Institute for Alternative Futures

The Future of Science & Technology and Pro-Poor Applications

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Foresight for Smart Globalization: Accelerating & Enhancing Pro-Poor Development Opportunities Workshop

March 16-20, 2009
Rockefeller Bellagio Conference Center

Institute for Alternative Futures

The Rockefeller Foundation

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Contents

1. Introduction

"Foresight involves systematic attempts to look into the future of science, technology, society and the economy, and their interactions, in order to promote social, economic and environmental benefit."[1]

The above statement is the definition of foresight as adopted by the APEC Center for Technology Foresight since 1998. It is to be noted that *the future of science and technology* is clearly stated in this definition. Among the most important elements of the future that need to be assessed with foresight, arguably there must be sufficient attention paid to science and technology (S&T) as the significant driver or accelerator of change, for better or worst.

No one can definitively map the future, but the future possibilities can be explored in ways that are specifically intended to support decision-making. When looking at the complex issues of the future world, scenarios has often been used, as one of the most widely accepted *foresight tools,* to capture and assess the possible future alternatives. Scenario building is particularly useful in helping us to wrestle with the developments and behaviors that shape what the future may hold and prepare more effectively. It can often inspire individuals and organizations to play a more active role in shaping a better future for themselves, or even on a global scale.

This paper will review some future scenarios and relevant foresight works, starting from the general "big picture" global scenarios which include the greatest challenges and opportunities of the future world. Then the paper will examine some sectoral or thematic scenarios that relate science and technology to the global scenarios. It will go further to take a closer look into the scenarios for futures associated with, or directly describe the prospects of global science and technology, its changing paradigms, and questions that will shape changes in science and technology over the next 5 to 20 years. Finally, the focus will be given to envisioning the wide-range implications, potential intersections and cross-cutting impacts on poverty and development issues (Figure 1).

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[1] APEC CTF, *Introducing Foresight and APEC Center for Technology Foresight*, 2009

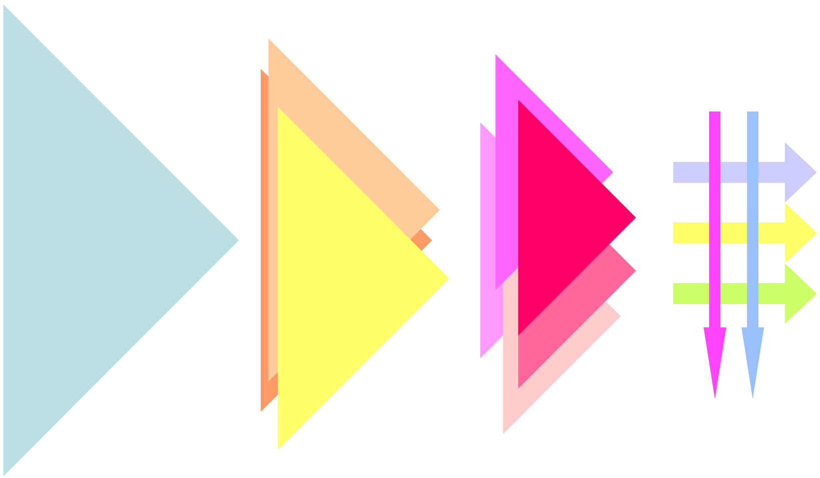


Figure 1: Logical Flow of Paper - from Landscape to Implications

2. The Changing Global Landscape and Alternative Scenarios

Some attempts have been made to project and build global scenarios to cast light on the context in which the world, the people, and organizations operate, to identify emerging challenges and to foster adaptability to change.

Generally in foresight studies five main groups of drivers (or driving forces) are identified:

- **S**ocial,
- **T**echnological,
- **E**conomical,
- **E**nvironmental,
- **P**olitical,

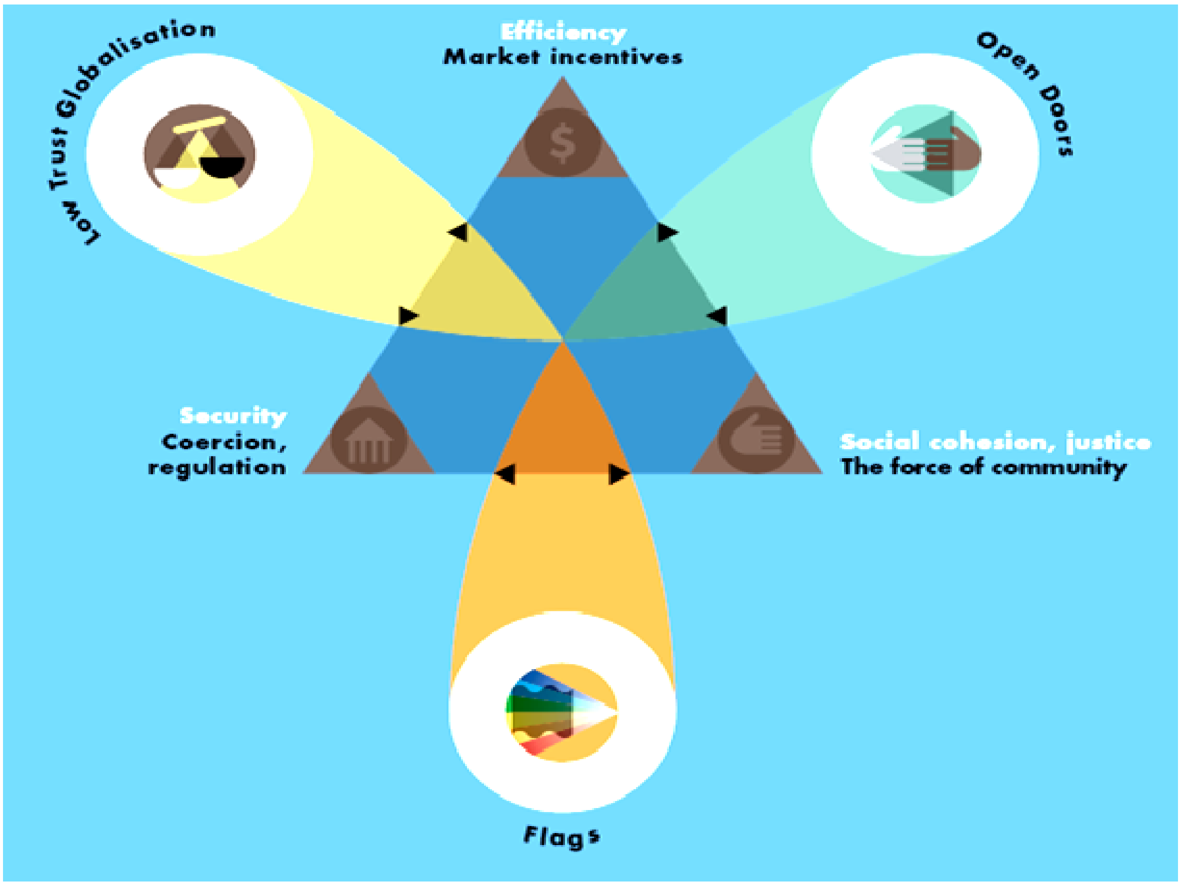
In accordance with the often used STEEP model, this paper will use the STEEP framework to examine some recent global scenarios and identify the future areas where science and technology could play significant role. We will start with Shell's scenario.

For almost four decades, the oil company Shell has developed scenarios to help review and assess its strategies. The company has also been publishing a number of “landscape”-type global scenarios. The *Shell Global Scenarios to 2025*[2], released in 2005, provided an analytical framework to help understand how the present day geo-political, economic, and social aspirations and forces are shaping our future. It explored how forces of market incentives, communities, and regulation or coercion by the state advance societies’ objectives of efficiency and growth, security and social cohesion. Societies typically aspire to all three objectives and those that are more successful find ways of achieving them in mutually reinforcing ways.

However, these forces can sometimes display elements of mutual exclusiveness – one cannot always be simultaneously freer, more secure and more socially cohesive – leading to difficult choices and trade-offs, particularly in the wake of sudden shocks such as 9/11 or Enron. Global Scenarios to 2025 explores the three dilemmas – a Trilemma – involved in the pursuit of these objectives.

The Trilemma Triangle (Figure 2) provides a map of relations and interactions among market participants, civil society and states. In particular, it examines the interplay of three complementary, but occasionally competing, objectives of efficiency, social cohesion and justice and security. Using this analytical framework Global Scenarios to 2025 developed three alternative scenarios – Low Trust Globalization, Flags and Open Doors – that capture the potential trade-offs facing society among these diverse, complex objectives in which two objectives dominate at the expense of the third.

[2] Shell, *Global Scenarios 2025,* 2005.



Source: *Shell Global Scenarios 2025*

Figure 2 The Trilemma Triangle

1. Low Trust Globalization: This is a "prove it to me" world, a skeptical world. The key words are compliance, compliance, compliance. It's about playing by the rules, and about being very aware of the diversity of jurisdictions that will come to you with their very different and often overlapping demands.
2. Flags: This is a "follow me" world, where people are dogmatic about their codes and courses. Although still interconnected with the rest of the world, people and communities feel a stronger need to express their own identity in terms of the group or nation to which they belong. It is a fragmented and polarized world.
3. Open Doors: This is a "know me" world, a world of trust: in global systems, and in globalization. It is pragmatic, proactive and co-operative world. People cooperate with others to deal with future problems, because it is the most efficient way to deal with them.

The difficulty of achieving a satisfactory balance among these goals is a source of challenge for decision makers – in business, government and society. The three scenarios analyze potential ways in which these trade-offs will be accomplished. They also recognize that this balance may be more difficult to strike in the immediate wake of crises that create new political imperatives and that these crisis responses can have persistent effects.

The Shell Global Scenario largely focused on the condition of *trust* in the global marketplace as influenced by future business environment. The Global Scenario is very useful in understanding the future world from corporate view point and the driving forces of the future particularly *social (S), economic (Ec) and political (P) drivers*, which continues from today. Importantly, it examined their interactions, and clearly illustrated how different implications of those interactions can play out on the behaviors of people and organizations within each scenario. However, it lacks in the dimension of natural environment (En), science and technological progresses (T), and the well-being of humanity as global challenges; we barely see any future for the poor in this scenario. Therefore it gave us an incomplete future landscape (at least for our purpose).

In contrast, the Millennium Project's work as reported in the *2008 State of the Future*[3] tried to provide insights that can help decision-makers and educators who fight against hopeless despair, blind confidence, and ignorant indifference to improve the prospects for humanity. Its report, published in its twelfth year of the project, is full of optimistic future of the world where advances in science, technology, education, economics, and management seem capable of making the world work far better than it does today.

The SOF set out to identify 15 Global Challenges and has been updating these challenges through Delphi process and environmental scanning since 1996. These challenges range from developmental to ethical challenges and, unlike the Shell Global Scenarios, they are mostly humanity challenges rather than business challenges. The 15 Challenges encompass all categories of future driving (or in many cases, pulling) forces, STEEP, and can be

[3] Jerome C. Glenn, Theodore J. Gordon and Elizabeth Florescu, *2008 State of the Future*, 2008.

categorized as shown in Table 1. For example, the changing status of women is a *Social* driver (Ctrl + click in each Challenge to jump to more details on the internet).

Table 1: The State of the Future 15 Global Challenges

Challenge	Category of Driving/Pulling Force				
	Societal	Technological	Economical	Environmental	Political
1. How can sustainable development be achieved for all while addressing global climate change?	✓		✓		
2. How can everyone have sufficient clean water without conflict?			✓	✓	
3. How can population growth and resources be brought into balance?	✓		✓	✓	
4. How can genuine democracy emerge from authoritarian regimes?					✓
5. How can policymaking be made more sensitive to global long-term perspectives?					✓
6. How can the global convergence of information and communications technologies work for everyone?		✓			
7. How can ethical market economies be encouraged to help reduce the gap between rich and poor?			✓		
8. How can the threat of new and reemerging diseases and immune micro-organisms be reduced?	✓		✓		
9. How can the capacity to decide be improved as the nature of work and institutions change?	✓				✓
10. How can shared values and new security strategies reduce ethnic conflicts, terrorism, and the use of weapons of mass destruction?	✓				✓
11. How can the changing status of women help improve the human condition?	✓				
12. How can transnational organized crime networks be stopped from becoming more powerful and sophisticated global enterprises?	✓		✓		✓
13. How can growing energy demands be met safely and efficiently?	✓		✓	✓	
14. How can scientific and technological breakthroughs be accelerated to improve the human condition?		✓			
15. How can ethical considerations become more routinely incorporated into global decisions?	✓				✓

Source: Analyzed using input from *the State of the Future 2008*

According to Table 1, most frequently the Challenges fall into the category of Social (S) and then Economical (En). There are only 2 Challenges with clear implication of science and technology, one in Challenge 6 *"How can the global convergence of information and communications technologies work for everyone?"* and Challenge 14 *"How can scientific and technological breakthroughs be accelerated to improve the human condition?".*

Where science and technology did receive some mentioning, the SOF 2008 believed that the acceleration of S&T innovations, improved communications among scientists, and future synergies among nanotechnology, biotechnology, information technology, and cognitive science will fundamentally change the prospects for civilization. We will come back to examine the details of future prospect of science and technology as seen in the SOF 2008 in the latter part of this paper.

To actually "measure" our future landscape, the SOF 2008 dedicated substantial effort in the *State of the Future Index (SOFI)* where it described and updated a measure of the 10-year outlook for the future based on the previous 20 years of historical data. It is constructed with key variables and forecasts that, in the aggregate, depict whether the future promises to be better or worse. A set of 29 variables was identified by an international panel of experts selected by the Millennium Project Nodes around the world during a study conducted in 2006–07. Participants were asked to rate the variables, give worst- and best-scenario estimates, suggest new variables to be included in the SOFI, and suggest sources that could provide at least 20 years of historical data.

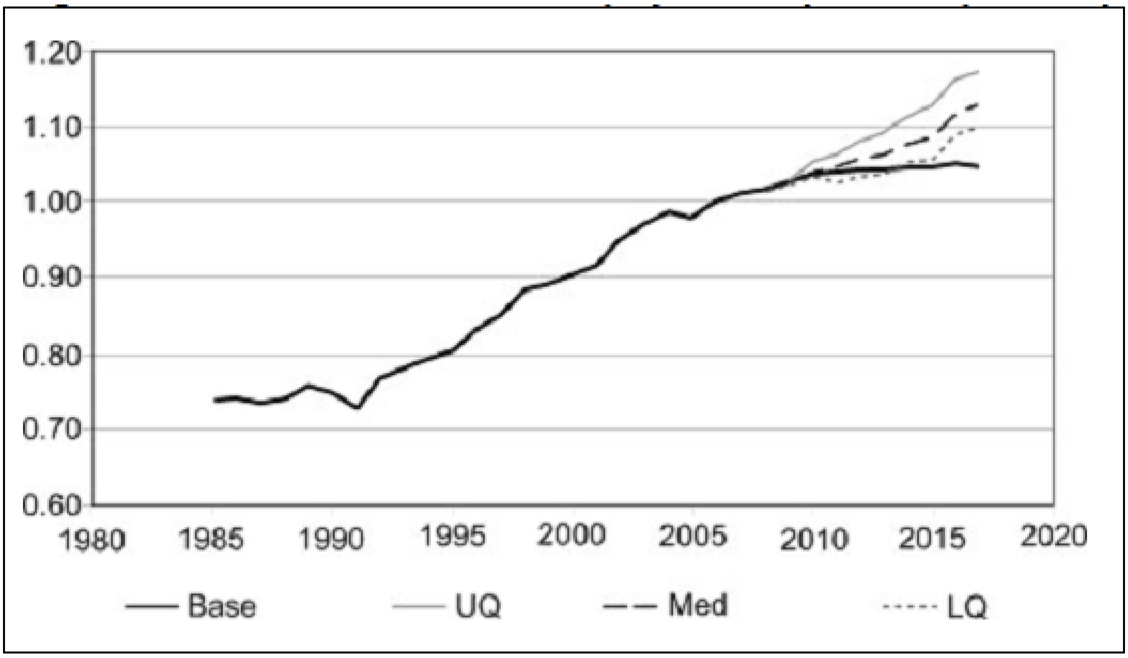
Assessing the world's key indicators over the past 20 years and projecting them for the next 10 gives the basis for a report card for humanity's future, showing where we are improving or worsening (Table 2).

Table 2: Areas where the world is improving vs. worsening.

Where we are improving:	Where we are worsening:
• Life expectancy	• CO_2 emissions
• Infant mortality	• Terrorism
• Literacy	• Corruption
• GDP/capita	• Global warming
• Conflict	• Voting population
• Internet users	• Unemployment

Source: Adapted from *the State of the Future 2008*

The global SOFI indicates that the future over the next 10 years is still getting better, although not as rapidly as it did over the past 20 years. The alternative projections are based on the potential occurrences of events that can alter the future trends.



Source: *State of the Future 2008*

Figure 3: State of the Future 2007 with alternative projections by trend impact analysis

A trend impact analysis (TIA) was also performed to examine the effect of events that might be important to the outcome of the SOFI. This analysis had the consequence of improving the forecasted SOFI so that the historical trends extended for the next decade (grey and dotted lines in Figure 3 – SOFI 2007 is the most updated data in the 2008 report).

Although the numbers are somewhat different, the 2007 SOFI curve shows the same general shape as the SOFI solutions of the past few years: relatively rapid growth since the mid-1980s, then a continued but slower growth into the next 10 years.

The *Science and Technology 2025 Global Scenarios* were included as part of the SOF 2008 and will be covered later in this paper. The scenarios provided the readers with some "what if" questions that are both optimistic and desperate such as:

- What if the world—led by the EU—pressured the U.S. and China to create a global energy R&D strategy with an Apollo-like goal to turn around greenhouse gas emissions in 10 years?
- What if governments declared increasing intelligence as a national educational goal?
- What if politicians campaigned on how to answer the 15 Global Challenges?
- What if we did not waste so much time and talent on trivia?

The SOF 2008 report concluded that *"After 12 years of the Millennium Project's global futures research, it is increasingly clear that the world has the resources to address our common challenges. Coherence and direction are lacking."* For example, climate change cannot be turned around without a global strategy. It becomes clear to the world in 2008 more than ever, that climate change is going to be one of the biggest challenges that threaten the very future existence of humankind and most other species on earth[4], that even the UNDP's Human Development Report 2007/2008 offered an unprecedented dedication to fighting climate change[5].

[4] See, for example, James Lovelock in *The Vanishing Face of Gaia: A Final Warning*, and http://www.reuters.com/article/homepageCrisis/idUSLP385741._CH_.2400

[5] UNDP, *Human Development Report 2007/2008, Fighting Climate Change: Human Solidarity in a Divided World*, 2008.

Our examination of the global future landscape has now more or less covered all the 5 areas of driving forces of the STEEP model, completed with the overview of what alternative futures and challenges are awaiting the world. From this overview, however, we can see the forest and possibly knowing little about the trees. While it is not possible to cover all the trees, we may examine some thematic scenarios that are relevant to science and technology – especially those themes in the areas of socioeconomic and environmental categories (S&T has been shown less promising in solving the problem in the category of political values and governance, comparatively), such as clean water supply and management, food, health, and energy.

3. Thematic Foresight Studies in High Impact Areas

When it comes to thematic foresight studies, the research community has never been short of inputs. Over the past 10 years, the APEC Center for Technology Foresight (CTF), among others, has been conducting some thematic foresight studies in these high-impact areas, with the prospect of encouraging the Asia-Pacific region in the development and use of potential science and technology to respond to these areas[6].

- Approximately 1.8 billion more people could be living in a water scarce environment by 2080[7]. Foresight studies on the issue of **water**[8] pointed out the need for an integrated global water strategy, plan, and management system to focus knowledge, finances, and political will to address this challenge. Countries could apply the lessons learned from producing more food with less water via drip irrigation and precision agriculture, rain water collection and irrigation, and replication of successful community-scale projects around the world. Improvement in water supply and management will also help improving sanitation and health in poorer countries as about 80% of diseases in the developing world are water-related[9].

[6] Ibid 1.
[7] Ibid 5
[8] See, for example, APEC CTF, *Water Supply and Management in the APEC Region*, 1998.
[9] Ibid 3.

- A large number of in-depth studies on the future of **energy**[10] have been conducted and released by many energy-related companies, governments, and international organizations. Consideration usually focuses around the issue of energy security, environmental and social consequences including safety and cleanliness (greenness) of energy sources and fuels. Renewable and low-carbon technologies are the areas where most R&D investment are put into, with solar and biofuels leading. CTF has recently conducted a study on future fuel technology and concluded that the integration of biofuels, unconventional hydrocarbons, and hydrogen will become the key to responding the future demand of fuel in Asia-Pacific[11].
- About 30% of all deaths are caused by **infectious diseases**, with emerging and re-emerging infectious diseases increasing at an alarming rate during the recent years, posing a clear global security threat. For sufficient preparedness, all control options - pharmaceutical or non-pharmaceutical, must be considered and fully explored. In most cases these options require capabilities in new technological development and usage, and/or convergence between existing technologies. These technologies include genetic-based vaccines and microbicides, modeling and simulation, ubiquitous computing, cheap diagnostic kits for developing economies, and tracking technologies for effective surveillance[12].
- The concept of **healthy city** including education, transport, and society has been repeatedly explored in studies conducted by CTF[13]. The year 2008 was commemorated as the time when for the first time more than half of the world population is living in cities[14], and there are many emerging risks and vulnerabilities accompanying this global urbanization. The Rockefeller Foundation has recently announced its new initiative for Climate Change Resilience intending to find good models at the city level[15].

[10] See, for example, *Scenarios for a Clean Energy Future*, DOE, 2000.
[11] APEC CTF, *Foresighting Future Fuel Technology*, 2006.
[12] See, for example, UK Foresight, *The Detection and Identification of Infectious Diseases*, 2006 and APEC CTF, *Roadmapping Converging Technologies to Combat Emerging Infectious Diseases*, 2008.
[13] For example, Sustainable transport, technology for learning and culture, healthy city
[14] UN, *World Urbanization Prospects: The 2007 Revision*, 2008.
[15] http://www.rockfound.org/initiatives/climate/climate_change.shtml

The impacts of risks and vulnerabilities related to water, energy, diseases and cities are the four areas that CTF have studied throughout the past decade, with considerable interactions and integrated impact being studied in its most recent ongoing foresight project on *"Futures of Low Carbon Society: Climate Change and Strategies for Economies in APEC Beyond 2050"*[16], with final result expected in 2010 (Figure 4).

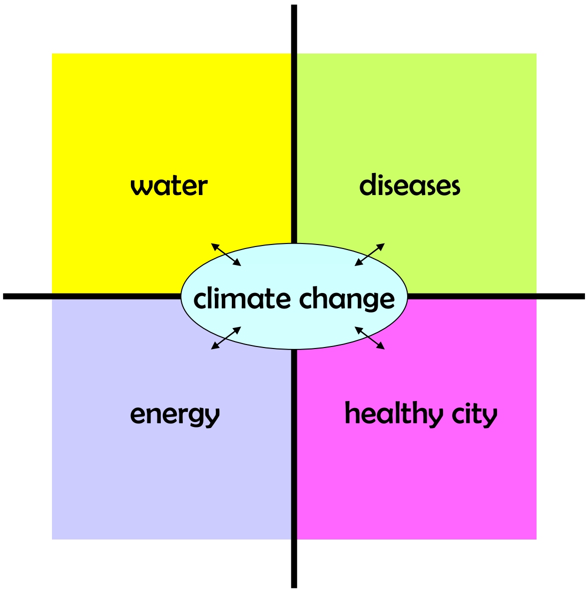


Figure 4: Interactions and Integrated Impact of Four Thematic Areas on the Area of Climate Change.

As the demand for specific S&T development and application is becoming clearer in these thematic foresight studies, our attention will now turn to the future prospects of global science and technology, including its governance, its changing paradigms, and questions that will shape changes in science and technology over the next 5 to 20 years.

4. Science and Technology Applications as the Building Blocks for the Future?

The progress in science, technology, and innovation usually happens either in private corporations, academic institutes, or government institutes. Recently there are increasing effort to link

[16] http://climatechange-istwg.wikispaces.com/

the activities in these three key players to maximize effectiveness of research, development, and engineering, and to facilitate sufficient knowledge acquisition and technology transfer[17].

"Towards 2020 Science" was published in 2006 from the private sector, led by Microsoft Research in Cambridge, UK, containing the initial findings and conclusions of a group of internationally distinguished scientists who met over an intense three days in July 2005 to debate and consider the role and future of science over the next 14 years towards 2020[18]. In particular they discussed the importance and impact of computing and computer science on science towards 2020. Here are some findings from this project as a proposed *vision* for science:

- An important development in science is occurring, with a leap from the application of computing to support scientists to 'do' science (i.e. 'computational science') to the integration of computer science concepts, tools and theorems into the very fabric of science.
- Conceptual and technological tools developed within computer science are starting to have wide-ranging applications outside the subject in which they originated, especially in sciences investigating complex systems, most notably in biology and chemistry. This is a potential starting point for fundamental new developments in biology, biotechnology and medicine.
- Computer science concepts and tools in science form a vital component, together with novel mathematical and statistical techniques in science, and scientific computing platforms and applications integrated into experimental and theoretical science. This combination will accelerate key breakthroughs in science and benefits to society, and helping to protect the life-support systems of Earth on which we all depend for our survival.
- An immediate and important challenge is that of scientific data management, from data acquisition and data integration, to data treatment, provenance and persistence.
- Even near-term developments in the computing infrastructure for science which links data, knowledge and scientists will lead to a transformation of the scientific communication paradigm.

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[17] Calestous Juma and Lee Yee-Cheong, *Innovation: Applying Knowledge in Development*, UN Millennium Project Task Force on Science, Technology, and Innovation, 2005.
[18] The 2020 Science Group – Microsoft Corporation, *Towards 2020 Science*, 2006.

- There will be fundamental new developments in biology, biotechnology and medicine, and potentially profound developments in the future of computing. Big challenges for future computing systems have elegant analogies and solutions in biology, such as the development and evolution of complex systems, resilience and fault tolerance, and adaptation and learning.

Although this report is heavily and narrowly computer/computational science-oriented, and seems to be mismatched with the global and thematic future scenarios discussed so far, the findings suggests a number of *Social* and *Economical* implications. According to this report, scientists will need to be completely computationally and mathematically literate, and by 2020, it will simply not be possible to do science without such literacy. This therefore has important implications for education policy right now. The output of computer scientists today barely meets the needs of the public and industrial computing sectors, let alone those required for future science sectors. These developments will also fundamentally affect how science needs to be funded, what science is funded, and many current assumptions underpinning existing science policies. They also have economic implications. We are starting to give birth to 'new kinds' of science and possibly a new economic era of 'science-based innovation' that could create new kinds of high-tech sectors that we can barely imagine today, just as we could hardly have imagined today's rapidly growing 'genomics' sector happening two decades ago.

In a wider-range examination of future science and technology and its impact, a technical report prepared by the *RAND Corporation* for the US National Intelligence Council in 2006 provided a governmental point of view[19]. Not only looking at the applications, implementation, and impact of a number of key future science and technologies, but also internationally comparing the different capacity to acquire technologies, problems and issues in applying technologies.

[19] RAND Corporation, *The Global Technology Revolution 2020, In-Depth Analyses: Bio/Nano/Materials/Information Trends, Drivers, Barriers, and Social Implications*, 2006.

The RAND report analyzed the technology trends and applications in the areas of biotechnology, nanotechnology, materials, and information. It argued that it is the *integration* of these developments that can have the most profound impact on society by providing multifunctional technologies to meet specific application needs. Examples of integration of key technologies that may be feasible by 2020, along with possible application and user groups are given in Table 3.

Table 3: Integration Trend of Technology Developments

Area	Single Disciplines	Multiple Disciplines: Partially Integrated	Multiple Disciplines: Fully Integrated	User Group/Application
	Traditional →	*Transitional* →	*Evolved*	
Materials	Solid state physics or chemistry	Solid state physics or chemistry of complex materials	Physics, chemistry, engineering of complex materials	Engineers/ design of biomaterials, catalysts, structural materials
Solar collectors	Semiconductors	Organic semiconductors	Chromophores, dendrimers, nanostructured organic semiconductors	Consumers/ mass-producible and affordable solar energy
Pharmaceuticals	Designer drugs	Time-release designer drugs	Encapsulated, targeted, self-regulated drug delivery	Patients/ less invasive treatment with less side effects
Water purification	Filters and catalysts	Catalytic membranes	Functionalized, controlled pore size, selective catalytic filters and membranes	General populace/ cleaner water, safer from disease
Genetic modification in agriculture	GM crops	Climate-tailored GM crops	Adaptive GM crops (e.g., controlled germination, self-regulated nutrient uptake)	Farmers and general populace/ higher yield, greater availability of food, nutrition

Source: ***The Global Technology Revolution 2020, RAND Corporation (2006).***

To evaluate the potential impact of technology applications on society, the RAND report used a rough net assessment index composed of the sum of the number of societal sectors[20] that the

[20] Including water, food, land, population, governance, social structure, energy, health, economic development, education, defense/conflict, and environment/pollution.

technology applications could affect and measures of technical feasibility, implementation feasibility, and global diffusion. While this rough net assessment index did not measure the magnitude of impact on specific sectors, it did highlight feasible applications with multi-sectoral impact and global reach. Of the 56 technology applications that emerged, the following "top 16," based on this net assessment index, formed a representative group that allowed further evaluation of worldwide variation in technology implementation and its relevance to significant societal problems and issues.

1. Cheap Solar Energy
2. Rural Wireless Communications
3. Communication Devices for Ubiquitous Information Access Anywhere, Anytime
4. Genetically Modified (GM) Crops
5. Rapid Bioassays
6. Filters and Catalysts for Water Purification and Contamination
7. Targeted Drug Delivery
8. Cheap Autonomous Housing
9. Green Manufacturing
10. Ubiquitous RFID Tagging of Commercial Products and Individuals
11. Hybrid Vehicles
12. Pervasive Sensors
13. Tissue Engineering
14. Improved Diagnostic and Surgical Methods
15. Wearable Computers
16. Quantum Cryptography

The "significant societal problems and issues" used as criteria include promoting rural economic development, promoting economic growth and international commerce, improving public health, improving individual health, reducing resource use and improving environmental conditions, strengthening the military and war fighters of the future, strengthening homeland security and public safety, and influencing governance and social structure. In addition to these direct impacts, the report also considered how each technology applications might contribute to problems and issues that have less-obvious linkages. For example, filters and catalysts will benefit rural economic development and homeland security, respectively, by providing clean water to rural populations that lack access to reliable and safe water supply, as well as to communities after terrorist attacks or hazardous materials spills that damage their regular drinking water source.

The relevant future technology applications for highlighted problems and issues of the society are summarized in Table 4.

The RAND report recognized that continuing development of these technology applications, changes in laws and policies, new business models to dissemination innovation, and other factors may make a technology application more or less relevant to a particular problem or issue. Thus, Table 4 represents the report's best assessment constrained by what we know today. The report accepted that many more innovative uses of these technology applications to address these and other problems and issues are entirely possible.

Table 4: Relevant Technology Applications for Highlighted Problems and Issues

	Technology Applications	Promote Rural Economic Development	Promote Economic Growth and International Commerce	Improving Public Health	Improving Individual Health	Resource Use and Improving Environmental Conditions	Strengthening the Military and War fighters of the Future	Strengthening Homeland Security and Public Safety	Influencing Governance and Social Structure	Total Number of Problems and Issues (Sectors) Affected
1	Cheap solar energy	food, econ dev, edu	energy	health	health	water, land, energy, environ			govern, social	6 (10)
2	Rural wireless communications	econ dev, edu	econ dev	health	health	environ	defense	defense	govern, social	8 (7)
3	Communication devices for ubiquitous information access		econ dev, edu	health	health		defense, edu	defense	govern, social	6 (6)
4	Genetically modified (GM) crops	food, econ dev, edu		health	health	water, land, energy, environ				4 (8)
5	Rapid bioassays		econ dev	health	health		defense	defense	govern	6 (4)
6	Filters and catalysts for water purification & decontamination	food, water, econ dev		health	health	water, land, energy, environ	defense	health		6 (8)
7	Targeted drug delivery		econ dev	pop, health	health			defense	govern, social	4 (6)
8	Cheap autonomous housing	econ dev, energy		health	health		defense	defense	govern, social	6 (6)
9	Green manufacturing		econ dev	health	health	water, land, energy, environ				3 (6)
10	Ubiquitous RFID tagging		econ dev				defense		govern, social	3 (4)
11	Hybrid vehicles					environ, energy				1 (2)
12	Pervasive sensors		econ dev				defense	defense	govern, social	4 (4)
13	Tissue engineering		econ dev	pop, health					govern	3 (4)
14	Improved diagnostic and surgical methods			pop, health						1 (2)
15	Wearable computers		econ dev, edu	health			defense	defense	social	5 (5)
16	Quantum cryptography		econ dev				defense	defense		3 (2)

Source: Adapted from *The Global Technology Revolution 2020, RAND Corporation (2006).*

The question of whether science and technology applications can actually become the building blocks for the future, and how, is also assessed in one of the most prominent work on this topic, the *2025 Science and Technology Management Scenarios* (also referred to as *Science and Technology 2025 Global Scenarios)*. This work was conducted as part of the Millennium Project of the American Council for the United Nations University (AC/UNU Millennium Project)[21].

During 2001 – 2003 the Millennium Project and its representatives Nodes around the world conducted a Delphi survey (a two-round questionnaire aiming at a limited number of selected participants) to assess future science and technology policy and management issues. The results of the survey were then used to produce long-range alternative scenarios on global science and technology. The project explored S&T issues over 25 years from the year 2000, the implications of these issues for S&T management, and finally the policy and management alternatives explicit via the scenarios. It was a worldwide effort to collect and synthesize judgments about emerging global challenges that may affect the human condition.

From the developing countries' point of view, the 4 global scenarios resulting from this research, though slightly outdated now, were of interest and value to the national governments, scientific communities and the institutions that fund such research, providing the context for setting long-term goals and strategies for technology applications. Here are abstracts of the scenarios[22].

Scenario 1: S&T Develops a Mind of its Own

The rate of scientific discoveries and advanced technological applications exploded. A global science/social feedback system was at work: science made people smarter, and smarter people made better and faster science. Better and faster science opened new doors to discovery, and new doors led to synergies and solving of old roadblocks. Removing the roadblocks created new science that made people smarter. S&T moved so fast that government and

[21] The Millennium Project of WFUNA is a global participatory futures research think tank of futurists, scholars, business planners, and policy makers who work for international organizations, governments, corporations, NGOs, and universities. The Millennium Project manages a coherent and cumulative process that collects and assesses judgements from its several hundred participants to produce the annual "State of the Future", "Futures Research Methodology" series, and special studies such as the State of the Future Index, Future Scenarios for Africa, Lessons of History, Environmental Security, Applications of Futures Research to Policy, and a 700+ annotated scenarios bibliography.

[22] Full description of the scenarios could be found at http://www.millennium-project.org/millennium/scenarios/st-scenarios.html

international regulations were left in the dust. Science and technology appeared to be taking on a mind of its own.

Scenario 2: The World Wakes Up

The murder of 25 million people in 2021 by a self-proclaimed Agent of God who created the genetically modified Congo virus finally woke the world up to the realization that an individual acting alone could create and use a weapon of mass destruction. This phenomenon became known as SIMAD—Single Individual Massively Destructive. Regulatory agencies and mechanisms were put into place to control the science- and technology-related dangers that became apparent. Education was a big part of the answer, but connecting the educational systems with the security systems was disturbing to some people. Nevertheless, further individual acts of mass destruction were prevented. International and government regulations did manage the S&T enterprise for the public good.

Scenario 3: Please Turn off the Spigot

Science was attacked as pompous and self-aggrandizing, as encouraging excesses in consumption, raising false hopes and—worse—unexpected consequences that could destroy us all. Particularly worrisome was accidentally or intentionally released genetically modified organisms and the potential for weapons of mass destruction. *The poor were ignored*. A science guru arose to galvanize the public. A global commission was established but failed because of corruption. But a new commission with built-in safeguards seemed to be working.

Scenario 4: Backlash

Control was low and science moved fast, but negative consequences caused public alarm. The golden age of science was hyped by the media, but it all proved to be a chimera. Some of the most valued discoveries and new capabilities had a downside and surprises abounded. Rogue nations took advantage of some of these shortcomings. The level of concern rose. Mobs protested. Regulation failed. Progress stalled. And corporate (or government) scientists frequently felt pressure from within their organizations. Both corporate and government organizations could not be counted on to self-regulate. What's next?

From each scenario emerge a number of questions that are relevant to the course of science and technology policy options for the future. These questions include:

1. Are dramatic increases in collective human-machine intelligence plausible?
2. Is it likely that organizations designed to regulate the course of S&T will generally fail to keep pace with accelerated advances of S&T?
3. Is it plausible that weapons of mass destruction will be available to single individuals?
4. Is it plausible that advances in cognitive science, information technology, and new educational systems and/or changes in older ones will be able to significantly improve tolerance for diversity?
5. Is it plausible that international S&T treaties and regulations will have provisions for enforcement police enforcement or military intervention?
6. Can S&T regulators and commissions be virtually free from corruption?
7. Is it plausible that an anti-science movement will be as or more powerful than the environmental movement?
8. Is it plausible that international systems (like the International Atomic Energy Agency - IAEA) will be established to monitor and regulate biotechnology, nanotechnology, and other areas of scientific research and development with enforcement powers?
9. When extreme unintended consequences are involved, can a cost-benefit trade-off be logically made?
10. Might scientists in the future unite into a global labor organization?
11. Can science disciplines effectively self-regulate?

The scenarios and the above questions reveal the prospects of global science and technology and its changing paradigms. They demonstrate that science and technology is recognized not only as positive but also possibly negative driver to the future, sometimes dangerous, depending on how it is managed and the setting where it is applied, as seen in the questions. How we answer these questions will shape changes not only in science and technology but the society we live in over the next 5 to 20 years. The next and final part of this paper will focus on the wide-range implications, potential intersections and cross-cutting impacts on poverty and development issues.

5. Cross-Cutting Impact and Implications on Poverty and Human Development Issues

As reviewed so far, it is evident that there are few literatures on foresight, and particularly technology foresight, which directly address the issue of poverty. Therefore we may have to also consider the indirect implications of future technology applications that might have less-obvious linkages.

Figure 5 maps the progress of science and technology with the improvement of quality of life in the broad definition: health, welfare, security etc. Our general assumption is that the quality of life improves with the progress of science and technology. The cross-cutting impact and implications (the blue solid arrow) lies in the background and they include opportunities, drivers, and barriers that play crucial roles *before* the achievement in S&T applications (acquisition and implementation of technologies). However, it is also important that the cross-cutting impact needs to be considered *after* the achievement in S&T applications: the adverse effects of science and technology to society, and the governance issues.

Therefore, from the foresight literatures, the 2 folds of cross-cutting impact and implications on poverty and pro-poor development are (in reverse order from the blue arrow in Figure 5):

1. Vulnerability and risks to the poor due to the (seemingly) successful development of S&T including its adverse effect;
2. Opportunities, drivers and barriers in using S&T for pro-poor development.

The role of technology foresight is to take a leap through time, envision the future where science and technology applications are put to work, identify the potential new technologies, including their cross-cutting impact and implications in advance, and bring some suggestions back to the science and technology policy.

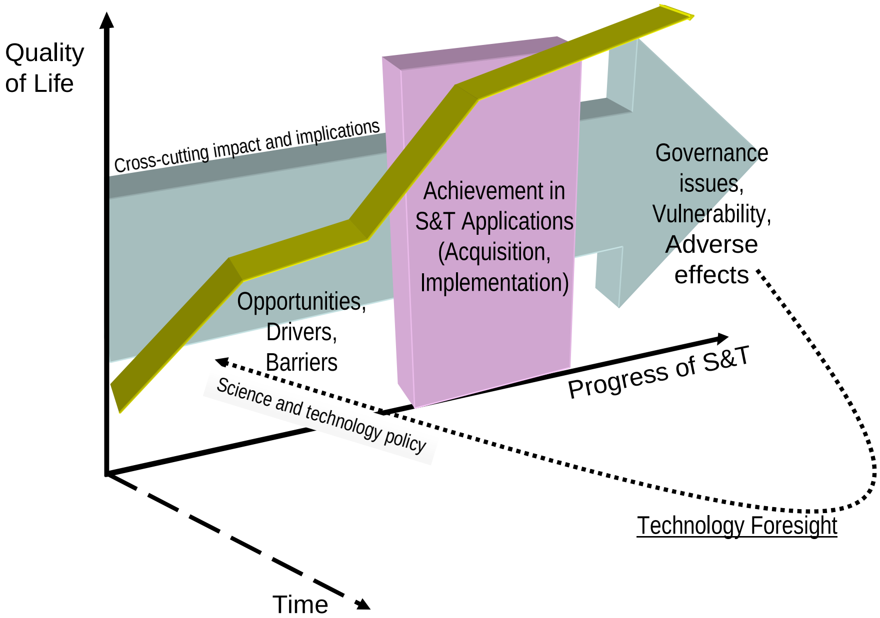

Figure 5: Cross-Cutting Impact and Implication of Science and Technology and the Role of Technology Foresight

Vulnerability and Risks

The AC/UNU Millennium Project scenarios covered in the previous section depicted some nightmarish futures where S&T caused serious adverse effects, intentionally or not, with substantial impact on the poor. For example in Scenario 3 "Please Turn off the Spigot" the scenario goes:

> *Particularly worrisome was accidentally or intentionally released genetically modified organisms and the potential for weapons of mass destruction. The poor were ignored.*

Another example is a scenario from *Nanotechnology Foresight* by the APEC Center for Technology Foresight, where nanotechnology had to retreat to the backstage due to fear of its adverse effect[23]:

> *Repeated bio-food and GMO scares, coupled with scandals on genetic profiling and DNA chips, led to a poor public image for nanotechnology products. Nevertheless R&D in APEC*

[23] APEC CTF, *Nanotechnology: The Technology for the 21st Century*, 2002.

economies increased and products based on nanotechnology continued to be introduced, although increasingly little mention was made of nanotechnology. By 2015, products based on nanotechnology had achieved clear technical success in many areas but widespread adoption and acceptance of the full potential has been clouded by uncertainty and nanotechnology is scarcely visible. It had to be re-branded and integrated with other technology labels to be accepted.

Jerome C. Glenn and Theodore J. Gordon argued that the risks from acceleration and globalization of S&T are enormous and give rise to future ethical issues. The world's increasing dependence creates new vulnerabilities such as, fraud, cyber terrorism, information warfare, cultural threats, widening knowledge gaps, making financial markets vulnerable to fast manipulations ($2 trillion/day moves around the world which increases the likelihood of speculation and money laundering widening the rich-poor gap[24].

It will take good governance and transparency in the development and application of S&T in order to ensure that the poor will *not* be ignored.

Opportunities and Barriers

Even if we disregard the nightmarish or worst case scenarios where science go wrong, hoping that the advanced nations will be obliged to take care of and control those issues, the scenarios still suggest that continued effort needs to be made proactively on the part of poor countries to seek opportunities from science and technology applications. For the reason against one-sided exploitation from the market economy alone, the poor cannot afford to be left behind in S&T knowledge and capacity.

Moreover, as the study by the APEC Center for Technology Foresight has indicated, the poor country's risk and vulnerability in water supply, mega-cities and climate change can be improved if S&T is

[24] Jerome C. Glenn and Theodore J. Gordon, *Views from the Millennium Project on the Future of Technology with Implications for Society and the United Nations System, On the Threshold: The United Nations and Global Governance in the New Millennium*, United Nations University, 2000

implemented properly. Besides, there are a number of technology applications already mentioned in Table 4 that can help in promoting poor rural economic development such as cheap solar energy, rural wireless communications, genetically modified (GM) crops, filters and catalysts for water purification & decontamination, and cheap autonomous housing.

These pro-poor applications can be realized only if poor countries can overcome the many barriers and find the right drivers and opportunities. This is not a simple task, since there is a complex dynamics between a country's capacity to *acquire* technologies and the specific drivers and barriers that affect its capacity to *implement* technologies.

Capacity to *acquire* does not necessarily equal capacity to *implement*, because the latter requires a threshold level of physical, human, and institutional capacity; financial resources; and the social, political, and sometimes even cultural environment necessary to maintain and sustain widespread use of technology applications[25].

Knowing the drivers and barriers and the relationships among them will better enable decision-makers to implement beneficial technology applications in a manner that fully addresses significant ethical, safety, and public concerns. In the RAND study, ten major types of drivers and barriers to technology implementation were identified:

1. Cost and financing
2. Laws and policies
3. Social values, public opinion, and politics
4. Infrastructure
5. Privacy concerns
6. Resource use and environmental health
7. R&D investment
8. Education and literacy
9. Population and demographics
10. Governance and political stability.

[25] Ibid 19.

It is important to also note that drivers and barriers often are present simultaneously, reflecting progress in some aspects and problems in other aspects. RAND further analyzed the factors influencing the capacity to acquire and implement the technology applications they identified. An example of such analysis made on selected countries' capacity to implement technologies is shown in Figure 6.

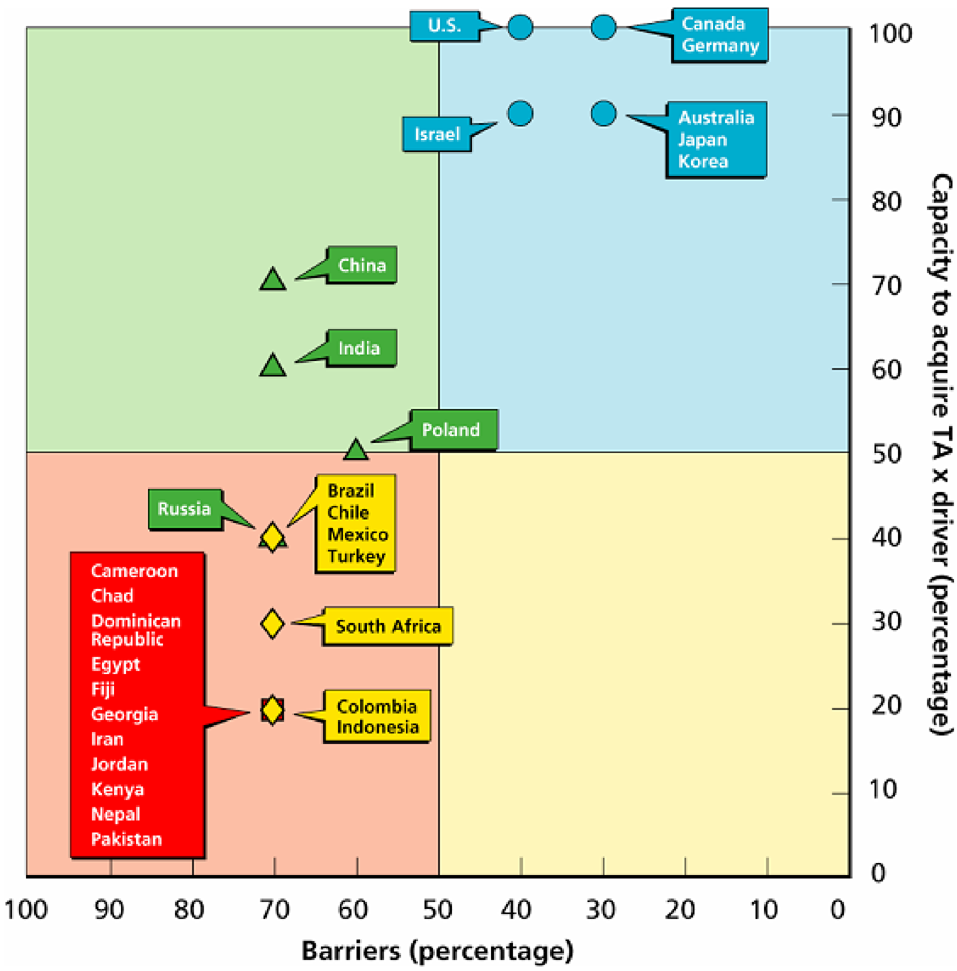

Figure 6: Selected Countries' Capacity to Implement Relevant Technology Applications for Rural Economic Development

Figure 6 shows the relevant technology applications for promoting rural economic development as defined in Table 4. Promoting economic growth in rural areas continues to challenge national governments, nongovernmental organizations, and multilateral development banks. This is particularly true for those areas in poor countries because reducing rural poverty is a top priority in all these

societies. The lack of infrastructure, weak institutions of governance, low level of knowledge and technical capacity, shortage of financial resources, and other difficulties have hindered efforts to spur economic growth in these communities.
It is clear from Figure 6 that countries that are most in need of rural economic development have little capacity to implement the relevant technology applications. These countries command few drivers and are saddled with numerous barriers. They lack financial resources and are short on institutional, human, and physical capacity. Poor governance and stability presents another significant barrier. In these countries corruption and abuses at lower level of government frequently go all the way up to the national leadership[26].

6. Recommendations, Potential Responses, and Conclusions

The SOF 2008 suggested the need for a global collective intelligence system to track S&T advances, forecast consequences, and document a range of views so that politicians and the public can understand the potential consequences of new S&T. Currently a worldwide network of 90 science academies called the *InterAcademy Panel* is increasing access to S&T information and cooperation around the world, and furthering basic science as necessary to replenish the pool of knowledge from which applied science draws its insights to improve the human condition.

This type of science and technology community will have to invest sufficient effort in bringing together the S&T knowledge in a more user-friendly fashion to illustrate balanced view of risks and opportunity. The community should also facilitate transparent international scientific assessments of controversial areas such as bio-nanotech and, wherever they are found feasible and desirable, make it clear how these would improve the human condition[27], particularly those living in poor countries.

Though some argue that bridging the science and technology gap should be a central role of the UN[28], the UN Task Force on Science,

[26] Ibid 19.
[27] Ibid 3.
[28] Ibid 24.

Technology, and Innovation (as part of the UN Millennium Project) emphasizes the need to create space for policy experimentation and learning in developing countries. Development is largely an expression of local initiative and international partnership; it cannot be sustained without local ownership and champions[29]. The report of this Task Force draws on the experiences of developing countries that dramatically alleviated poverty and grew their economies in past few decades, especially those in the Asia-Pacific region. In every case, scientific and technical information was a crucial factor in their success. These countries and economies could and should help other developing countries by sharing their best practices and experiences in the spirit of South-South cooperation. Evidences show that a growing number of countries in the developing world are showing how economic prosperity can be achieved by turning innovation into profits, and benefits the society as a result[30].

This brings our agenda, examining the future of science and technology for pro-poor applications, closer to the arena of science, technology and innovation for development. The achievement will require a substantial reorientation toward development policies that focus on key sources of economic growth, including those associated with new and established scientific and technological knowledge and related institutional adjustments. To promote the use of science, technology and innovation for development, countries need to adopt strategies for technological learning at the local, national, regional, and international levels. These strategies will involve continuous interactions between government, industry, academia, and civil society.

One key strategy for developing countries will be to remain their linkages with the international science and technology community, for example the OECD who could help to identify good practices in international science and technology co-operation. The OECD countries are particularly concerned on the issues of sustainable development and could provide useful resources and experiences[31].

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[29] Ibid 17.
[30] Calestous Juma, *Learn to Earn*, 2008.
[31] OECD, *Integrating Science and Technology into Development Policies: An International Perspective*, 2007.

In working for pro-poor applications, the foresight community should interact closely with the development community and encourage the use of anticipatory intelligence and governance in this area. More specifically:

1. Countries with certain level of industry development (e.g. middle income developing countries) could use some practical foresight tools such as technology roadmapping (TRM), as practiced in industrialized countries, to help in identifying new market opportunities, link technologies and product to the global market before set out to develop new technologies. The APEC Center for Technology Foresight has involved developing countries in all of its international foresight projects to ensure interaction and mutual learning in the process. The roadmaps are usually focused on a number of technologies or converging technologies, with specific and implementable recommendations as their outputs. Usually the recommendations will include not only new knowledge but the identification of platform technologies with wide applicability, mostly consist of existing technologies, while giving direction for building a foundation for long-term R&D activities.
2. The foresight community should come together and create a sense of urgency in issues that has long term implications but need immediate action and therefore high priority needs to be maintained. In this regard, the influence and interaction between the foresight community and governments, international organizations, and the business community is vital. Unfortunately, evidence so far shows that the foresight community has not been very successful in this endeavor, as we have seen in the recent global financial crisis. However, evidence-based foresight could potentially provide good recommendations to governments on how they should spend money on reviving the economy, such as the Chinese government has include major spending on transportation and rural infrastructures, and tax incentives for technology upgrading[32].

[32] Institute of Development Studies, *Voices from the South: The Impact of the Financial Crisis on Developing Countries*, 2008.

The author of this paper expects that there will be more effort within the foresight community to collaborate and focus on the foresight for poor regions and countries of the world.