, 1998). For the developing countries, the focus of evaluation is most likely to be on the socio-economic effects or impacts of innovation and technology transfer and on the management of the programmes that seek to deliver these effects. Similar comments apply to the quality of indigenous research activity, but only to those countries where there is significant scientific research effort. For the scope of an evaluation, a key issue is the level of aggregation. Innovation and technology transfer programmes may be conceived in terms of macro or meso-level objectives but their implementation is firmly rooted at the micro-level and that is where evaluation is aimed.

The purpose of evaluation needs to be thought of in the following way:

- Participants in the innovation and technology transfer programmes need to be aware of the impacts arising from their activities, but this is not necessarily the case. Participants are a varied group. It may be necessary to consider the motivations of researchers separately from those directly involved in markets and corporate or national decision-making. The benefits of adequate impact

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<sup>57</sup> Much of this section is drawn from Bach, L. & Georgiou, L. "The Nature and Scope of RTD Impact Measurement: A discussion paper for the International Workshop on 'Measurement of RTD Results/Impact,'" Brussels, 28-29 May 1998

evaluation provide the opportunity to learn and manage their resources in a more effective way by reinforcing success, and obtaining evidence which motivates management to maintain or increase the use of innovation and technology transfer

- The programme manager's interest mirrors that of participants. Understanding the linkages between actions and effects improves the selection and management of future projects, while broader evidence of the impacts sustains the case for public resources to continue to be invested in their particular domain
- Policy makers include both those responsible for implementation at a higher level and those whose function is to represent the broader interests of citizens. For policy makers the arguments of learning and justification apply at a higher level of aggregation, but with the addition of public accountability

Evaluation looks for the identifiable and measurable inputs and outputs at each stage of the innovation process. It also looks for the final stage where monetary or social benefits are incurred and then, according to the methodological choice, either associates them with the benefits of the innovation or else works back through the sequence calculating a coefficient governing the input-output relations. More recent approaches feature learning phenomena, structural changes induced by knowledge generation, establishment of standards and the creation of networks in the frame of analysis. Differences between technologies and markets then become crucial in understanding the impacts of an innovation. Such differences include appropriability, often founded in the degree to which knowledge is tacit or codified leading to different intellectual property protection strategies. With a more complex view of appropriability the distinction between private and public goods becomes less significant. There are several implications for evaluation, including the need to give appropriate weight to the contribution of intangible outputs to the effects and the need to understand the relationships, and interactions between outputs at all stages of the innovation process. Knowledge generated through RTD is just as likely to be applied to a problem arising from an innovation.

Recent discussion of *ex ante* valuation of RTD, in an industrial context, has focused upon option pricing - where investment in a research project is thought of as analogous to the purchase of an option to buy future stock. In other words, by performing the project the opportunity to progress in a particular direction is created. It is worth noting that option-pricing generally leads to a higher valuation of research than a straightforward net present value calculation. Furthermore, this way of thinking can be extended to higher levels of aggregation.

Evaluations are concerned with the influences of innovations and their conduct faces a number of dichotomies; these are summarised in **Box 5.2**.

### Box 5.2 Dichotomies faced by evaluations

- *Artefact vs. knowledge and skills* - is what is produced, tangible or embodied (product, process, service) or intangible in terms of knowledge and skills
- *Output vs. impact* - to some degree it is possible to distinguish between *outputs* from innovation and *impacts* or effects which arise from the interaction between the outputs and the economy or society
- *Short term vs. long term* - the time-profile over which impacts are manifested including short-term effects which end abruptly as market conditions change and outputs which are not used for some years and then become very important
- *Intended vs. unintended* - excessive focus on project or programme goals as the basis for evaluation could lead to important unintended effects being missed
- *Participant vs. non-participant* - impacts upon participants in innovation programmes are inherently easier to study than those of non-participants
- *Core vs. peripheral* – often, but not necessarily related to the size of a participant is the issue of whether the effect is upon the core or the periphery of the technological and business strategies of the participant
- *Economic vs. social impact* - it is not always clear in which category a particular effect may fall. Economists may argue that ultimately social impacts may be captured in a monetary way, for example through the polluter pays principle. However, such transformations often involve arbitrary translations
- *Economic vs. structural impact* - structural effects take on an added importance as they manifest the creation of a critical mass in the in the host country. The formation of a new network may be of increasing economic importance, with external linkages often being a precondition for innovation in many areas. The ‘temporary’ network required to execute the innovation project may form all or part of a network, which performs further functions in the technological or market domains. Since the cost and risk of forming new linkages is high there is clearly added-value in stimulating their formation

Almost every evaluation or approach to evaluation generates its own list of impacts. **Table 5.2** illustrates this with a list derived from the COMEVAL Toolkit (PREST/Smith Engineering, 1996)

**Table 5.2 Illustration of Types of Impact**

Outputs		Impacts/effects	
Intermediate outputs	Prototypes Technological subsystems Demonstrations Models/simulators Integration of technologies Tools/techniques/methods Intellectual property Decisions on further RTD	Competitiveness	Sales market share open up markets create new markets lower costs faster time to market licence income
Products	new products improved products	Employment	jobs created jobs in regions of high unemployment jobs secured jobs lost
Processes	new processes improved processes	Organisation	formation of new firm joint venture to exploit results new technological networks/contacts new market networks/contacts improved capacity to absorb knowledge core competence improvement further RTD change in strategy reorganisation of firm to exploit results increased profile
Services	new services improved services processes for delivering new services	Quality of life	Healthcare safety social development & services improved border protection & policing support for cultural heritage
Standards	de facto standard de jure standard	Control & care of the environment	reduced pollution improved information on pollution & hazards



Outputs		Impacts/effects	
	reference conformance memoranda of understanding common functional specification code of practice identified need for regulatory change		reduced raw material use reduced energy consumption positive impact upon global climate decrease in pollutants
Knowledge and skills	management & organisation technical	Cohesion	Employment in LFRs Infrastructure of LFRs Participation of LFRs Further RTD in LFRs Regulation & policy in LFRs
Dissemination	training activities workshops/seminars/ conferences technology transfer activities knowledge & skills transfer publication & documentation	Development of infrastructure	Transport telecommunications urban development rural development
		Production & rational use of energy	energy savings renewable sources nuclear safety assurance of future supply distribution of energy
		Industrial development	development of internal market development of SME sector development of large organisations support for trade
		Regulation & policy	EU regulations or policy national regulations or policy worldwide regulations or policy coordination between national & Community RTD programmes

Two warnings need to be in mind when reading **Table 5.2**. The first is the constant theme that what is common evaluation practice in the industrial countries may not fit circumstances elsewhere. The second is that the approach to evaluation requires a new mind set, which will take time to be accepted in the developing countries. Even in the developed countries, the need for formal evaluation is not universally accepted. Some issues complicate the evaluation of the impacts of an innovation and technology transfer programme; these are:

- Separation of the evaluated programme and the evaluated effect to attribute their individual effects. For example, policy-makers may see a contract they fund as an entity that produces discrete effects. However, the firms involved see it either as a part of a larger programme of work, or one that requires substantial follow up work and combination with knowledge from other sources before an economic effect is achieved. The key distinction is between a contract and a project. Attempts by evaluators to ask firms to calculate a rate of return for a particular project typically meet with the response that this is not a meaningful question - as firms see the rate of return as one on the entire innovation cost. An analogous situation is true for social effects
- The issue of additionality: Whether the policy intervention encourages projects that would otherwise not be done. Whether the project would have been carried out differently without the intervention. Whether the existence of the project or programme has an influence on technology strategy and whether expenditure on innovation and technology transfer were increased by an amount equivalent to the value of the project

All of these questions are difficult to answer definitively.

Practically, evaluation depends crucially on the source of information. The dominant approach is that of reports by participants in innovation and technology transfer programmes either through monitoring or in response to questionnaires. The latter cannot be relied upon to capture the complexity of an innovation by comparison with a series of in-depth interviews. Management of the trade-off between cost and quality is a central design issue for evaluation. Verification of data, for example by comparison with statistics collected for other purposes, or by accumulating data throughout the life of the project and beyond, is also important in order to avoid the temptation of looking back with hindsight.

Another practical issue is clarity of the evaluation work and the evaluation process. However clear the outcome, differences in interpretation by different stakeholders cannot be avoided but clarity of presentation increases the credibility of the outcome.

It has to be recognized that multiple models of the influences and processes of innovation and technology transfer will coexist and will be revealed by evaluation procedures; they do in the industrial countries and it cannot be otherwise in the developing countries.

All evaluation methods demand information at the project or participant level. For this reason the following practical points need to be observed:

- Participants should not be required to give the same information in slightly different formats to studies initiated at different levels of responsibility or location
- Once unnecessary inquiries have been limited, the work that remains should be given resources that are adequate to the task, while any surveys should be carried out under well managed conditions and should observe the necessary statistical sampling criteria as far as that is possible (piloted, confidential from line management, etc.)
- The limitations of surveys need to be recognized, particularly their requirement that a substantial sample of expert interviews is used
- That effects take place over an extended period after the completion of the innovation and technology transfer; this implies tracking the outcome for some time, which in itself requires an incentive or obligation for participants to continue reporting.

### **5.3 Is there such a thing as 'best practice'?**

'Best practice' implies the notion of a way of doing things that is, for the time being at least, universally recognised as more effective than any competing process. To claim 'best practice' is then to claim that all other processes are known and are known by some measure to be less effective in innovation and technology transfer than the one for which 'best practice' is claimed. Is there then a 'best practice' in innovation and technology transfer? The response is almost certainly 'No', but there are ways of doing things that will, in most circumstances, help innovation and technology transfer proceed more smoothly while evading the major pitfalls. Most of these have been discussed in **Chapter 2** and will not be repeated here. For innovation, creating an appropriate atmosphere in which motivation is high, but is balanced by an appropriate level of 'forgiveness' for occasional failure (but not for recurrent failure based on choosing inappropriate innovations and technologies to transfer or through evident incompetence) is essential. How to create an appropriate atmosphere is a topic that has filled many innovation management texts without adding greatly to its practical achievement. For projects in the developing countries, this is a point where Lauterbach's dictum of 'self help' is essential. Much can be learned from the industrial countries experience, but that will need adaptation to their own cultural conditions.

For successful technology transfer the 'rules' are clearer and while still needing adaptation, the guidelines given earlier should help the developing countries in their negotiations with their industrial counterparts. The greatest concerns need to be for the identification of appropriate and appropriable technologies to be transferred and then for the terms under which that transfer can take place. However, the amount of technology that is freely available in publications and elsewhere should never be overlooked. For this effective 'intelligence' is vital and can repay its costs.

## 5.4 Indicators of Development

The Human Development Index (HDI), used throughout this report, was developed in the United Nations Development Programme and originates from 1991. The HDI has undergone much development: the current format is described in the technical section of the Human Development Report for 2010. The main components of the HDI are life expectancy at birth, mean years of schooling, expected years of schooling and the GNI/capita. The two schooling components are subsequently combined into a single component representing education. In more detail the education component is measured by mean of years of schooling for adults aged 25 years and expected years of schooling for children of school going age. The mean years of schooling is based on the duration of schooling at each level of education while the expected years are based on enrolment by age at all levels of education and the population of official school age for each level of education. The indicators are normalized using a minimum value of zero and maximum values are set to the actual observed maximum values of the indicators from the countries in the time series, that is, 1980–2010. The education index is the geometric of two indices. Life expectancy at birth is calculated using a minimum value of 20 years and maximum value of 83.2 years: these are the observed values in the countries in the time series, 1980–2010. For the wealth component, the minimum income is \$163 (PPP) and the maximum is \$108,211 (PPP).

The HDI has evolved for 20 years so that it seems unlikely that it has a serious competitor in its field. Its use in conjunction with the targets set under each of the Millennium Goals, set out in the Preface, seems likely to provide some helpful ways of tracking the progress of developing countries. The HDI will characterize progress in a quasi-quantitative way while many of the Millennium targets will provide parallel qualitative measures. For these reasons it is recommended that the HDI ought to figure among the policy toolkit in the developing countries.

## Chapter 5 References

- Bach, L. & Georghiou, L. (1998) *The Nature and Scope of RTD Impact Measurement*. A discussion paper for the International Workshop on 'Measurement of RTD Results/Impact, Brussels, 28-29 May
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## **Appendix 1 Further sources and reference materials**

In a relatively short text only major matters relating to the subjects of scientific breakthrough, invention and innovation can be presented. In this chapter signposts to other sources and reference materials are given for those who wish to learn more about the many aspects of science, invention and innovation as they influence modernisation of a country's economy, to use Lauterbach's term. Those who embark on that journey should not expect it to be either short or to be completed quickly; the literature is immense and often repetitive. Every author has preferences and the signposts given here are no exception to that rule, but like all signposts they indicate different and alternative roads for the traveller to follow, though they do not all end up in the same place.

### **Scientific breakthrough and invention**

No one can be sure when a breakthrough in science will occur or what its nature will be. Often a series of breakthroughs will occur after an initial one has led the way. An example of this has been the breakthrough in understanding that led to the transistor created by Shockly, Bardeen and Brattain in 1947. However, electronic circuits based on large individual transistors were soon perceived to have severe limitations and this led Kilby to invent the 'planar process' that led to the integrated circuit and to all that has followed in large scale integration. The unravelling of the structure of DNA and subsequent events, including gene splicing techniques follows a similar pattern the evolution of integrated circuits. However typical these breakthroughs may seem, generalisation from them is inclined to become vague or at least to be represented by the generalities of the 'scientific method' and all the disputes that surround it. Insights into breakthroughs in science are best obtained from individual case studies.

The closeness of the relation between scientific breakthrough and invention is evident in the literature relating to invention. Here the situation is complicated by the need to patent an invention to secure the inventors rights, which usually implies that significant parts of the invention process are omitted in any publication relating to it. However, there are some remarkably open and amongst these is Sir Alistair Pilkington's paper to the UK's Royal Society in 1969 (Pilkington, 1977). However, it has to be said that the blurring of the boundaries between scientific breakthrough and invention, and innovation is much in evidence in the literature. For that reason the following resources provide many signposts to further reading in all three fields:

Tushman, M.L & Moore, W.L. 'Readings in the Management of Innovation', contains important articles by Abernathy, Utterback, Quinn and others. There are also eight pages of reference to further reading.

Uusitalo, O. 'A revolutionary dominant design: the float glass innovation in the flat glass industry',<sup>32</sup> discusses how a particular invention became the dominant design for process plant in part of the glass industry. The author also presents 15 pages of relevant references.

Edosomwan, J.A. 'Integrating Innovation and Technology Management,' sets out to be a handbook on the subject and contains a number of case studies and contains a

comprehensive list of references and recommended further reading that runs to some 20 pages.

Other useful sources of information are the:

- European Commission's Cordis website <http://cordis.europa.eu/> which deals with the EU's research and development programmes
- EU's Europa website <http://europa.eu/> which deals with most other EU matters
- European Commission's Innovation/SMEs Programme DG XIII - publications include Innovation & Technology Transfer
- OECD who regularly publish material related to innovation and economic development
- UK Office of Science and Technology's Knowledge Pool website that contains a growing amount of information related to possible developments in science, technology and innovation
- European Patent Office website <http://www.epo.org/> contains some 30 million searchable documents relating to patents and gives information on courses, etc.
- Strong, W.S. *The Copyright Book: a practical guide*, gives a detailed account of US copyright law and requirements, published by MIT Press in 1986
- Courses on the management of technology, with a strong content on innovation, are run by many universities and institutes, at master's degree level, including MIT (The Sloan School) and the University of Manchester (Manchester Institute of Innovation Research)
- Intermediate Technology Development Group, Myson House, Railway Terrace, Rugby, CV21 3HT, UK for innovative projects and practical programmes in many fields
- J.P.M. Parry & Associates Ltd., Corngreaves Trading Estate, Overend Road, Cradley Heath, West Midlands, B64 7DD, UK for innovative projects and practical programmes particularly in building materials

## Finance

Just as there is an immense literature on invention and innovation, the provision of finance for projects in the developing countries and developing countries comes from too wide a variety of sources to be covered in any depth. The instruments and technicalities of providing finance are diverse and complicated if not complex and each needs specialist explanation. All that is attempted here is to give indications of some of the organisations involved in project finance, excluding funding from national governments and United Nations organisations.

- International Finance Corporation (IFC), 2121 Pennsylvania Avenue, NW Washington, DC 20433 [www.ifc.org](http://www.ifc.org). Among its activities supporting private sector development the IFC runs The Small and Medium Scale Enterprise (SME) Program in conjunction with the Global Environment Facility. A useful publication is 'Impact' a review of private investment in the developing countries and developing countries
- The IFC has also published "Project Finance in developing countries" as Number 7 in its 'Lessons from Experience' series. Several case studies are included
- The International Monetary Fund (IMF), Washington, DC 20431, USA publishes 'Finance and Development' quarterly [www.imf.org/fandd](http://www.imf.org/fandd) among its many activities in promoting economic development

- All of the world's major banks have interests in financing projects in the Developed Countries and developing countries
- Similar remarks apply to the world's major aid charities (e.g. The International Red Cross and Red Crescent, Save the Children Fund and similar agencies and many others too numerous to mention)
- Many private research agencies work globally; the largest of these is the Wellcome Foundation based in the UK



## Appendix 2

### **Reflections on innovation metaphors and their relevance to the innovation Toolkit: Academic debates regarding systems of Innovation and the geography of innovation**

The review describes systems of innovation (SI) and geography of innovation (GI) as these two theories are the most relevant to the Toolkit. Both metaphors offer explanations of invention and the evolution of innovation from economic and geographic viewpoints. The merits of each are continually debated concerning how and whether they provide an adequate understanding of innovation processes. Morgan (1997) points to the growing convergence between the two fields of study yet a number of fundamental differences remain and each has a distinctive set of authors who continue to promote one approach over the other.

Invention is a pseudo-random process: innovation is set apart from invention but dependent upon it, though it is a non-linear, interactive, cumulative and socio-technical phenomenon. Much has been written, about the 'context of interaction' (Carlsson and Jacobsson, 1997) that may permit and enhance innovation. The distinction between SI and GI, and their common elements, offers an explanatory power that each metaphor brings to the field of innovation studies. Criticisms of innovation studies to date are that they are often heavy on conceptualisation, through 'discursive persuasion' (Martin, 1999), and that this remains the dominant mode of theorising.

#### **Observations on the existing literature**

Key authors set out clearly the state of knowledge associated with each of the approaches discussed here, while empirical work supports each. For SI work by Edquist (2001); studies edited by Andersen, Lundvall and Sornn-Friese (2002); and the comparative approach of Chang and Chen (2004) are exemplars. Publications focused on GI include reviews of economic clustering by Breschi and Malerba (2001); "Regional Innovation Systems in Europe", introduced by Leydesdorff, Cooke and Olazaran (2002); critical surveys in Regional Studies on territorial innovation models by Moulaert and Sekia (2003); and innovation and geographic space by Simmie (2005). Martin (1999) has reviewed critically the role of geographers and the science of geography in an economic context including criticisms of the work on clustering by Martin and Sunley (2003).

Such reviews often indicate maturation of the literature and coalescence as core material and concepts seem to become well-founded appearing to display some common ground. Conversely, it could be argued that these reviews may also reinforce the fragmentary, diverse, over-lapping and sometimes position-entrenched approaches to innovation studies. Discrepancies between these reviews (and acknowledgement of differing opinions) indicate that a unified theoretical position continues to elude researchers and theorists. The negative effects of these contrasting views include inconsistencies in terminology that hamper progress in innovation studies impeding conceptual clarity and practical application of theory restricting the development of suitable policy actions.

### **Structure of the review**

The review sets out (i) an historical review of the antecedents of SI and GI to provide a basis for discussion; (ii) the main features of SI and GI, definitions of terms and how these were developed and are used, landmark studies, publications and researchers associated with each approach; and (iii) each approach will be examined to reveal similarities and dissimilarities.

### **Antecedents to modern theories**

Historically the work of Smith, Marshall and Schumpeter provides the platform for the development of modern metaphors of the field of innovation studies and also creates the conditions for divergence in the SI and GI approaches.

Adam Smith's, 'An inquiry into the Nature and Causes of the Wealth of Nations' (1776), provides the basis for the development of economics as an analytical concept and identifies the importance of technological innovation as essential to economic progress; it did not separate the functions of invention and innovation. Smith's views on efficiencies resulted from the transpositions of specialisations and divisions of labour forward into specialised R&D departments. In addition to technological change and division of labour Smith also proposed the accumulation of capital as drivers of economic change. Smith's 'discovery principle', or 'recourse to new divisions of labour and new improvements in art' is his notion of 'drivers for incremental innovation.'

In contrast to Adam Smith's ideas, Friedrich List (1841) postulated the notion of 'The National System of Political Economy' to attempt an economic explanation of the rise and fall of nations. He concluded, for example, that American society accumulated social and cultural resources which as a nation had a major impact on economic growth. List's other contribution was to stress the importance of infrastructure as an enabler of economic growth, with particular emphasis on the German railways which permitted the circulation of commodities, individuals and information.

Schumpeter (1939, 1942) reinforced the importance of innovation as the key factor in dynamic, capitalist economies and stressed, in his earlier work, the role of entrepreneurs in delivering innovations (in later work Schumpeter acknowledges the importance of international links to scientific knowledge and the importance of large corporations). Schumpeter also distinguished between 'inventions' and 'innovations', the latter being the material economic benefit of the widespread use of new products, new processes or new devices. Lastly, the broadening of the concept of innovation from restricted technical innovations to encompass new forms of production (Schumpeter 1939, 1942) encompassed organisational forms, which may flow from organisational, social, technical and market change.

Some authors have observed that Schumpeter was not concerned with the spatial distribution of innovations. Accordingly, traditional agglomeration theory was not concerned with innovation, though Schumpeterian aspects of technological evolution have, since the 1980s, become more apparent in economic geography. In the 1940's Schumpeter rejected perfect competition, while postulating the introduction of new methods of production and new commodities as being hardly conceivable with perfect (and perfectly

prompt) competition. Key to this is the concept of product-led, as distinct from price-led, competition. Links can be drawn to internal organisational dynamics as well as to external dynamics represented in open systems models.

It has been argued that metaphors of economic processes should take space and location seriously in order to account for the reality of economic activity taking place in local, regional, national and global space. Thus the mechanisms of economic development, growth and welfare, which operate unevenly across space are included. Those mechanisms are themselves spatially differentiated and in part geographically constituted.

Marshall (1890) is generally credited with the identification of 'knowledge' as being fundamental mechanism to economic progress. Marshall links a 'triad' of labour market pooling of skilled labour, technological or knowledge spillovers and intermediate goods supply, from ancillary industries, with demand linkages to produce these 'localisation externalities'. The links between the system and space were further emphasised in 'Industry and Trade' (Marshall 1919). Dunning (1998,) suggested that the benefits realised from the agglomeration effects of related activities in a geographical concentration, had been relatively neglected by trade economists. Best (2001) describes Marshall's major contribution as adding 'organization' as the fourth factor of production to labour, land and capital. However, Marshall's 'industrial districts' approach emphasised the beginnings of networks and complementary assets to support and enhance the innovation-promoting potential of firms (Dodgson 2000).

### **The Innovation Systems Approach**

The systems of innovation (SI) metaphor draws on evolutionary ideas associated with economics and technological change. SI's have four sub-categories: national, sectoral, technological and regional. Each is discussed in the review, including regional innovation systems (RSI). One of the issues of framing discussion on SI and GI approaches is whether to consider RSI from a geographical or systems perspective. Arguments for the former are that the RSI concept is seen as having its roots in evolutionary economic metaphor and lays claim to systemic properties. Arguments for the latter is that RSI's should have a distinct geographical content to them and indeed authors such as Moulaert and Sekia (2003) consider the RSI as a territorial innovation model as distinct from a theoretical construct.

Systems of innovation as a concept appeared in 1980s' and 1990's as a new approach to the study of innovation within economies (Acs and Varga 2002). The approach has become widely accepted (Edquist, 2001). Initially the approach reflected National Systems of innovation (Edquist 2001). A central premise of the systems approach is that individual firms do not carry out innovations in isolation (Edquist, 2001). Nelson and Rosenberg (1993) define SI as "a set of institutional actors that, together, play a major role in influencing innovative performance". Carlsson et al, (2002) state that "...the function of an innovation system is to generate, diffuse and utilize technology. Thus the main features of the system are the capabilities (together representing economic competence) of the actors to generate, diffuse and utilise technologies (physical artefacts as well as technological know-how) that have economic value." The boundaries to the system can then be very wide which means that it becomes difficult to define the innovation system, and what it should include, when employing broad definitions of innovation (Nelson and Rosenberg 1993).

Lundvall (1992) defines a system of innovation as “constituted by elements and relationships which interact in the production, diffusion and use of new, economically useful, knowledge and that a national system encompasses elements and relationships, either located within or rooted inside the borders of a nation... A central activity in the system of innovation is learning, a social activity, which involves interaction between people”. By comparison, Edquist (1997) prefers the “all important economic, social, political, organisational, and other factors that influence the development diffusion and use of innovations”. Again, Carlsson et al (2002) provide a definition of a ‘system’ from Webster’s Collegiate Dictionary as “a set or arrangement of things so related or connected as to form a unity or organic whole”. To Edquist (2001) the term ‘system’ is used generously and variably, with “limited demands of a precise definition” while Nelson and Rosenberg (1993) indicate that the word system may have connotations of being “consciously designed and built”. That is not the concept offered by SI which is meant to convey the interactions of a set of institutions. And again, Teece (1986) described the systemic nature of innovation and impediments to its successful economic realization. Teece emphasised the importance of complementary assets (such as service, distribution and competitive manufacturing) in delivering and sustaining innovations. He also acknowledged that complementary assets may be other parts of a system concluding that “If government decides to stimulate innovation, it would seem important to clear away barriers which impede the development of complementary assets which tend to be specialised or co-specialised to innovation” (Teece, 1986).

Anderson et al (2002) claim three reasons for studying SI conceptually; these are:

- the enhancement of understanding “historical processes of economic evolution”
- the opportunity to influence policy and decision-making
- to “contribute to theory”.

Lundvall et al (2002) speculate on the reasons why the concept of SI diffused rapidly (in less than 10 years). They suggest that failure in other macroeconomic and policy instruments has prompted the need for other frameworks which can explain reasons for “national competitiveness and economic development”. These other reasons included the specialisation of policy institutions that provided too narrow a perspective and, consequently, the broader SI concept was welcomed. The ubiquity of SI was supported by Edquist (1997) who claimed “...the system of innovation approach can serve as a fundamental concept which encompasses different structural environments of firms together with an “actor-oriented approach”. In turn, this is seen as critical to understanding the dynamics of innovation as a response to changing environmental and competitive conditions: this is widely perceived to have accelerated in the last quarter of the 20<sup>th</sup> century for many industries across many nations.

Edquist (2004) criticized SI as “undertheorized” and lacking the status of a formal theory. Contrary positions from Lundvall (1992) promoted the view of maintaining an open and flexible definition of SI. Consequently, a debate continues as to the seriousness of the perceived weaknesses of SI.

SI has also been criticized for “conceptual diffuseness”. Evidence for this stems from variations in the definitions of key terms, particularly the term “institutions” which is used inconsistently between authors, some seeing these as different kinds of organisation (Nelson and Rosenberg, 1993) while others take it to encapsulate rules of behaviour and the pervading norms, routines or laws that may be apparent within the system. There are also perceived deficiencies with respect to the definition of the boundaries to the system with a consequent lack of specification on what is included and excluded from it. Edquist (2004), points to the essential requirement to specify boundaries if empirical studies are to be carried out proposing that boundaries can be identified: spatially/geographically or sectorally or in terms of activities.

The study of innovation from a systems perspective is conducted via a number of units of analysis: geographic (national or sub national/regional), technological and sectoral. These are now discussed in turn.

### **National system of innovation (NSI)**

The idea of an NIS stresses the importance of a nation’s science and technology base and the institutions which link these activities to firms and other actors. Each country may be seen as having distinctive sets of these attributes or arrangements. Lundvall (1992) focused on the various actors in the system and role of the public sector, finance, scientific and technical institutions together with the opening-up of the national system to the influences of multinational enterprises (MNEs). By contrast, Nelson (1993) acknowledged that innovation systems do transcend national boundaries and that transnational aspects have become of increasing importance.

Porter (1990) proposed a model of the determinants which affect the competitiveness of a national industry: firm strategy; factor conditions; demand conditions; and supporting industries. The systems perspective could describe sectoral innovation and some authors (Lundvall 1992 & Molina and Kinder, 2000) have suggested ways of encompassing the Porter model into the wider systems approach. These approaches differ in their level of analysis (a not uncommon feature of the innovation systems literature). The varieties of spatial boundaries and choices of levels of analysis remain persistent issues in the study of innovation systems.

Nelson (1993) concentrates on studies of the US system and produced case studies which represented the attributes of innovation systems in high, medium and low income countries. These attempted to compare and contrast approaches to innovation in different countries, to establish elements of distinctiveness and to learn from the implications. The comparison of national innovation systems, their similarities and differences are therefore of interest – particularly if it can be shown that the “differences explain variation in national economic performance” (Nelson and Rosenberg, 1993). The differences sustain continuing awareness and interest in the systems of innovation concept (Archibugi and Michie 1997). However, the theme of globalisation as a means of by-passing the national perspective is echoed by de la Mothe and Paquet (1998) in their criticism of NSI.

Through reflection Nelson (ibid) identifies the differences between NSI, within the chosen group of countries, to emanate from “...differences in economic and political circumstances

and priorities". He noted that the innovation priorities of low-income countries were concerned with national security issues. At the time of publication Nelson observed that other forms of government support are evident in the space, electric power and telecommunications sectors of many countries illustrating differences in the role played by government in shaping innovation.

Subsequently, Nelson attempted to distil a basic set of requirements for effective innovative performance from a NSI, from similarities that appear to support the comparative economic performance of some countries over others. These include innovation as the underlying principle behind competitiveness, competence throughout the supply chain, from product design to marketing, and the financial resources behind these capabilities. He also observed that the availability of fiscal, monetary and trade policies greatly assisted the innovation process (Nelson 1993).

Archibugi and Michie (1997) observe that the NIS approach has been taken up by the OECD. The European Union also supports NSI as demonstrated by increasingly regional development and growth of a number of Regional Innovation strategy bodies that share best practise and distil approaches that may be transferred to other regions.

Nelson's concept of a NSI is thought to be too restrictive to examine the interconnections of a firm (Acs and Varga 2002). A regional perspective seems to reinforce the proximity elements of innovation implying a sub-national element, which has to be set against supra-national elements of innovation delivered perhaps, but not exclusively, by multinational enterprises.

### **Technological system of innovation**

Carlsson et al (2002) employed a definition of a technological in which the authors claim technological systems to be delineated by the boundaries of its knowledge. As with other SI concepts, the analysis involves some judgments, while the dynamic nature of technologies may require periodic re-definitions of system boundaries.

Carlsson et al (2002) quote four basic assumptions of the technological systems approach:

- The primary unit for analysis is the system as a whole (rather than the individual components); this is consistent with the general systems approach and Edquists's (1997) holistic and interdisciplinary view of the SI approach
- The system is dynamic which reinforces the methodological time/snapshot issue of the systems approach
- Global technology opportunities are practically unlimited. The boundaries of the system and the interface with the environment is clearly evident here.
- Each actor (component) in the system operates with bounded rationality
- Coombs, Harvey and Tether (2003), acknowledge that Carlsson's approach included more systemic properties than either the national or sectoral approaches and criticized the treatment of the definition of system boundaries, the unit of analysis and the measurement of system performance.
- Edquist (1997) points to the growing importance of transnational interactions and the globalization of firms (and in a business to business sense the emergence of global

suppliers and customers); these would tend to support the notion of sectoral or technological innovation systems.

### **Sectoral system of innovation**

Malerba (2002) defined sectoral systems of innovation (and production) (SSI) as “a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products”. The existence of SSI’s may be a stronger and more binding influence than NSIs, particularly from the perspective of participating firms (Howells 2000). Carlsson et al (2002) built on this theme in principle “to view a national system of innovation as the aggregate of a set of technological, sectoral, or regional systems”. To Coombs, Harvey and Tether (2003) a sectoral approach may be successful when boundaries to the sector are distinct and when conditions within the sector are stable, which they rarely are. The same authors consider the ability for the perspective to deal with inter-sectoral interactions and explain the emergence of new sectors to be problematic.

The interaction of these various lenses is demonstrated by Chandler, Hagström, and Sölvell (1998). Here the emphasis is on the importance of connectedness and extra-firm activities. The authors observe that “a new literature is emerging, bringing inertia and trajectories to the forefront, thus limiting the impact of strategic choice ..... these trajectories ..... are embedded in the environment [which] connects them to regions and geographical districts”. Geographical boundaries are important (Malerba, 2002) with localisation issues being of particular importance to SSI’s suggesting that “national boundaries are [not always] the most appropriate ones for ..... the structure, agents and dynamics of these systems”. Breschi and Malerba (1997) developed a general typology of the geographical boundaries of sectoral systems using “technological regimes” which they defined by “the level and type of opportunity and appropriability conditions; by the cumulativeness of technological knowledge; by the nature of knowledge; and the means of knowledge transmission and communication”.

### **Regional Innovation Systems**

Regional innovation systems (RSI’s) have their origins in the study of regional science (Cooke and Morgan 1998). Doloreux and Parto (2005) acknowledge that RSI’s originated from SI’s and that the concept of innovation as a “partly territorial phenomenon..[and]..is fundamentally a geographical process ...[in which]..innovation capabilities are sustained through regional communities that share common knowledge bases”.

Similarly, Cooke and Morgan (1994) highlighted the spatial context of innovation and the relevance of (fundamentally geographic) concepts such as ‘territorial production systems’, ‘industrial districts’, ‘innovative milieux’ and ‘regional innovation networks’. The imperative for the investigation of successful regional agglomeration networks has come from success stories such as Silicon Valley in California, Baden-Württemberg in Southern Germany and Emilia-Romagna in Northern Italy. These are the regional equivalents to Freeman’s study of the Japanese system of innovation at the national level.

The origins of the modern SI concept stressed the importance of *national* systems. Freeman (2002) suggested that some authors would argue that the forces of globalization have since

diminished the importance of the nation state (Sabel, 1994 (reprinted from 1989), Ohmae, 1990; Storper, 1997) and that the focus of attention in theory development should be at an alternative level to the nation.

Braczyk, Cooke and Heidenreich (1998) identified the origins of the RSI concept and the emergence of the region, as a frame of reference. Of particular significance was the apparent success of regions involving small sub-contracting firms, a feature that may explain the sustained interest in regional systems by policy makers and regional administrators concerned with the development of the small business sector. Similarly, Nelson (1993), Braczyk, Cooke and Heidenreich (1998) provide a range of *regional* case studies from a number of contributors. In trying to understand regional governance of the system, these authors developed a typology of systems ranging from market-driven and informally coordinated regions to those displaying a more centrally coordinated approach. The outline typology uses aspects of a *governance* infrastructure and *business* superstructure in order to categorize RSI's

Wiig and Wood (1995) offer the following characteristics of an RSI:

- A strong (distinctive) regional economic environment
- A dynamic system in terms of user-producer interfaces
- Strong trade linkages
- Evidence of clustering
- Collaboration between firms and institutions
- Innovation in products and processes
- Provision of trained labour
- Collaboration for provision of services
- Strong technological expertise
- Interaction between firms for innovation
- Links with institutions.

Territorial innovation models developed in literature surveys of regional innovation in Silicon Valley and the notion of clusters. These emphasised market competition rather than networking as the primary driver for innovation, a view distinct from networking and social interaction. The typology of territorial innovation models provides was based on attributes of innovation; types of institution; the nature of regional development culture and the nature of relationships between actors; and the relationship with the larger environment of the system. The latter increased focus on local issues and is likely to be attractive to policy makers in directing and influencing policy at a regional level. RSI's can provide 'cognitive coordination' in identifying and promoting shared knowledge mediated by the regions institutions. Further policy implications of these regional networks suggest that development of policies that "help companies to learn and respond quickly to changing conditions - rather than policies that either protect or isolate them from competition or external change" should take priority.

Oinas and Malecki (2002) believe the RSI literature fails to distinguish between different types of RSI because it is top-down with limited integration at the regional level (in effect a



regionalized NSI) and bottom-up, with an extensive regional-wide network – a ‘territorially integrated innovation system’.

Edquist (1997) rarely mentions explicitly the RSI literature and confines them to technological discontinuities. Successful discontinuities can be promoted by spatial factors that map closely onto the regional approach to innovation and the connectivity of the system; the collective knowledge in the region and the facilitation the region provides for firms to respond to technological discontinuities (Ehrnberg and Jacobsson 1997).

Regional or local analysis of clustering of economic activity can be revealed simply from the geographical distribution of firms. De la Mothe and Paquet (1998) conclude that “there is no such convergence on the innovation process front” and therefore this “ill-specified innovation process” causes persistent problems to the study of systems of innovation and that a “ ‘territorialised system of innovation’ remains an essentially contested topic.”

### **Overview of the innovation systems approach**

The ‘systems approach is not a formal theory’...it does not provide convincing propositions as regards established and stable relations between variables. The most it does in this direction is to provide a basis for the formulation of conjectures that various factors are important for technological innovation’ (Acs and Varga 2002, p.141). By comparison Molina and Kinder (2000) identify a range of attributes, properties or components within an innovation system that may be common to all systems but are likely to differ in terms of geography and thereby provide the basis for distinctiveness at a given (and by inference, national) spatial level. Nelson (1993) and Lundvall (1992) have identified broadly similar elements which could be contributors to ‘distinctiveness’ at the national level:

- Firms’ structures, inter-firm relationships and industry-university relationships
- National education systems, including the nation’s systems of university research and public laboratories
- Nations’ other public infrastructure, laws, their financial institutions, and their general economic ambience
- Governments’ educational and macroeconomic policies and programmes bearing explicitly on science and technology.

SI’s are perceived to draw on different mixtures of these elements and this may be dependent on historical considerations of culture, language and the timing of industrialisation.

Given the above descriptions of SI’s and the scope for co-existing pluralist views, it is important to seek some form of common ground within the study of SI’s. Edquist does this by setting out a number of common characteristics that SI’s study. His overview emphasises key issues associated with the study of each characteristic **Table 1**.

Table 1: Edquist's Nine Common Characteristics of SI's

Characteristic	Overview
Innovation and learning at the centre	Acknowledges different interpretations of innovation. The process involves “producing new knowledge or combining existing knowledge” and “transforming this into economically significant products and processes”. Learning can encompass both formal and informal processes. “Many different actors and agents in the system of innovation are involved in learning processes”. Edquist concludes that it is vital to “analyse the knowledge and learning aspects of innovation”
Holistic and interdisciplinary	The SI approach encompasses a wide array of the determinants of innovation, through a variety of lenses – spatial, sectoral (and by implication, technological). This constitutes a much wider definition than formal R&D processes. This generosity of scope creates some methodological issues for the study of innovation systems and an approach centred on the research of sub-systems is not only not uncommon but may be necessary.
Historical perspective	Given the time lag involved in the appearance of an economic impact due to an innovation, a historical perspective is often stressed, for example, case studies in Nelson (1993) use this approach. Often innovations are anchored in the country's natural resources, and Edquist (p. 19) observes the role of technology policy as an “engine for ‘liberating’ a country's system of innovation from its natural resource base”. Institutions and organisations may also be historically framed, and the level of dynamism within a system may be assessed over time.
Differences between systems and non-optimality	The systems of innovation can vary from country to country, region to region and sector to sector. The role of similar actors may vary from location to location as do “legal systems, norms and values (p. 19). Edquist explains that “in the systems of innovation approach the differences between the various systems are stressed and focused upon rather than abstracted from”. Given that there is no reckonable “optimal” system, then no comparison can be made with an ideal system, leaving only comparisons with other systems.
Emphasis on interdependence and non-linearity	Here the systems approach is emphasised – a variety of interactions of the elements (actors) within the system is possible. “interdependence and interaction between the elements in the system is one of the most important characteristics (of the systems of innovation approach)”. These relationships are complex and non-linear. This creates one of the main challenges of capturing these interdependencies. Edquist goes on to discuss the issue of demand as a determinant of innovation which links to the Porter (1990) framework for establishing competitive advantage for home industries.

Encompasses product technologies and organisational innovations	The argument here is that organisational innovation can also contribute to economic growth and employment in addition to the accepted contribution of product innovation. Organisational change is an important source of enhanced productivity, is linked to technological change in that it often enables the implementation of technological change and that technologies are “socially shaped” and therefore influenced by the form of the organisation. In arguing that the SI approach can encompass both the organisational and technological perspective, Edquist acknowledges that their determinants and circumstances may differ from one another.
Institutions are central	A number of workers have emphasised the centrality of institutions to the SI approach (including Lundvall, 1992). The lack of consistency between authors, however, on the meaning of the term ‘institution’ does create some issues of ambiguity and differing interpretations. This clearly demands a clarification of the way in which various authors use the term. Edquist also points out that institutions, because of their longevity, may also in some circumstances be potential barriers to innovation.
Conceptually diffuse	Building on the previous issue of ambiguity, Edquist states that there are additional conceptual problems and differences of approach evident in the work of a number of authors. The issue of boundaries to the system is clear– “there is simply no given demarcation between a system and its surrounding context” (p.27). This emphasises the need to identify and focus on core elements and their interrelationships.
Conceptual frameworks rather than formal theories	“The systems of innovation approach is not a formal theory” (p.28) “the most it does in this direction is to provide a basis for the formulation of conjectures”. There is a need to raise the “theoretical status of the approach and to making it more formal, rigorous, and coherent” (p.29).

**Source: Edquist (1997) ‘Systems of Innovation: technologies, institutions and organisations’”pp. 15-29 (specific page numbers given in brackets within the table)**

### **Challenges to the innovation systems approach**

Some areas of relative neglect in the SI approach can be distilled. These include issues relating to the performance of SIs, a theme is taken up by Niosi (2002) in respect of NSIs. De la Mothe and Paquet (1998) sum up much of the richness and frustration in the study of SI’s revealing the range of approaches by authors. The considerable effort to date has yet to crystallize in the form of a “definitive template for modelling the innovation process and local/regional dynamics in a knowledge-based economy” (de la Mothe and Paquet); this supports Edquist’s (1997) review of common characteristics in the study of SI’s.

Problems of terminology and vocabulary pervade the field. However, one of the strengths SI studies is their flexibility to accommodate different levels of analysis, but this is also a weakness when it comes to developing a formal theory.

Services seem to be a neglected aspect of the SI (Howells 2000) a view confirmed by the lack of mention of 'services' in the index pages of many key texts concerned with the SI studies, Edquist (1997) and Nelson (1993) being prime examples. Given the growing importance of knowledge-based economies services should be an important component of SI. Howells examines services in the context of SSI's only and sets out a typology of 'technology innovation intensity'. Howells highlights the hidden nature of services within the SI approach in describing elements such as education and training: this list could be extended to other actors such as government agencies, providers of finance, IPR, consultancies and also software systems designers. Howells concludes '...if we are to have successful national systems of innovation we need successful, *dynamic* systems of both nations *and* sectors. Efforts to study or create policy for such systems, need to recognise the intangible – but crucial – nature of innovation in many service sectors'.

The breadth to the SI approach is acknowledged and even encouraged (Johnson 1997) as a certain aspect of the economic process located in *almost* (emphasis added) every part of the economy. The latter would include production and distribution of knowledge as well as intended and unintended learning and innovation. The use of the word *almost* begs the question as to which part of the economy is *not* reached by the SI approach but we are not enlightened as to this issue.

To some authors (Cooke, 2001 and Iammarino, 2005) the SI has never shaken-off its national roots and may be seen to ignore sub-national variations in economic activity, and to avoid dealing with the complexity and heterogeneity with consequent issues such as multi-level governance, localised characteristics of institutions and the possibility of path dependency.

### **Summary of the innovation systems approach**

SI research, in a historical context, has many key authors: here the fundamental subset that comprise the research field has been explained briefly in ways the developing countries may note. Important variables that permeate SI research by different authors have been presented. The persistence of complexity, the dynamic nature of innovation systems and the lack of common ground present significant concerns when trying to apply SI research in a uniform and manageable way. By contrast, its general approach has been positively viewed by many authors who point to the 'richness' of the output and the descriptive nature of findings.

The dynamic nature of SI's adds to their complexity. Freeman and Soete (1999) illustrate the dynamic nature of NSIs over time arguing that the sources of this change lie in institutional and technical change, and in differing modes of 'importing, improving, developing and diffusing new technologies, products and processes'.

The lack of a unifying model which could be applied to systems in different spatial, industrial or technological milieu's, sustains rather than reduces the complexity of the topic. What is clear is that SI's are complex and this complexity makes it worthy of study.

### **Geography of innovation (GI)**

Variation in economic wealth and economic output is not evenly distributed in space; this is the central issue in the geographic imperative in innovation. The heterogeneity in

distribution and observable patterns of distribution has to be explained by the processes which are deemed to generate such patterns (Lloyd and Dicken, 1977). It is therefore the spatial dimension, and more specifically the spatial arrangement and agglomeration of economic activity, which is at the core of the GI.

Berry (1964) declaimed “the geographical point of view is spatial... the integrating concepts and processes of the geographer relate to spatial arrangements and distributions, to spatial integration, to spatial interactions and organization, and to spatial processes”. Two distinctive and contrasting explanations of the geographical agglomeration of economic activities have been proposed: the ‘new economic geography’ and the ‘new industrial geography’.

The ‘new economic geography’ of Krugman (1991) views the reasons for agglomeration to lie primarily in reductions to transport costs and the achievement of economies of scale. These can be measured and can be modelled. Knowledge and innovation were recognised but viewed largely as intangibles.

The ‘new industrial geography’ encompasses ‘... innovation dynamics of regional agglomerations [studied] from non-mainstream economic, geographical and institutional-sociological points of view’ (Caniëls and Romijn 2003) Much of the empirical evidence to support this claim is built on case studies such as Silicon Valley, Route 128, and Italian SME industrial districts, all of which point to success as measured from their persistence. In this way innovation can be seen as a “partly territorial phenomenon” (Doloreux and Parto, 2005,). It needs to be remembered that these locations are the same as those used to support the notion of RSIs in the SI approach.

Piore and Sabel (1984) coined the phrase ‘flexible specialisation’ to encapsulate a strategy of permanent innovation: this was based on the failure of mass production systems to accommodate the needs of the increasingly heterogeneous demands of consumers. Flexible specialization relies on departure from the vertically integrated firm to one which can draw on flexible, multi-use internal resources (including equipment and skills) and a range of external resources. Externalisation is then claimed to initiate sets of users and producers which aggregate at the local level. The flexible specialisation thesis underpins a core concept of new industrial districts and innovative milieux. Tomaney (1994) considers the theory of flexible specialisation as a new form of working which is replacing ‘Taylorist’ and ‘Fordist’ patterns. Elements of flexible specialisation emphasise changing interactions between firms and between industry, and the state, suggesting a more systemic nature to these relationships.

Other changes to business processes, such as the development of just-in-time delivery systems and the persistence of localised transactions within firms and between firms, also means there must be some spatial limits to the feasibility of such activities. Thus, “in very general terms, the greater the substantive complexity, irregularity, uncertainty, unpredictability and uncodifiability of transactions, the greater their sensitivity to geographical distance” (Storper and Scott 1995). Any given local community is likely to demonstrate a mixture of geographical scales, that mirrors the different kinds of transactions in which it is engaged. They rebut the idea that globalisation lessens

geographical constraints and that new networks develop which exhibit the attributes of complexity, uncertainty and recurrence that are indicative of the need for localised transactions. These centres are 'natural economic zones' in a borderless world in which "...what matters is that each region [or] state posses, in one or another combination, the essential ingredients for participation in the global economy" (Ohmae 1995) reinforcing the interconnection and linking activities in the new industrial geographies (Simmie (2005).

The *manifestation* of spatially bounded sets of economic actors are modelled as 'new industrial districts', 'innovative milieu' 'local production systems', 'learning regions' and clusters'. These are the predominantly considered to be the enduring 'territorial innovation models' (Moulaert and Sekia, 2003). As has previously been discussed, RSIs also form part of this suite in the review by these authors.

## **Territorial innovation models**

### ***New Industrial Districts***

Marshall was the first to coin the phrase 'industrial district' a notion that was taken up by others (Moulaert and Sekia (2003), Bagnasco (1977)) as the start of the modern industrial district school while. Again others (Simmie (2005), Becattini (1990)) identified these localised production systems that exhibit a distributed division of work in which clusters of small firms are perceived to develop greater factor productivity than large firms. The agglomeration is said to be due to dynamic spatial externalities (Capello 2002); this is then a local district focus, which is also being applied now to cities/urban areas. The concept is dynamic and has become attractive to policy makers seeking to pursue an agenda of small firm growth and development.

### **Innovative Milieu**

Moulaert and Sekia (2003), and Simmie (2005) trace the beginnings of the industrial district thesis to Groupement Europeen des Milieux Innovateurs (GREMI) with an emphasis on the incubation of innovations. Milieu is seen to offer a reduced uncertainty associated with innovation emphasising trust, cooperative learning and networking skills as essential ingredients in sustaining incubation. Geographically, these traits are enhanced by face-to-face contact between actors and thus close proximity is required for these conditions to flourish.

### **Learning Region**

The notion of a learning region that '...integrates innovation ..... institutional evolutionary economics, learning processes, and the specificity of regional institutional dynamics' has been described (Moulaert and Sekia 2003) while Martin (1999) describes them as 'area-based networks'.

Convergence between innovation studies and economic geography (Morgan 1997) presents a paradigm for the learning region, drawing on innovation as an explanation of uneven regional development and adding a spatial factor when considering issues of technological change. In particular Morgan (*ibid*) points to the work of Storper (1995) when seeking to explain the important role of regions (and therefore locally confined economic activity) at a time when globalisation (placeless economic activity) was deemed to be evident. Moulaert and Sekia (*ibid*) conclude that by adding to the model:

- Localised input-output traded interdependencies
- Labour markets, regional conventions, norms and values
- Public or semi-public institutions

as enablers of local learning puts the region as a key and necessary element in the 'supply architecture' for learning and innovation". In this sense Boekema, Morgan, Bakkers and Rutten (2000) talk of the learning region as a paradigm rather than a theory, and one which embraces a range of theories with a common emphasis on the learning process, a focus attractive to policy makers given that regions may have specific interest in their own economies.

Cooke and Morgan (1998) describe the shift of the social interaction between firms towards more collaborative and co-operative arrangements via networks against a background of technological globalization. When clustering involves multinational enterprises, "...the key conclusion was that, as economic coordination becomes increasingly *globalised*, the key interactions among firms in specific industry clusters becomes *regionalised*" (Cooke and Morgan 1998).

### Clusters

The literature on clusters proliferated in the 1990s. Some of the debate was controversial, as, despite claims from some authors (Martin and Sunley, (2003), Maskell and Kebir, (2005)), the construct lacks clear theoretical underpinning. Nevertheless the concept has attracted the attention of policy makers wishing to emulate perceived well-performing clusters. Despite this interest the concept remained fuzzy (Martin and Sunley, 2003), which may be due to the phenomenon being perceived as lacking an analytical 'family' for its investigation (Moulearet and Sekia, 2003).

There is a range of definitions of 'clusters' (Martin and Sunley (*ibid*)). Some common ground lies in the terms 'proximity', 'closeness', 'concentration of firms' coupled with 'links', 'interdependence' and 'interconnections' between firms, often of a transactional or supply chain nature. Disparities in the definitions extend to the 'industry' and whether the industry is 'common' or 'related' or in a similar 'field'. Some definitions describe the consequences of clusters in respect of the firms having "greater competitiveness". Martin and Sunley (*ibid*) bring these issues into focus when they consider the problems of boundary definitions for the geographical limits to clusters and the industrial makeup of clusters.

Porter is primarily concerned with the 'competitiveness' of the cluster and draws on his 'diamond' framework of national competitive advantage to explain this sub-national phenomenon. R&D spillovers occur in the diffusion of innovations, learning effects and networking arguing that "...the diffusion of new technological processes may occur faster in geographical areas where the density of sources of knowledge about such technologies is higher" (Baptista 2001). The local dimension of networks informs and promotes diffusion and the implication from this is that intensity of diffusion is likely to be stronger at the local level.

The theoretical mechanisms of cluster formation offered vary. Gordon and McCann (2001) present arguments for cluster existence from the perspectives of pure agglomeration, the creation of industrial-complexes, and social networks. Maskell (2001) points to a knowledge-based theory of geographical clustering. Amin and Cohendet (2003) consider that aspects of tacit or codified knowledge may not be sufficient to explain local clustering. Here they offer “relational aspects of community” as an explanation - in effect approaching what could be considered as a sociological perspective on cluster formation and sustenance mechanisms. Breschi and Malerba (2001), when discussing the cluster concept, talk of the “accumulation of capability in key actors”. In this respect the growth of successful, key firms is essential in the development of the cluster.

The debate on ‘firm strategy and structure’ (Porter, 1990) considers clusters of enterprises allied to supporting institutions, an approach that still leaves room for competition between firms, but also draws on elements of the locations of firms that are critical to their success. Best (2001) discusses issues of regional specialisation and innovation processes which are seen as important elements of cluster dynamics. Thus there is some evidence of systems thinking being applied to clusters by some authors.

The benefits of a systems approach (via clustering) is delivered succinctly by Acs and Varga (2002) when they compare this model of economic development with more traditional, vertically integrated nature of firms. The systems approach provides three distinctive competitive advantages: increased productivity via lower transaction costs, increased innovation (dependent on “interactive knowledge exchange between a variety of knowledge actors”), and the creation of conditions conducive to new business formation (“mentoring, role-model provision, learning, and communication gains”). Vertical de-integration is therefore seen as a means of achieving competitive advantage at the firm level and has added benefits for government in respect of new business formation and, perhaps, reinforcement of distinctiveness, appearing to echo the views of Piore and Sable (1984) in respect of fundamental changes to divisions of work in modern economies.

Although the literature provides good coverage of what is called ‘regional cluster’ development (Enright, 1998) it is not always clear why certain cluster activity arises in specific locations. Enright makes a strong claim for the “growth and persistence of regional clusters result[ing] from the development of pressures, incentives and capabilities to innovate provided by the local environment”.

### **Agglomeration economies**

Agglomeration refers to the co-location of economic activities. It is based on the argument that increasing returns, economies of scale and imperfect competition are far more important than constant returns, perfect competition and comparative advantage in causing trade and specialisation. The market, technological and other externalities underpinning these increasing returns “... are not international or even national in scope, but arise through a process of regional or local economic agglomeration” Martin (1999). However, “Agglomeration economies have always been interpreted as the economic explanation of efficiency of firms located in urban areas” (Capello 2002). Linkages, a “rich array” of them, between firms are clearly (de la Mothe and Paquet 1998). There is a feeling that there is more to clustering than simply a driving force of agglomeration economies.



### **Network theory**

Several authors including Coombs, Richards, Saviotti and Walsh (1996), and Robertson and Langlois (1995) debate the degree of “connectedness” and the merits of networks as an alternative institutional form to vertical integration. These authors develop a typology of organisational forms based on the degree of ownership integration and the degree of co-ordination integration. Richardson (1972) is credited with the origin of the term ‘network’ in the context of the co-ordination of inter-firm activities providing an image of industry as a “dense network of co-operation and affiliation by which firms are inter-related”.

The second European Community Innovation Survey (Tether, 2002) reported that firms engaged in R&D could be considered as seeking “higher level innovations” and are more likely to engage in co-operative innovation. Tether summarises the recorded history of co-operative arrangements for innovation over some 50 years and to have received significant academic attention in the last two decades of the 20<sup>th</sup> century. The concepts of ‘distributed forms of innovation’ and innovation networks sought to describe mechanisms and deliver explanations for the motivation of firms looking outside their traditional boundaries, both within and outside, the supply-chain. Tether draws out some other characteristics of firms engaged in co-operative innovation: these reflect the size of the firm, its age and the type of linkages formed and whether these are suppliers, customers, universities and other actors, distinguishing between service and manufacturing sectors. Networks have significant implications for innovative activity at all spatial levels and particularly at localised levels. However, Simmie (2005) has questioned the relevance of ‘networked production systems’ to high tech sectors, so the extent to which this perspective can be rolled out as a universal explanation for distributed innovation remains unresolved.

Embeddedness is a key concept in industrial geography. Simmie (2005) links this to institution's multiple institutional and social arrangements creating ‘thick’ supporting phenomena for innovation and endogenous economic growth that Howells (2002) has drawn attention to knowledge spillovers as an important phenomenon in geography in ‘shaping knowledge interactions’ though Martin (1999) claims that the “localised nature of technological spillovers” had yet to make a significant impact on ‘new economic geography’. Mathematical modelling of economic geography has been criticised (Martin 1999), for its approach to increasing returns and externalities in spatial agglomeration, as it neglects other factors that influence the geographical distribution of economic activity, including:

- The role of the local infrastructure
- Local institutions
- State spending and intervention
- Regulatory arrangements
- Foreign investment and disinvestments
- Global competition.

Martin seems to make a plea for an SI approach with regional, national and international influences.

Breschi and Lissoni (2001) comment that the concept of knowledge spillovers has been stretched from its original meaning of 'knowledge externalities' while Caniëls and Romijn (2003) point to the regional (meso) level of analysis common to both champions and sceptics in the localised knowledge spillover debate.

Howells (2002) sets out five key aspects to knowledge and its links with geography:

- How it is developed within social, cultural and economic conditions (and these may be strongly place-dependent)
- Levels and forms of interaction (may be constrained by distance)
- Access to externally acquired information (may incur scanning costs, which may be spatially bounded)
- Learning which is also influenced by social and economic conditions (may be locationally-specific)
- Interpretation of information (which may be influenced by past experience and shaped by geography).

Proximity is an essential enabler of knowledge transfer that is strongly linked to the concept of knowledge spillover. The concept of proximity is, to economic geographers, one of the 'softer sources of innovation' as opposed to the role of institutional economics (Amin and Thrift (2000)). Proximity may lower the costs of knowledge transmission thus co-located firms will benefit in many ways.

To Boschma (2005) the combination of proximity and innovation offers a range of typologies for the former:

- Cognitive
- Organisational
- Social
- Institutional
- Geographical

Boschma concludes that "...geographical proximity per se is neither a necessary nor a sufficient condition for learning to take place. Nevertheless it facilitates interactive learning, most likely by strengthening the other dimensions of proximity: Boschma also sees the possibility of negative effects resulting from 'lock-in' arising from a defined location.

Learning is related to an increased interest in tacit knowledge and the spatial significance of transmitting such knowledge, with a corresponding requirement for proximity (Morgan 2004). In this respect, Storper, Maskell, Gertler explain clustering of knowledge intensive industries on the basis of Polanyis' (1966) distinction between 'explicit' and tacit knowledge.

### **Comparison of IS and G of I approaches**

Comparison of two significant strands of literature on innovation, the SI and GI approaches, is not straightforward. Each strand is significant in its own right. The necessarily brief review has demonstrated enduring concerns regarding not only which construct within each approach is most useful (that is; national, regional, sectoral or technological within the SI approach or learning region, clusters, industrial district or innovative milieu within the GI

approach), but has also highlighted persistent diverging opinions in fundamental mechanisms underpinning the interaction of actors, regardless of approach. The links between the respective commonalities of the SI and GI approaches are not fully delivered. There is clear evidence in innovation studies of a multiplicity of languages and a lack of a shared language (Morgan, 2004), and a lack of conceptual clarity (Markusen, 2003).

As Edquist (1997) points out “the systems of innovation approach is compatible with the notion that processes of innovation are, to a large extent, characterised by interactive learning. It could be argued that some kind of systems of innovation approach is inherent to any perspective that sees the process of innovation as interactive; interactivity paves the way for a systematic approach”. So the SI approach could, from one perspective, be seen to accommodate all GI approaches, models and frameworks.

The range of terminology, and the looseness with which it is deployed, is a weakness of both approaches. For example ‘knowledge spillovers’ are seen as ‘stylised fact’ (Bresch and Lissoni, 2001) along with issues of ‘embeddedness’ and the role of tacit knowledge (Breschi and Lissoni, 2001). If the core concepts are used variably, and that these may have been stretched to accommodate ‘add-on’ issues, then the ambiguity and fuzziness surrounding these conceptual building blocks does not help to firm up the respective claims to a solid theoretical position in either the SI or GI approach. Of most concern in the analysis of innovation, innovation itself, may be [is] subject to a plurality of definitions (Chang and Chen, 2004) and misunderstanding.

It seems the SI approach to geography is “taken for granted” while the GI approach may also be guilty of taking for granted the role of geographical proximity as a given mechanism for the enhancement of innovation. Some degree of integration of the two approaches is becoming evident yet issues remain to be resolved. The following areas of concern, or challenges, to the study of innovation via the SI and GI approach may be distilled:

- **The unit of analysis:** The SI approach has emerged as “accepted wisdom” in the study of innovation. There is evidence from some authors (Edquist, 2001 and Carlsson, 2002) of the requirement to re-visit (or perhaps for the first time, to more properly define) the fundamental elements of SI’s based on the application of systems theory. The SI concept does not consider the role of services, that is made explicit, but is based heavily on a manufacturing-centric base. The study of innovation using the GI concept uses a different geographical unit of analysis. Consequently, there is a degree of fragmentation in the study of innovation in which a range of authors use a variety of observations for the presence or absence of one or more spatial boundaries
- **Definition of boundaries:** The choice of boundaries remains elusive to both concepts: this may be less problematic for SI’s, it remains of significant importance to GI. It could be argued that the creation of boundaries is not essential for both approaches. The idea of the system or space demonstrating the capability to reach out to new systems or locations is evident and may mean that drawing geographic boundaries *per se* is neither valid nor desirable. Links between global, national, local are not fully explained or understood in either SI or GI.

Treatment of boundaries in both approaches is both acknowledged and ignored. In the GI approach it could be assumed that establishing the geographical boundary to the approach would be of paramount importance, yet some authors, particularly Porter (1998) use variable geographic boundaries in different examples (Martin and Sunley, 2003). To Porter drawing boundaries is "... a creative process informed by understanding the most important linkages and complementarities across industries and institutions" (Porter 1998): which resonates with the Edquist's approach when considering SI boundaries. It also offers flexibility in deciding boundaries on the basis of the object of the study.

So is the SI metaphor boundary-transcending or boundary-irrelevant? Various authors claim that where the boundaries are drawn depends on circumstances, e.g. the technological and market requirements, the capabilities of various agents and the degree of interdependence among agents (Edquist (1997) Carlsson and Stakiewicz (1995)). Does defining the boundaries define the system? Perhaps the notion of porous and permeable boundaries is relevant and readily absorbed by the SI metaphor but remains a distinct aspect in the GI metaphor. In the latter boundaries or edges to the space are evident and can be established. In effect the observation that innovation occurs within distinctive geographies is fundamental to the GI metaphor. However, geography has, been largely subsumed or taken for granted in the SI metaphor. Cooke (2001) points to the "blind spot" about regions in national systems of innovation and its failure to "schematise systems typologically" with a preponderance to present systems as unique.

To Edquist SI's may be supranational, national or sub-national (regional, local) while being simultaneously sectoral within any of these geographical boundaries. There are many potential permutations. Whether a system of innovation should be spatially or sectorally delimited depends on the object of study which has the connotation of the Mad Hatter's argument over meaning. All this suggests that the SI metaphor can mean whatever one wants it to (more kindly it is infinitely adaptable) or that the process of study and the objectives of the study are co-determinate. The SI approach is able to adopt both geographic specificity and geographic blindness as required: this is reinforced by Breschi and Malerba (1997) in their discussion of "technological regimes" though their claim that the sectoral innovation systems (SSI) metaphor "comes to grips with the geographical boundaries of innovative activities" is somewhat over-stated.

The nature of interaction: What is missing from both the SI and GI literature is an explanation (and even consideration) of the activities, motivations and decisions made by firms. Given that firms are the prime sources of economic activity [and the information on which the two metaphors are based] in any space or system it is appropriate and overdue that the role of firms becomes more. As Markusen (2003) claims '...in most regional accounts, networks are presented generically and extolled without examining the motivations of participants... ...or gauging the durability or fragility of relationships among members or gauging the durability or fragility of relationships'. Lundvall (2005) comments that 'The focus on interactive learning .... may lead to an underestimation of the conflicts over income and power, which are also connected to the innovation process'.

Similarly, Martin and Sunley (2003) comment that "In too many accounts. 'territorial learning' is privileged, yet what this process actually is remains ambiguous and its interactions with firm-based learning are left completely unexamined".

The SI approach does not fully address the issues of spatial agglomeration, neither does it reject them. If path dependency is a real phenomenon, then the institutional dimension of the SI approach could be seen as the cause/mechanism by which it comes about. The GI approach could look to clustering as a means of creating the conditions by which path dependency is promulgated and created.

- **The role of institutions:** Fischer (2001) emphasizes that in the SI metaphor economic performance requires interaction between actors [between businesses and between businesses, and the public sector] in order to create knowledge and disseminate it for improved economic performance firms both contribute to and use knowledge [a blindly obvious conclusion!]. The emphasis on institutions differentiates the SI metaphor from that of networks. Here the use of the term ‘institution’ abstractly conveys ideas of socially inherited habits, conventions including regulation, values and routines
- **The processes of knowledge creation and transfer:** There is a degree of ‘taken for granted-ness’ in processes which are deemed to underpin innovation. The argument can be directed to both SI and GI metaphors. For example, Howells (2002) claims that “most of the metrics *imply* the imparting of knowledge, but do not actually measure it” [original emphasis].

The concept of ‘collective learning’ was given a geographic connotation by Martin and Sunley (2003) in referring to ‘territorial learning’. The importance of geography in promoting knowledge transfer and learning are considered by Amin and Cohendet (2003) to be “The ‘secret’... ..of local clusters may reside much more in the relational aspects of community (i.e. as one spatial form of knowing through communities) than on balance between tacit and codified knowledge”.

In a further comment related to collective learning, Breschi (2000) claimed that “while innovative activities tend *in general* to agglomerate within specific locations, the intensity of the geographical concentration and the spatial organization of the innovative processes may differ remarkably *across sectors*” [original emphasis]; this sectoral emphasis was consistent with the same author’s view of the SI perspective

- **The performance of the metaphors:** Given that both the SI and GI approaches may be observed independently, there tends to be limited consideration of the performance of systems. However, in a regional sense there is some consideration of ‘regional competitiveness’. There is no consideration of maximization or optimization of the system. Comparative analysis was seen to be sufficient, perhaps while addressing some considerations of gaps or missing or weak elements. There is still scope for the benefits of SI and GI approaches to be realized and of being achieved, and being seen to be achieved.

Emergence and dynamics: the extent to which stages of development are evident?: These are problematic issues associated with the current development of the SI metaphor that have been highlighted. Edquist (1997) looks positively on the matter commenting that “... the conceptual ambiguity of the systems of innovation approach is a strength in providing

openness and flexibility that make room for competing perspectives and solutions...” “[we/authors] are certainly aware that conceptual ‘pluralism’ remains in many respects.” Many authors also acknowledge some of the broad ontological issues in the study of systems: “Technological systems are not identifiable with simple means” (Onias and Malecki 2002) and “all descriptions of systems are simplifications “ (Edquist 2001).

One possible approach when considering the relevance of each [SI and GI] metaphor is to consider the ability of each to treat, react or respond to issues such as path dependence. Path dependence (and thereby innovation) is influenced by the past and a set of initial conditions relating to the genesis of the technology. In other words it is also important to consider matters of history as a determinant to the dynamic capabilities of the system and the possibility of path dependency as a means of locking-in firms and actors within the system.

- **Arguments for a unity within approaches:** Given the different emphases in the innovation systems literature, how do these apparently different metaphors interact? There have been attempts to link some of metaphors directly; for example Molina and Kinder (2000) successfully link Lundvall’s NSI elements with Porter’s diamond of competitiveness concerning industrial clusters.

Part of the difficulty in distinguishing between the SI metaphor and the geographic approach is that overlaps remain evident. Andersen, Lundvall and Sornn-Friese (2002) discuss papers by Freeman (2002) and Lundvall et al (2002) that “analyse innovation systems as spatial and economic-political entities”. Moulaert and Sekia (2003), in their review of territorial innovation models, identify SI along with economies of agglomeration, endogenous development, evolution and learning, network organization and governance as evidence of “semantic unity” in the set of territorial innovation models.

Moulaert and Sekia (2003) in the context of their concept of Territorial Innovation models claim that “the apparent semantic uniformity and the shared theoretical sources hide a pluralism of interpretations of innovation dynamics and their theoretical inspirations”. Their suggestion for improvement lies in improved definitions of market-led innovation which would then prompt re-examination of its “ingredients” and a clear separation of innovation into distinctive camps. Firstly, “normative innovation strategies” and secondly, and less innovative in their view, “development strategies”. They also consider re-visiting and thus re-defining the epistemological boundaries with a resulting expansion of the context to incorporate “...a multi-dimensional view of innovation, economic dynamics and community governance”. The latter appears to be an expanded social and community perspective, but with a distinctly local scope, which, in their own admission, adopts elements of the concepts of industrial districts, milieu innovator and learning regions.

MacKinnon, Cumbers and Chapman (2002) point to a number of overlapping concepts within the field of economic geography and regional science, namely ‘relational assets’, ‘learning regions’, ‘social capital’, ‘institutional thickness’ and ‘associational economies’. Onias and Malecki (2002) proposed the concept of “Spatial Innovation Systems”. Its distinguishing characteristic was the ‘external relations of actors’ that draws on the technological systems approach and appears to draw on technological trajectories (Dosi

1982). Their approach draws on the need for diversity in industries in the given space plus also requires relationships between these different industries which are actual [innovative] relationships. Links with diverse, specialized and distant regions were also permitted within the SSI approach, thus extra-regional partners are important to sustain diversified technological capabilities. Nooteboom (2004) summarizes the view from Oinas and Malecki that “we should think not so much in terms of knowledge at a location, but of movements of knowledge across space, within and between regions”.

A number of attempts to transcend the ‘traditional’ units of analysis are evident (Geels, 2004) with an approach to extend sectoral systems of innovation to socio-technical systems in the sense of spatial systems of innovation (Iammarino 2005).

Arguments for a multiplicity of approaches: Both SI and GI metaphors go some way to explaining the distinctiveness and uniqueness which may be observed in innovation metaphors or attributed to them via empirical studies. For example, if a network involves a novel combination of localised capabilities, institutional capability, natural and built endowments, resources, skills, firms, sectors, industries, life cycle and technology trajectories then this is likely to influence the performance of the space or the system. These unique combinations may be impossible to replicate in other spaces or systems.

Part of the problem in attempting to identify common characteristics in innovation processes to produce a general and transferable model applicable to many other areas, may lie in the attraction of the more “successful” examples of localised innovation. It may be that the success of these examples is down to the distinctiveness of relationships between agents rather than some universal, underlying approach. Doloreux and Parto (2005) concluded that “there is no single model that is able to generalise the dynamics of successful regional innovation systems”. There is no one single type of industrial district or agglomeration; rather, such districts differ considerably in origin, economic structure, social regulation, institutional organisation and degree of political intervention (Martin (1999) in summarizing the work of Markusen (1996)). Similarly, Oinas and Malecki (2002) concluded that “much of the thinking on innovation systems in economic geography and regional science is centred on localities or regions”. These authors conclude that different places should be viewed as manifesting systems, industrial, technological, socio-cultural, or otherwise, but that a contrasting metaphor may be that innovation systems are worked out differently in space. The authors go on to suggest that these systems exhibit different spatial configurations; that they may originate in one place, but often they spread beyond local, regional, and even national borders.

## Conclusions

The review has sought to assemble, compare and contrast the SI and GI approaches to the study of innovation. Overlap is evident between them. While the persistence of authors to plough their own furrow, the use of a variety of terminology for similar processes, mechanisms or outcomes creates persistent ambiguity and inconsistency in the use of these terms. It could be argued that each approach exhibits a degree of its own ‘path dependency’ with a corresponding ‘lock-in’ effect for individual authors, with resulting lower levels of progress in the realization or firmness to the concepts which have been categorised as metaphors rather than ‘theories’.

The range of models and frameworks presented are often rooted in the core science of their author and believer; this stems from discipline-specific [which are fundamentally drawn from evolutionary economics or economic geography] perspectives. Empirical evidence is presented by these authors to support their various theories [better called subjective metaphors] so it appears that all of these positions may be sustained when used to address or explain specific cases or circumstances. The extent to which these metaphors can be rolled out for a wide of circumstances remains elusive. Some reflection on the methodologies used to illustrate and substantiate the use of a given metaphor needs to be considered systematically; this is important as the selection of methodology and scope of empirical work underpinning each metaphor may have a significant bearing on the robustness and rigour of the approach, and may limit transferability, raising questions about wider deployment.

Some authors, notably from the 'geographic' camp (Martin, 1999, Amin and Thrift, 2000 and Morgan, 2004) are keen to see the re-emergence of geography within evolutionary approaches. Indeed these authors also recognize the importance of cross-disciplinary analysis to provide greater conceptual clarity. De la Mothe and Paquet (1998) also concur with the need to develop analytical frameworks that explore the various processes of learning, coordination, proximity and entrepreneurship. An effort is needed to bring these partial views together to produce a broad interpretive framework that is capable of guiding a future research agenda. There is a similar 'historic' resonance with Lloyd and Dicken (1977) when they consider that the understanding of the reality of spatial distribution must allow and embrace interaction with other fields, social scientists, political scientists, sociologists, economists and others.



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