

Innovation, Sustainability, Development: A New

MANIFESTO

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New Models of Technology Assessment for Development

Adrian Ely, Patrick Van Zwanenberg & Andrew Stirling

Technology Assessment





About this report:

This report explores the role that 'new models' of technology assessment can play in improving the lives of poor and vulnerable populations in the developing world. The 'new models' addressed here combine citizen and decision-maker participation with technical expertise. They are virtual and networked rather than being based in a single office of technology assessment (as was the case in the United States in the 1970s-90s). They are flexible enough to address issues across disciplines and are increasingly transnational or global in their reach and scope. The report argues that these new models of technology assessment can make a vital contribution to informing policies and strategies around innovation, particularly in developing regions. They are most beneficial if they enable the broadening out of inputs to technology assessment, and the opening up of political debate around possible directions of technological change and their interactions with social and environmental systems. Beyond the process of technology assessment itself, the report argues that governance systems within which these processes are embedded play an important role in determining the impact and effectiveness of technology assessment. Finally, the report argues for training and capacity-building in technology assessment methodologies in developing countries, and support for internationally co-ordinated technology assessment efforts to address global and regional development challenges.

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About the Manifesto project

In 1970 a radical document called The Sussex Manifesto helped shape modern thinking on science and technology for development. Forty years on, we live in a highly globalised, interconnected and yet privatised world. We have witnessed unprecedented advances in science and technology, the rise of Asia and ever-shifting patterns of inequality. What kind of science and technology for development is needed in today's world? The STEPS Centre has created a new manifesto, launched in June 2010, that tries to respond to this challenge. Bringing cutting-edge ideas and some Southern perspectives to current policy, the New Manifesto recommends new ways of linking science and innovation to development for a more sustainable, equitable and resilient future.

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About the STEPS Centre

The STEPS Centre (Social, Technological and Environmental Pathways to Sustainability) is an interdisciplinary global research and policy engagement hub that unites development studies with science and technology studies. Based at the Institute of Development Studies and SPRU Science and Technology Policy Research at the University of Sussex, with partners in Africa, Asia and Latin America, we are funded by the Economic and Social Research Council.

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About the Rockefeller Foundation

The Rockefeller Foundation's mission to promote the well-being of people throughout the world has remained unchanged since its founding in 1913. Today, that mission is applied to an era of rapid globalization. Our vision is that this century will be one in which globalization's benefits are more widely shared and its challenges are more easily weathered. To realize this vision, the Foundation seeks to achieve two fundamental goals in our work. First, we seek to build resilience that enhances individual, community and institutional capacity to survive, adapt, and grow in the face of acute crises and chronic stresses. Second, we seek to promote growth with equity in which the poor and vulnerable have more access to opportunities that improve their lives. In order to achieve these goals, the Foundation constructs its work into time-bound initiatives that have defined objectives and strategies for impact. These initiatives address challenges that lie either within or at the intersections of five issue areas: basic survival safeguards, global health, environment and climate change, urbanization, and social and economic security.

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FOREWORD

Looking back on attempts to apply new technologies as a way of addressing the major challenges associated with global poverty and development, it is becoming increasingly clear that technology is not reaching its full potential in improving people's lives around the world. New, forward-looking models are needed that consider how people use technology in their daily lives and how novel innovations are disseminated and adopted over time. My colleagues and I at the Rockefeller Foundation are pleased to support the authors of this report—Adrian Ely, Patrick Van Zwanenberg, and Andy Stirling from the STEPS Centre at the University of Sussex—in outlining the contours of such a model by envisioning how new tools, techniques, and analytic approaches can be used to anticipate the emergence of new technological innovations that are arising throughout the developing world.

Underlying the findings presented in this report is a systems thinking point of view to problem solving. This systems thinking approach centers on gaining a deeper understanding of the varying perspectives held by key stakeholders, examining critical relationships and inter-dependencies, and exploring the effects of changes or shifts in one part of the system on other areas. In this way, the viewpoint informing this report advances the systems thinking approach that is at the heart of the Foundation's current work, which aims to integrate across problem domains, broker strategic partnerships, leverage resources, and foster innovation to achieve sustainable and scalable solutions.

Similarly, in addition to the Foundation's long history in building technological capacity to improve the lives of poor and vulnerable populations, the questions addressed in this report speak to the two major goals of the Foundation's current efforts: *building resilience* that enables social, economic, and physical challenges to be more easily weathered and *promoting growth with equity* to ensure that globalization's benefits are more widely shared by more people in more places around the world.

By articulating the viability and potential impact of new models of technology assessment for development, this report demonstrates how the potential negative, unanticipated consequences of utilizing new technologies in a development context might be identified and mitigated at earlier stages. It also shows how the positive consequences of technologies that are well thought-out can motivate the right kind of innovation to take place. In short, the perspectives presented in this report indicate how resilience and growth with equity can be fostered simultaneously, as new models of technology assessment for development serve as an early warning signal to decision-makers about potential opportunities and drawbacks, thereby ensuring that technologies are more easily scaled and more responsibly distributed. More thinking and action along these lines are needed over the coming decades to develop innovative, sustainable, resilient, and equitable solutions to humanity's greatest challenges.

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ABBREVIATIONS AND ACRONYMS

BVGH = Bioventures for Global Health
DBT = Danish Board of Technology (Teknologirådet)
ECAST = Expert & Citizen Assessment of Science & Technology Network
EPTA = European Parliamentary Technology Assessment network
IAVI = International AIDS Vaccine Initiative
IAASTD = International Assessment of Agricultural Knowledge, Science and Technology for Development
MCM = multicriteria mapping
NAS = National Academy of Sciences (United States)
OTA = Office of Technology Assessment (US Congress)
OSTP = Office of Science and Technology Policy (US White House)
PATH MVI = Program for Appropriate Technology in Health Malaria Vaccine Initiative
POST = Parliamentary Office of Science and Technology (UK)
pTA = participatory Technology Assessment
PTD = participatory technology development
R&D = research and development
S&T = science and technology
STI = science, technology and innovation
STEPS Centre = Social, Technological and Environmental Pathways to Sustainability Research Centre
STOA = Science and Technology Options Assessment (EU)
STRATA = Strategic Analysis of Specific Political Issues (EU)
STS = science and technology studies
TA = technology assessment
TNA = technology needs assessment
UNFCCC = United Nations Convention on Climate Change

EXECUTIVE SUMMARY

It is widely acknowledged that science, technology and innovation have key roles to play in achieving the Millennium Development Goals and addressing the sustainability objectives at the centre of the Rio+20 summit in May 2012. This important function cannot be realised without informed and democratically legitimate policies to guide technological developments. Technology assessment (TA) is vital to this process. It involves the collection, interpretation and evaluation of information and perspectives around contending technological options. In the absence of TA, technologies may fail to serve their desired function, or create unforeseen negative impacts. In domains such as health, energy and agriculture, TA can assist in identifying priorities and help improve the cost-effectiveness, environmental sustainability and long-term impact of technology policies and investments. Yet conventional forms of TA often fail to deliver on this potential, particularly in the developing world. They provide inadequate accounts of the social, technical and ecological complexities and uncertainties at stake, and pay insufficient attention to the power relations that often drive directions of technological change. New approaches are required that position technologies within dynamic pathways of change at the system level, recognise alternative understandings of these systems by different groups within society and attempt to build resilience in the face of pervasive uncertainty. Fortunately, these are already emerging in many contexts. This report takes an overview of these new methods and surveys their potential in relation to pressing global challenges of sustainability and development.

The 'new models of technology assessment' addressed here combine citizen and decision-maker participation with technical expertise. They are virtual and networked rather than being based solely in a centralised location such as an office of technology assessment. They are flexible enough to address issues across disciplines and are increasingly transnational or global in their reach and scope. This report examines the utility of these 'new models' of technology assessment in a broad range of geographical contexts, asking to what extent they can be applied to improve the lives of poor and vulnerable populations in the developing world. Drawing on lessons from the past four decades of TA, especially paying attention to recent experience with a variety of approaches in developing countries, the report puts forward a number of recommendations. These highlight how the new models of technology assessment can contribute to development goals and suggest how particular components of the new methods and processes might work especially well in developing countries.

New models of technology assessment, or certain characteristics that they embody, have made important contributions to technology decision-making and innovation processes. For sometimes very little cost, they have highlighted important considerations that would otherwise have been neglected. In general, we argue that these kinds of models present benefits in comparison to the *status quo* because they enable the 'broadening out' of knowledge and value inputs to technology assessment. They do this by involving diverse stakeholders and citizens, making it more likely that assessments attend to their priorities and questions and take on board their knowledge. This produces more analytically robust technology assessment outputs and helps to anticipate otherwise unforeseen constraints. Involving diverse stakeholders and citizens can also facilitate continuous learning and discussion throughout society as a whole (rather than only within a small group of experts). This in itself can act as a spur to more effective innovation.

At the same time as broadening out inputs, these new models (when appropriately designed and implemented) can help to produce more plural policy outputs that recognise multiple perspectives and priorities. This means that, rather than providing a single recommendation around the 'best' technology or policy, the preferences of different groups within society are

communicated more effectively and transparently to decision-makers, thus helping to foster accountability and democratic legitimacy in subsequent decision-making. Without compromising on quality, the relaxing of pressure to deliver a single 'definitive' recommendation means that these new forms of technology assessment can be less onerous than conventional approaches. When appropriately designed and implemented, networked approaches drawing on distributed capacity may also be less costly than centralised, technical approaches in terms of the resources and in-house expertise required – an important consideration in many developing countries.

New models of technology assessment have an important role to play in guiding investments and policies aimed at addressing development goals. The processes and methodologies involved in 'new models' of TA are many, and can be improved by following a number of simple principles:

- TA processes should focus on divergent views of pros and cons across alternative dynamic *directions* for technological and associated institutional change – rather than on the attributes of some particular selected technology treated in an essentially static fashion. This is often easier if exercises are focused around well-defined problems / problem fields, rather than on specific technologies. For example, attention might be given to different strategies for insect pest control on cotton and their future potential or to agricultural and livelihood options in general, rather than confining assessment to, say, first generation transgenic Bt crops.
- Participatory elements of the new models are often most usefully focused on *deliberation* and decision-making about issues concerning the nature of the problems to be addressed, the questions to be asked, and the criteria by which technologies are to be assessed. The outputs of these processes can then usefully inform more traditional analytical expert-based elements of the new models. For example, assumptions that the central problem requiring technological solution is simply about the volume of water provision, can miss important issues around water access and quality and gender relations in water provision.
- Criteria for assessment should be selected on the basis of multi-stakeholder deliberation. They should, however, aim at an explicit focus on the immediate *distribution* of costs, benefits and risks from technological change, rather than just the post-hoc redistribution following inequitable impacts. For instance, innovative crop strategies that require new forms of land tenure should be appraised in their direct consequences, not just according to presumed 'trickle down' effects of revenues generated for beneficiaries by aggregate increased productivity.
- Technology assessments should focus on maintaining and enhancing the *diversity* of social and technological approaches to addressing specified challenges. Potentially negative impacts of technologies that particularly threaten diverse solutions should be especially guarded against. For example, a disproportionate focus on proprietary pharmaceuticals to treat diseases may draw resources and attention away from existing public health measures and lifestyle choices, so 'crowding out' a variety of effective approaches that contribute to disease prevention.

At the same time, many lessons for technology assessment gleaned in OECD countries, (including the move towards certain characteristics of 'new models') are not practically applicable in many developing country contexts:

- Though internet infrastructures are improving in many of these contexts, a reliance on Web 2.0 or other 'virtual' models is not realistic where the necessary infrastructures do not exist.
- Capacity in the methodologies associated with 'new models of technology assessment' are often lacking in many developing countries. In these cases pooling resources between countries may, where appropriate, enable more effective TA activities.
- Data and statistics that can form the basis of technology assessment activities in Western contexts, as well as levels of understanding and language required for meaningful citizen engagement in debates about some technologies, are less often present in developing countries. However, established statistics in even the best documented innovation systems are often not sufficient for the kinds of question about technological directions addressed in new models. Either way, methodological innovation is required.
- Resources and capacity may not be available to act on TA outputs and subsequent political decisions. In these circumstances, new models of technology assessment can help generate tacit learning within the innovation system, even if their outputs do not go on to guide concrete investments. As such, rather than presenting an additional burden, these innovative models can offer ways to help address these challenges and build new capacity,

The effectiveness of technology assessment rests not only on the process and outcomes themselves, but also on responsiveness and openness on the part of both government and wider governance actors, and on the availability of resources to enable the outputs of TA to be considered and acted upon.

- New models of technology assessment place the responsibility for decision-making more firmly on democratically accountable leaders, and enhance political debate around scientific and technological investments and policies. It is a prerequisite for realizing the potential benefits of new models of TA that wider conditions are also in place for improved democratic discourse.
- Governments, funders and other audiences for TA exercises should commit in advance to responding in detail to the outputs of technology assessment. This does not constrain the agency of such bodies to decide as appropriate, but simply places a responsibility for publication of reasons. It is in this way that TA can contribute to transparency, quality and audit in decision-making bearing on technological choices.

Assessing the effectiveness of new approaches to technology assessment requires a long-term view, and would need to recognise multiple criteria for success. Quantitative studies to evaluate the cost/benefit or social returns on investment in technology assessment are extremely challenging, if not impossible. Nevertheless, a number of examples have already yielded tangible impacts on the kinds of information provided by TA, and on subsequent political discourse. These may be found in areas including agriculture (the International Assessment on Agricultural Knowledge, Science and Technology for Development), energy (Worldwide Views on Climate Change) and emerging technologies (eg various citizens' juries around genetically modified crops). Other examples have, based on budgets of under

\$20,000, highlighted design requirements (eg user preferences) that would otherwise have been overlooked. This report argues that there are important opportunities to scale-up such initiatives across co-ordinated, international networks, and that research into the efficacy of evolving TA approaches requires baseline studies and long-term support.

Increasing interest in new models of technology assessment, and the politicisation of debates over science, technology and innovation in recent years, are themselves an indication that more inclusive decision-making is now *expected* by a range of constituencies. Adoption of new models of TA addresses this cultural change. Along with other approaches, they can contribute to more democratic governance – not only of science, technology and innovation, but also more widely. It is in this way, also, that new models of TA offer a crucial means towards meeting the challenges of international development.

INTRODUCTION

There is increasing global recognition of the key role that science, technology and innovation must play in fostering sustainable development objectives in the run-up to the Rio + 20 Summit in 2012, as well as in maintaining progress towards the Millennium Development Goals to and beyond 2015. Global annual expenditure on research and development now exceeds one trillion dollars (STEPS Centre 2010) but economic realities and current systems of governance mean that only a tiny proportion of this investment is focussed on these global challenges, and that even then the allocation of resources is often driven by powerful interests rather than those of potential beneficiaries. Investments and policies to promote technologies that target poverty alleviation and environmental sustainability need to be informed by the best available evidence, as well as being democratically legitimate, accountable and open to adaptation and improvement.

In this regard, Technology Assessment (TA) is a set of practices that attempt to anticipate and analyse the broader social, environmental, and economic implications of technological projects, and to investigate the consequences of the options available to decision-makers. TA attempts to anticipate impacts and feedbacks in order to reduce the human and social costs incurred in social learning about technology purely through trial and error.

TA has a long history. It was first institutionalised in the United States in the 1972, at the Office of Technology Assessment (OTA) (Van Zwanenberg *et al.*, 2009). Although the OTA shut in 1995, TA is currently practiced in divergent ways across various parts of the world and has evolved to combine differing forms and degrees of technical analysis and deliberative process. Scholars interested in technology assessment have recently been describing possible future approaches that avoid the criticisms of the US OTA (Rodmeyer *et al.*, 2005). These include concerns on grounds of cost, slow delivery, uneven treatment of social consequences; and misleading claims to objectivity, limited insights into socio-technical dynamics and a focus on technical inputs to the exclusion of citizen perspectives (Sclove, 2010). They describe and advocate 'new models of technology assessment' that are more global, networked, virtual and flexible than their predecessors. Crucially, these new approaches combine citizen and decision-maker participation with traditional subject-matter-based expertise. Pointing to examples from a number of OECD countries, recent work illustrates the benefits of these new models of TA in comparison to the conventional approaches exemplified by the OTA.

Considerably less work has been done on technology assessment in developing countries and its role in fostering development goals. There are far fewer examples of TA applications in developing countries (of either 'new' or 'old' forms). There is a shortage of critical policy analysis from which to draw lessons. In particular, the relatively rare cases of TA exercises are not adequately assessed, either in the short or long term. Drawing on literature and empirical case studies, this report tries to go some way towards remedying this situation.

AIMS AND OBJECTIVES OF THIS REPORT

The overall aim of this report is to address the following question:

To what extent and under what conditions can new models of technology assessment be applied to improve lives of poor and vulnerable populations in the developing world?

The specific objectives are to:

- Summarize changing debates about technology assessment at national and international levels, and characterize and compare contrasting assessment approaches, their crucial distinguishing features and relevant applications, and their potential to be implemented in ways that improve the lives of poor and vulnerable populations in the developing world.
- Review a number of case studies of the more innovative, emergent forms of technology assessment and TA-like activities in specific domains - food and agriculture, water, health and disease and energy and climate, that have been applied in developing country or transnational contexts, with a focus on the substantive impacts of those activities.
- Consider how new models of technology assessment, or elements of those models, might be applied in developing countries or at transnational or global levels, and the likely impacts of these new TA exercises on current challenges in health, climate change and agriculture.

OUR APPROACH

The report draws upon work carried out at the STEPS Centre, which we use to reflect on and evaluate the new models of technology assessment for development. The STEPS Centre approach (Leach *et al.*, 2007) extends beyond narrow, conventional forms of *technology* assessment to allow broader social appraisal of alternative '*pathways to sustainability*'. By social appraisal, we refer to the collection of social processes through which knowledges are gathered and produced in order to inform decision making and wider institutional commitments (Stirling *et al.*, 2007). While traditional forms of TA focussed on individual technologies, current physical, social and political realities necessitate a more systemic view, focusing on the long-term *directions* of technical change and their impacts on a variety of sustainability and development goals. How can this best be achieved in technology assessment for development?

These technological, but also environmental and social dynamics (Scoones *et al.*, 2007) require that we adopt a more explicit and rigorous approach towards some often-neglected intractable aspects of incomplete knowledge (incertitude) – including states of uncertainty, ambiguity and ignorance as well as conventionally-highlighted 'risk'. This highlights the potential of an array of unduly marginalised practical methods for social appraisal which offer means more robustly to characterise and address this 'incertitude'. What implications do these methods raise for new models of technology assessment?

Based on the lessons from social appraisal in both the global North and South (including in its own work), the STEPS Centre experiments with and investigates approaches to social appraisal based on their ability to *broaden out* the *inputs* to appraisal (by incorporating the knowledge and perspectives of a broader range of stakeholders and citizens), whilst also *opening up* the *outputs* to wider governance processes (delivering 'plural and conditional', rather than 'single, definitive' advice to decision-makers) (Stirling, 2010). How can new models of technology assessment be applied in ways that forward these objectives?

Box 1. The International Assessment of Agricultural Knowledge, Science and Technology for Development

The International Assessment of Agricultural Knowledge, Science and Technology for Development, or IAASTD, a joint initiative of the World Bank, UNDP, FAO, and other institutions, ran between 2003 and 2008. Its aim was 'to assess the impacts of past, present and future agricultural knowledge, science and technology on the reduction of hunger and poverty, improvement of rural livelihoods and human health, and equitable, socially, environmentally and economically sustainable development'. (IAASTD 2009, Agriculture at a Crossroads: Synthesis Report, p. vi). The outputs, five regional reports and one global report, took four years to produce, and involved some 900 people across 110 countries in a multi-stakeholder process involving business, civil society and policy-makers. The process as a whole cost some 15 million dollars. The intention was that the results would provide a global consensus for investing in agricultural science and technology, setting priorities for both national and global organizations.

The IAASTD embodied all of the features of the 'new models' of technology assessment. In particular, it was participatory, combining technical expert assessment with, if not citizen participation, at least wide stakeholder representation; it was global in scope; it was networked insofar as it involved multiple institutions in public, civil, and private sectors, it was partly virtual, although this was inevitably combined with physically-based meetings and a physically located secretariat, and it was flexible in the sense that it handled a range of technological and non-technological issues simultaneously across various disciplines.

There are several reasons why 'new models' of technology assessment might be regarded as unfeasible (or unpromising) in developing country contexts. These relate not only to the practicalities of conducting such exercises (cost, infrastructure and capabilities required) but also the governance structures within which these exercises would be embedded (Leach 2007a). At the same time, there are many reasons to suppose that new models of TA applied in developing countries or at transnational levels might be able to better broaden out inputs and open up outputs to policy-making. We shall argue that in doing so the new models, or elements of them, could help to provide improved understanding on the part of policy-makers, funders and other decision-makers of poorer users' interests, priorities, and needs, and of the multiple perspectives held by others involved in innovation processes.

Through providing this improved understanding, new models of technology assessment could not only contribute to more cost-effective policies and technology investments and more impactful innovations but also aid in the anticipation and mitigation of adverse or negative environmental, health-related or social impacts of new technologies. Furthermore, we shall argue that they could – under favourable circumstances – be less onerous and costly than centralised, technical approaches to TA in terms of resources and the in-house expertise required. In order to investigate the applicability of 'new models' to various contexts and to identify the components of technology systems that are required for success, we will adopt a case study approach to draw lessons from activities already carried out across the global South.

Box 2. Multicriteria Mapping (MCM) of Maize Innovation Pathways in Kenya

Climate change and variability pose new challenges for development. In 2008, a UK supported research project took maize in Kenya as a starting point from which to examine different types of innovation proposed by various actors in response to climate change. Discussions with farmers, plant breeders, policy-makers, extension workers and executives in commercial seed companies identified nine distinct 'innovation pathways'. The idea was to open up the debate about alternative responses to environmental change, both within maize agriculture (including high input/low input and public/private options) and out of maize, to other crop-based livelihood options.

A novel aspect of the project involved using an investigative tool, called a Multicriteria Mapping (or MCM) exercise. MCM is a data-collection tool that can be used during interviews or group discussions to identify and assess a series of different options. In this particular exercise, a broad cross-section of stakeholders were each asked to evaluate the nine core innovation pathways, alongside any others they wished to add. Crucially, the MCM tool asks interviewees to select their own criteria against which to evaluate the pathways.

A further unusual feature of the MCM method is that it does not just ask interviewees to score each option (in this case an innovation pathway) against their own chosen criteria; it asks them to provide two scores – an optimistic score, and a pessimistic score – for each criterion. Once interviewees have assessed all the pathways against each of their chosen criteria, the software then calculates their aggregated weighted optimistic and pessimistic scores for all the pathways against all the options.

In terms of the new TA models, MCM as a method is intentionally flexible, insofar as it is designed to enable a range of technological and non-technological issues to be considered simultaneously across various perspectives. It is also participatory, insofar as the whole point is to capture the richness of inputs from diverse stakeholders and citizens. As a piece of software it lends itself in principle to use within more virtual forms of assessment, and in principle it could be used on any scale, from a single village to a transnational set of participants.

What are the case studies – why are we using a case study approach?

Among a large number of examples drawn from around the world, this report will focus in detail on three core case studies in areas of food, agriculture and emerging technologies (summarised in boxes 1, 2 & 3). Each embodies one or more of the characteristics of 'new models of technology assessment' listed above. The extent to which each case study illustrates the characteristics is illustrated in table 1 below, which also illustrates the characteristics of other examples covered in less detail in this report (marked with a *).

A key point that is considered throughout the report is to what extent have the characteristics of 'new models' been reflected in each of the case studies, what difference to the practice of TA they make, and what consequences have these new forms of TA made, if any, to technology policy-making processes in developing countries.

Case study	Extent to which each characteristics of New Models is illustrated by case studies				
	Participatory	International	Networked	Virtual	Flexible
IAASTD					
Maize MCM, Kenya					
Nanodialogue, Zimbabwe					
WWV on Global Warming*					
Nano-purification, Peru*					
Nano-sensing, Nepal*					
Prajateerpu*					
Argentina scenario exercise*					
Peri-urban MCM, India*					

Key

Poorly illustrated by case study
 Somewhat illustrated
 Well-illustrated

Table 1. Mapping various technology assessments against each of the characteristics of the 'new models' discussed in this report

Box 3. Exploring the role of new (nano)technologies in clean water provision in Zimbabwe (Grimshaw *et al.*, 2007, Stilgoe, 2007, Mellado, 2010)

The broad category referred to as “nanotechnologies” (those technologies which contain components measuring below 100nm in one dimension) contains within it techniques and applications that have the potential to bring about pervasive changes in society and its interactions with nature. These changes have been studied using both conventional and new models of technology assessment in OECD countries, but there are relatively few examples of such debates in developing countries. One such example occurred over three days in 2006, when UK researchers from the think-tank DEMOS and the University of Lancaster, the non-government organisation Practical Action, local stakeholders, scientists and members of two communities in Zimbabwe gathered in Harare to examine the following question:

Can Nanotechnologies help achieve the millennium development target of halving the number of people without access to clean water by 2015?

This was part of a larger, UK-supported programme of 'Nanodialogues' run by the government centre on public engagement in science and technology policy, ScienceWise. The Zimbabwe workshop focussed on identifying and understanding the various sources of the problem of water provision, as well as discussing a number of potential technological and non-technological solutions. Nanotechnologies were included as one option within this complex situation. Through involving community members directly in a participatory process, and addressing not only technological, but also cultural and political issues in discussion, the Zimbabwe nanodialogue broadened both technical and lay inputs to the debate and also delivered a number of general recommendations to government and non-government actors at national and supra-national levels. Stakeholder workshops and conferences to discuss similar questions have since taken place in Peru and Nepal, again co-ordinated by Practical Action and partners, however opportunities for networking these cases have not yet been fully exploited. Findings from these other exercises are also dealt with in this report, although in less detail.

The three case studies summarised in Boxes 1-3 have been chosen to represent not only different aspects of 'new models of technology assessment' but also a diversity of scales (of timeframes and geographical reach), cost (between \$15,000 and \$15 million) participants (private, public and government sector), domains of interest (agriculture, climate and water/health) and methodologies. In addition to the core case studies above, we will be drawing upon evidence from other examples where various characteristics of 'new models' have been demonstrated in other TA-like exercises. Given the paucity of data in this area, linked to the relatively small number of TA processes that have taken place in developing countries, a targeted case study approach of this kind is the only possible way to empirically gauge the potential for new models of TA to contribute to development, and the conditions under which this contribution can be most effective. At the same time, the absence of counterfactuals (in other words, what would have happened without any given TA exercise) mean that drawing definitive conclusions about the impact of specific TAs is impossible. Even when TAs have served to alter policies or technologies, decision-makers will only rarely acknowledge their importance in official communications. In addition, the long time-scales involved make it difficult to attribute impacts on technological trajectories to particular TA activities, and in cases where TA has taken place in the last 10 years, it is unlikely that concrete impacts can be identified.

STRUCTURE OF THIS REPORT

This report continues with a summary of the changing debates around technology assessment, the problems of investing in technologies in the absence of any TA, and the weaknesses of certain conventional forms of TA. We then provide a description of the 'new models', outlining both some of their challenges, and the opportunities they present for more explicit attention to incomplete knowledge, and for broadening out and opening up debates about technological choice. We analyse the three case studies in the light of that discussion, and draw lessons that illustrate how new models of technology assessment, or elements of those models, might best be applied in developing countries or at a transnational level. After analysing the possible impacts of TA on specific sectors, we conclude by making recommendations for the future of technology assessment for development.

CHANGING DEBATES ABOUT TECHNOLOGY ASSESSMENT

TA emerged initially in the United States during the 1960s, and was institutionalized in the Office of Technology Assessment (OTA) in 1972, and subsequently in several other OECD countries in the 1970s and 1980s. TA emerged partly as a consequence of the fierce political controversies around technologies such as civilian nuclear energy. It was seen by its proponents as providing an unbiased analysis of the impacts of a technology in order to guide political decision-making about which technologies should be supported.¹ Brooks argued, for example, that "ideally the concept of TA is that *it should forecast, at least on a probabilistic basis, the full spectrum of possible consequences of technological advance,*

¹ The act of Congress that established the OTA in 1972 sought assessments that would "provide unbiased information concerning the physical, biological, economic, social and political effects" of technologies.

leaving to the political process the actual choice among the alternative policies in the light of the best available knowledge of their likely consequences” (Brooks, 1976).

The audience for TA has usually been the legislature,² one intention being that TA would provide decision-makers with a counterpoint to Executive monopoly on technical advice and know-how. TA has been used with a focus on either a specific technology or group of technologies, or sometimes on technology related problems. Early efforts focused on the use of statistical and mathematical models to identify and analyse the environmental, and economic implications of new technological innovations, but a variety of quantitative and qualitative methods have been used. These range from brainstorming, literature research, document analysis, expert consultation, case studies, cross impact analysis, cost/benefit analysis, trend extrapolation, decision trees, Delphi methods, computer simulations, and scenario development. The most common data sources were surveys of existing literature supplemented by ‘opinions of experts’ based on discussions, simple questionnaires or Delphi techniques (Dylander, 1980).

Following the institutionalization of TA in the OTA, it became clear, in practice as well as in principle, that technology assessment was not, and crucially could never be, definitively neutral and objective. Critics pointed out that technology assessments were necessarily dependent on non-technical and often implicit assumptions, for example about the nature of the problems requiring assessment, the scope of appraisal, the types of effects to assess, the appropriate methods to employ, the criteria by which effects were to be assessed, and the interpretation of outcomes (Wynne, 1975, Sclove, 2010). These ‘framing’ assumptions as they are often called, determined, for example, the range of concerns included in and excluded from assessment, the future scenarios considered and those sidelined, and the policy options taken into account and those ignored. However, they were rarely recognised explicitly for what they were, namely contestable value judgements. Consider, for example, the questions of how the relative weight should be balanced of the potential benefits of a technology on employment creation, with the potential risks to future generations of children’s health?

In addition to questions about claims of objectivity, the OTA was criticised for the slow delivery of its assessments (typically taking two years to produce a report); for uneven treatment of social consequences (the focus was often on technical feasibility, and on economic, health and environmental implications of technologies and the social, ethical, social, cultural and political repercussions of technologies tended to get less attention); for limited insights into socio-technical dynamics (for example, the interactions between different technologies) and a focus on technical inputs to the exclusion of citizen perspectives. Although the OTA did respond to accusations of lack of social neutrality by involving organised stakeholder groups (academia, industry and civil society groups), it did not create the capacity to examine or integrate the informed views of laypeople. Critics argued that the values, outlooks and interests of lay citizens were often quite distinct from the perspectives and judgements of organised stakeholder groups.

Technology assessment as a more general policy tool declined in the United States after the OTA was ‘defunded’ by a Republican Congress under the first Clinton administration in 1995 (Houghton 1995). Yet, interest in TA has especially increased in the US over recent years, where in 2008 Congress asked the Government Accountability Office to establish a permanent TA capability. Beyond the United States the active international debate around TA has been moving forward over the past two decades, delivering a number of new

² (eg Congress in the case of the Office of Technology Assessment) and the European parliament in the case of the Science and Technology Options Assessment Unit (STOA)

approaches to technology assessment, many of which have been experimented with in different jurisdictions. Various referred to as “constructive technology assessment” (Rip *et al.*, 1995), “participatory technology assessment” (Klüver *et al.*, 2000), “real-time technology assessment” (RTTA) (Guston and Sarewitz, 2002), “interactive technology assessment” (Loeber, 2004), open-source technology assessment or e.TA (Rejeski, 2005), “integrative participatory technology assessment” (IPTA) (Hirakawa, 2010), or a “third generation of technology assessment” (Yoshizawa, 2010) these new approaches are diverse but aspire to more broad-based, inclusive forms of appraisal.

For example, Danish ‘participatory TA’ involved politicians, NGOs, trade unions, journalists, scientists, technology developers and lay people in assessment processes, and experimented with different methods to capture and represent those actors’ views (eg dialogue fora, focus groups, and consensus conferences). It was concerned to make interests and values explicit. The goals of agenda building, articulating views about new technology and fostering public debates on technology became as important as the assessments themselves. Dutch ‘interactive TA’ has stressed the importance of involving all relevant stakeholders so as to offer insights into the extent to which possible development paths are considered meaningful to those actors. It explicitly aims to open up not only a wide array of possible solution strategies but also the definitions of the problem at issue (Loeber 2004).

Importantly, the European approaches all recognised that there are a wide range of norms and values extant in society that have a bearing on technology assessment, particularly on ‘upstream’ issues, such as ways in which issues and problems get defined, or over the choice of effects or impacts to assess. These norms and values were not seen as hindrances to rigorous TA, or in some way separate from it, but were recognised as intrinsic to it: inescapable and necessary to guide, inform and enrich analysis. The onus was therefore on identifying those norms (through participatory processes) and therefore justifying the assumptions informing TA. These participatory forms of TA often had a substantive impact on several areas of European technology policy in both public and private sectors. In the UK, for example, the 1994 Biological Science and Biotechnology Research Council (BBSRC)-funded consensus conference on plant biotechnology³ was an early example highlighting emerging citizen concerns. Along with other research, this helped to influence the UK government’s subsequent investment in research into ethical, legal and social issues around transgenic crops. Subsequent government investment in research around nanotechnologies and society is currently feeding into policies around new materials within the Department for Business, Innovation and Skills.

WHAT ARE THE NEW MODELS OF TECHNOLOGY ASSESSMENT?

Scholars interested in technology assessment have recently been describing possible future approaches that draw on some of the features of the European tradition in TA, and that avoid the criticisms of the US Office of Technology Assessment. Instead of the old model of a country-based, government-led, ‘glass and concrete’ technology assessment office, a redesigned conceptualization of these activities has been proposed; one that is more transnational, networked, virtual and flexible than its predecessors, and crucially that combines citizen and decision-maker participation with traditional subject-matter-based expertise.

³ <http://www.ncbe.reading.ac.uk/NCBE/GMFOOD/conference.html>

These features, it is argued, provide the following advantages:

Combining participatory and analytical inputs: Given that many aspects of TA exercises are value-laden, there is a powerful argument that TA should be informed by the values held by citizens and other stakeholders. This requires a combination of participatory and expert-analytical assessment. Furthermore, other forms of knowledge relevant to a TA, including technical knowledge, are not solely the preserve of a small group of experts, but are also held within broader stakeholder networks.

Transnational: The capability to conduct TA exercises beyond national borders means that in principle, a wider array of organizations, spread over a broader geographical area, can be included in TA activities, and the outputs can be available for use by multiple countries.

Networked: The involvement of multiple types of institutions in private, public and civil society sectors can provide opportunities for participation by a broader set of actors, stakeholders and beneficiaries (across a more distributed geographical range) than older models. Rather than involving technology assessment offices alone, then, they can bring in (as required), expertise from research centres, the private sector, universities and other research organizations, museums, professional associations, NGOs, some of which may in turn be able to provide venues and expertise to organize broader citizen input into TA-like activities.

Virtual: Information and communication technologies present opportunities for TA models to move online, benefitting from Web 2.0 developments that are radically changing the ways in which we create and share information. These have the potential to foster knowledge sharing, and enable networked forms of technology assessment. They can also help TA exercises be more efficient and cost-effective than was previously the case.

Flexible: Networked, decentralised, transnational TA institutions may be able to address a range of technological issues across various disciplines simultaneously, and respond more rapidly to requests for information or advice on a broader range of topics.

TECHNOLOGY ASSESSMENT IN DEVELOPING COUNTRIES

Technology assessment has been much less common in developing countries than in OECD member states, and where it has occurred, it has been largely technical in nature, carried out within centralised institutions or by external consultants in order to inform government or donor projects. Examples include the application of cost-benefit analysis to the construction of large dams (Mehta and Srinivasan, 1999) and Vision 2020, in which the UK's Department for International Development and the World Bank supported the government of Andhra Pradesh to develop its agriculture and development strategy (which included an important technological component) (Kuruganti *et al.*, 2008).

It has long been recognised that the introduction of technologies without regard to the cultural contexts and preferences to which they are being disseminated often leads to low adoption of the technologies, as illustrated by examples from the energy, health and agricultural sectors. The introduction of solar cookers in Africa in the 1970s largely failed due to cooking preferences amongst local women – they were afraid to burn their hands, preferred not to cook outside at noon and in any case reserved their traditional 'stove' for evening cooking (Châtel, 1979). More recent approaches have included village meetings, interviews and discussions in the assessment of rural energy technologies (Hifab/TaTEDO, 1998). These more participatory approaches have been expanding throughout the continent. Research at CIFRES (the International Centre for Research and Training in Solar

Technologies) in Senegal, for example, currently uses an iterative approach involving users in the continuous assessment and improvement of solar 'greenhouse' ovens. A team of researchers visited villages over a period of months in 2011 to discuss the various oven designs with women, and to experiment with local artisans on how they can be manufactured using local materials.

Similarly, low adoption of bed-nets for malaria prevention in Western Kenya has been attributed to the similarity of the white nets to burial shrouds used in those communities. Uptake was thus improved when the colour of the nets was changed (STEPS Centre, 2010). The move towards 'appropriate technology' (specifically designed with cultural compatibility in mind) and participatory approaches of technology development (eg participatory plant breeding) were attempts to avoid such wasted domestic and external expenditure on science and technology. However, mechanisms for meaningfully involving stakeholders including users in technology assessment activities beyond dispersed and isolated experiments have not really materialised. This does not mean that the importance of broadening out technology assessment is not recognised, as illustrated by a number of contemporary policy examples.

The UN Framework Convention on Climate Change encourages developing countries to undertake 'technology needs assessments' (TNAs) in order to inform technology transfer efforts by other parties to the convention. Many have adopted primarily technocratic approaches to such assessments, and earlier needs assessments sometimes often read more like technology wish lists than detailed assessments of technological needs and existing capabilities (Ockwell *et al.*, 2009). However, handbooks on the process (CTI, 2002, UNDP, 2004) have highlighted stakeholder participation as an important part of the process and include "households, communities, small businesses and farmers that are or will be using the technologies and who would experience the effects of climate change" as one of the potential groups to involve (UNDP, 2010, page 13).

Only a few limited examples of participatory technology assessment activities associated with emerging technologies have taken place in developing countries. For instance, it was during the early 2000s that arose an increased interest in participatory, 'deliberative and inclusionary processes' (DIPs) (Wakeford, 2001) which were applied around emerging technologies and other potential solutions to development challenges (Wakeford, 2004). For instance, several examples exist of innovative TA processes that investigated the potential role of genetically modified crops in food or fibre production. A Citizens' Jury on Genetically Modified Organisms (GMOs) in Karnataka, India, delivered a verdict that questioned the effectiveness of Bt cotton in responding to the challenges of poor farmers, raised concerns around environmental sustainability and put forward non-technological alternatives (ActionAid, 2000). Citizens' juries have since been facilitated in Mali (IIED, 2007), Zimbabwe (Rusike, 2003), and Brazil (Toni and von Braun, 2001).

Similar approaches were adopted in a later jury which included, but was extended beyond the technological domain when Indian farmers in Andhra Pradesh were engaged in a process to outline their vision for agriculture. The outcomes of this process, known as *Prajateerpu* (Telugu for 'the peoples' verdict') questioned the vision of the state government (outlined in its 'Vision 2020' proposal) and put forward an alternative constructed by more marginalised and voiceless groups, including those from lower castes (dalits) and tribal areas (adivasi), and women, which took a notably different view on the promotion of genetically-modified crops (Kuruganti *et al.*, 2008). This initiative resulted in parliamentary questions being asked of the UK Secretary of State for International Development (Hansard, 2001a, Hansard, 2001b), may have had political impacts in Andhra Pradesh and contributed to "a re-assessment of technological fixes to agricultural production", reflected in the framing of IAASTD, one of the

case studies analysed here (Kuruganti *et al.*, 2008). The controversy that emerged following this episode highlighted the difficulties involved when participatory TA threatens trajectories favoured by powerful governance actors. Opening up the outputs of such processes to highlight plural viewpoints may provide a platform more suited to ongoing, constructive debate, and early exploration of marginalised perspectives (in advance of, and feeding into policy proposals) may offer the opportunity for linking the outputs of pTA with governance and innovation processes.

The governance systems in which technology assessments are embedded are a key factor influencing the ways in which their outputs are applied. Some have argued that while deliberative and inclusionary processes “have at times been misused or abused in the rush to scale up and spread the new innovations”, they still offer opportunities for more democratised governance (Pimbert, 2001). A lesson from the above processes is that impacts are only likely to emerge when the organisations involved, and the systems into which the DIPs feed, are also transformed to be flatter, more open, democratic and accountable. The question remains, therefore, whether new models of technology assessment, especially their ‘global’ and ‘networked’ characteristics, can build upon these more isolated experiences with DIPs to deliver outputs that can constructively feed in to decisions at an international level, against a backdrop of power dynamics which too often see participatory approaches appropriated by elites or forced aside by the momentum of technological change.

HOW CAN THE ‘NEW MODELS’ CONTRIBUTE TO DEVELOPMENT?

There are several *potential* reasons why the new models of technology assessment might be better suited to addressing the interests of poor and vulnerable populations in the developing world, as compared to the status quo. In this section we first argue that those potential benefits are most likely to occur where the new models, or elements of those models, are explicitly orientated to a) ‘broadening out’ the inputs into TA exercises, and b) ‘opening up’ the outputs of TA to wider policy debates. The second part of this section then returns briefly to the characteristics of these new models – that they are global, networked, virtual, flexible and that they combine citizen participation with traditional analytical expertise. We highlight why those features might themselves be useful in a development context but we also argue that many aspects of the new models are also highly compatible with broadening out inputs and opening up outputs to TA.

BROADENING OUT THE INPUTS TO TECHNOLOGY ASSESSMENT

One aspect of broadening out the inputs to technology assessment is that of providing a real voice to a greater range of perspectives, including both technology users and other stakeholders involved in innovation processes. The key rationale for broader participation is not simply participation for participation’s sake (whether in terms of democratic ideals or in order to help legitimise an assessment activity). Instead, it is the substantive impact of broader participation, particularly in coping with different dimensions of incomplete knowledge that matters.

Earlier we pointed out that a key problem with the old models of TA was that they effectively assumed a shared consensus over certain ‘framing assumptions’, for example about the questions that should be asked about technologies or technological systems, the kinds of

impacts, harmful and beneficial, that matter, and that matter the most, the kinds of criteria by which those impacts should be assessed, and the ways in which different kinds of impacts should be compared. Attention to these subjective, value-based issues needs to be central to any rigorous approach to assessment.

A practical response is simply to ensure that there is effective engagement with a full range of stakeholders and public constituencies. This helps ensure that the priorities, questions and framing assumptions that are important to people are identified, and subsequently included in assessment. This particularly applies to poorer communities, who are marginalised not only from policy processes, media and other institutions, through which they might otherwise make their preferences and values known, but who are also unable to make those technology-related preferences and values explicit through market mechanisms, by dint of the fact that those groups exercise little effective demand. Including the perspectives of marginalised groups in TA exercises may therefore serve as a means of translating the 'needs' of poorer users into 'demand' that can be subsequently brought to bear on innovation actors. A more general point here is that involvement of multiple stakeholders, including importantly the private sector, offers a means of 'wiring up' and strengthening the connections between actors and institutions involved in innovation processes (eg private firms, public sector research centres, users, funders, decision-makers) so that knowledge can flow more freely among the constituent actors, and the system as a whole (Martin and Johnston, 1999).

Engagement with a wider range of stakeholders and citizens also has the virtue of enabling a more robust response to uncertainty. Knowledge relevant to TA exercises resides in many different groups of stakeholders and locations, and may be ignored or undervalued unless explicit mechanisms exist for bringing it into assessment processes. Stakeholder engagement may also reduce the costs of TA exercises if that knowledge is already available within business, civil society and other stakeholder networks.

A second aspect of broadening out the inputs to technology assessment is that of extending the scope of assessments to include a wider range of issues and options. In practice this means taking care that TA is able to move away from the assessment of the attributes of a single technology – often that favoured by dominant actors or under prevailing market forces – to addressing a range of contending options favoured under a range of different interests and perspectives, including those that are held by less powerful groups. This can be facilitated by organising assessment around a well-defined problem, rather than on the attributes of some particular selected technology. Different technological, non-technological and hybrid options for responding to the problem can then be more readily identified and assessed. Only in this way can TA genuinely enable real choices to be made explicit among a variety of different possible technology or policy trajectories.

OPENING UP THE OUTPUTS FROM TECHNOLOGY ASSESSMENT

Opening up the outputs of technology assessment means that instead of providing a single, ostensibly definitive (objective and comprehensive) characterisation of a technology or technology-related problem, the assessment delivers a more plural set of outputs – each conditional on stated assumptions. Crucially, this is not a license for 'anything goes'. There is nothing that prevents such a process from identifying those options that appear less favourable under a variety of scenarios and perspectives. Instead, this plurality of outputs offers greater robustness in the face of irreducible uncertainties and ambiguities uncovered during the TA process. This may occur, for example, when the identified social, environmental, and economic implications of a technological option are considered

variously 'good' or 'bad' depending not on technical aspects, but on value judgements. TA oriented towards 'opening up' therefore seeks fully to reflect different stakeholder and expert perspectives as to what the different technological and policy options are, or the different priorities, questions and criteria relevant to preferring one option over another (Stirling, 2010).

Plural TA outputs can thus help decision-makers and funders recognise the multiple perspectives and priorities among users and others involved in innovation processes, and the range of uncertainties that exist. It can help highlight new options, neglected issues, areas of uncertainty, and perspectives that would otherwise be marginalised. Although not determining a specific decision, this can nonetheless makes it easier to arrive at decisions about which kinds of projects to support or where to allocate resources. It does this by revealing more clearly the particular assumptions, values and interests under which different courses of action might be favoured and by ruling out a range of possibilities that fail to command support across a wide range of perspectives. Where TA refrains from 'closing down' around singular forced conclusions and instead deliberately represents divergent reasonable conclusions, then there can be much greater confidence in the basis for excluding those conclusions that are rejected. In short, 'opening up' TA in this way helps ensure that associated decisions are properly informed and more robustly accountable.

Opening up the outputs of TA in this way – so that they reflect more explicitly the different kinds pros and cons of competing technological and policy options, and the uncertainties associated with those pros and cons, can also help prevent institutions and policies from becoming locked in around certain, singular technological solutions. Greater attention to the existence of real choices over desired directions of social and technical change also means that the option is open to encouraging multiple technology-based strategies in the face of uncertainty. If, for example, it is not clear whether a particular low carbon technology will or will not involve unacceptable risks in the future, perhaps a better option is to encourage two or more technological options that would allow one to be withdrawn if it later turned out to involve unacceptable risks. Plural and conditional TA outputs can therefore help recognise the possibility of flexibility in technological options.

One important implication of opening up the outputs of TA – of relaxing the pressure to claim a single definitively objective and comprehensive characterisation – is that TA could be less onerous and costly than centralised, technical approaches in terms of resources and the in-house expertise required. The expectation within traditional TA that results should be impartial and comprehensive, demands a time-consuming, resource intensive process. In the end, intrinsic uncertainties and ambiguities mean that the aim of justifying definitive objectivity is in any case never fully defensible. By contrast, TA exercises that explicitly deliver plural outputs can be more relaxed about claiming definitive status for analysis. This does not imply a compromise on quality, indeed: this deeper attention to unavoidable conditionalities might be seen as enhanced technical rigour and quality in relation to political decision making. What is different is primarily the greater technical humility of an 'opening up' approach, acknowledging that no single one among a diversity of perspectives is necessarily in itself comprehensive or definitive. They merely need to be able to reflect the diversity of opinion accurately to decision-makers.

METHODS TO ENABLE BROADENING INPUTS AND OPENING OUTPUTS

The twin characteristics of broadening inputs to technology assessment and opening up outputs often involve new methods for conducting TA, as well as changes in the expectations of those commissioning TA exercises, and those who are expected to respond to the outputs. Figure 1 below, highlights a range of methods, both expert/analytical and participatory/deliberative that can be used in TA. These are depicted along two axes, according to whether they tend to involve a narrow or broad range of inputs, and whether they involve closing down or opening up of outputs.



Figure 1. A schematic space for imagining individual methods in TA design (from Stirling *et al.*, 2007).

PARTICIPATORY APPROACHES AND THE NEW MODELS (COMBINING CITIZEN PARTICIPATION WITH TRADITIONAL ANALYTICAL EXPERTISE)

Most of the characteristics of the new models of technology assessment are highly conducive to broadening out inputs and opening up outputs in the ways described above. Most obviously, the ambition and methods to broaden participation – by linking deliberative with expert/analytical approaches to technology assessment - can clearly expand the range of inputs. This has long been recognised, both in the United States (Fiorino, 1998) and Europe (Renn, 1999) as vital in order to capture the social and technical complexities and uncertainties at stake in technology development. This applies no less, in principle, in developing country contexts as it does in industrialised countries. Indeed, there is probably a greater gap between the life experiences, realities and priorities of poor users of technology, those of urban based scientific and economic experts, in developing country contexts than in industrialised nations. It is perhaps more important therefore that decision-making about the priorities, funding and development of technological projects in the developing world are informed by broader citizen and stakeholder perspectives. Furthermore, poor technology users generally exert little market demand on private sector actors, and there are thus no

other mechanisms, other than participatory TA, by which the perspectives of marginalised groups can be brought to bear on innovation actors.

The participatory features of the new models are also compatible with methods that seek to deliver a more plural set of outputs – each conditional on stated assumptions. It is by doing this that the value of involving a broader range of stakeholders and citizen groups is maximised because it reveals more clearly to decision-makers and those responsible for the allocating of funding and investment the particular assumptions, values and interests under which different courses of action might be favoured.

NETWORKING – MULTI-ACTOR COLLABORATION ACROSS NATIONAL AND INTERNATIONAL LEVELS

The networked nature of the new TA models means that it is easier to broaden out the inputs to technology assessment in terms of issues, options, and knowledge. This is because networked approaches make it easier to involve a wider array of organizations, spread over a broader geographical area, than would be possible using conventional forms of technology assessment. Such organizations include private sector firms, universities, other research organizations, professional associations, who might not otherwise be involved in TA exercises.

Over and above the utility of networked models for broadening out inputs to TA exercises, if relevant knowledge is already available within business, civil society and other stakeholder networks, networked forms of assessment can help bring in that knowledge to TA processes in ways that are more cost-effective than a centralised approach. This may be particularly advantageous in developing country settings. Networking approaches to TA also enable the inclusion of actors that are important for making innovation process function. This offers a means of strengthening the connections between actors and institutions involved in innovation processes (eg private firms, public sector research centres, users, funders, decision-makers) so that knowledge can flow more freely among the constituent actors, and the system as a whole.

Whilst the involvement of museums (with an educational as well as engagement remit) has been highlighted as a possibility in the United States with respect to the ECAST Network, it is questionable whether most developing countries possess the required capacity in this area. One example where museums have played a role was 'Nanoaventura' - a travelling exhibition on nanoscience and technology developed by the UNICAMP science museum in Campinas, in the state of São Paulo, Brazil. The exhibition involves an introductory educational video and presentations, followed by interactive games in which participants (9-14 year olds) are able to simulate nanoscience experiments or conduct virtual laboratory tours, leading to discussion (Murriello *et al.*, 2006). Here, the focus was on introducing the ideas behind the science and technology rather than conducting technology assessment.

Even so, it may be possible that museums could play a role in applying new models of technology assessment to development, especially if this is on the basis of regional networks that pool resources in order to overcome limits to national domestic capacity. One such example is The Latin American network on nanotechnology and society (ReLANS), co-ordinated by the Development Studies Department at the Autonomous University of Zacatecas and the Centre for Interdisciplinary Research in Sciences and Humanities at the Autonomous National University of Mexico⁴. This has amongst its objectives the creation of

⁴ <http://www.estudiosdeldesarrollo.net/~webrelans/inicio.html>

a forum for dialogue and information exchange on the development of nanotechnologies in Latin America, especially its political, legal, ethical, environmental and social impacts. It has held training sessions and multi-stakeholder meetings to discuss these issues, and produced publications on nanotechnology and society in Latin America and various countries within it.

VIRTUAL APPROACHES - UTILISATION OF WEB PLATFORMS FOR TECHNOLOGY ASSESSMENT

Virtual forms of TA can enable participation of institutions and citizens in developing countries that are more difficult and costly to achieve with conventional TA. Again this can help serve to broaden out inputs to TA exercises, but virtual forms of TA may also be easier to scale up, or operate at varying scales, as compared to traditional, institutional-bound TA.

Based on experiences in the United States with the National Citizens' Technology Forum on Nanotechnology and Human Enhancement (2008) and focussed research in the UK (Wilson and Casey 2008) Sclove argues that "use of the Internet may also make it possible to increase the number and diversity of participants in pTA at relatively low cost" (Sclove, 2010). This mass engagement requires scalable technology assessment activities working on mobile/internet platforms. Although not yet available, it is possible that MCM-type approaches or other tools and methodologies could be converted to run on a web interface to invite online participation from across the world. At the same time, such forms of engagement need to be easy to participate in and to be highly engaging in order to be successful. To date, successful virtual participatory processes have usually been oppositional, failing to deliver enhanced policy (Wilson and Casey 2008). Despite rising access to the internet in many parts of the developing world, limited access is an obvious barrier to engaging the poorest. Blending modern ICTs with existing information systems (radio, extension services) may offer a way to 'connect the first mile' (Talyarkhan *et al.*, 2004), for example in using small-scale podcasting in local languages, alongside community-level support (as has been utilised successfully by Practical Action in Peru, Zimbabwe and Kenya). Innovative solutions will need to be sought in specific local contexts and building on local infrastructure and modes of knowledge sharing.

FLEXIBLE AND AGILE TECHNOLOGY ASSESSMENT FOR DEVELOPMENT

Technology assessment that, through its networked and virtual character, provides for more flexible, responsive activities could prove particularly useful in developing countries. Where capacity and resources are limited, the ability for organisations to reconfigure themselves to address particular challenges can deliver cost savings and allow meaningful TA to take place, even in the absence of the resources required for formal assessment. When citizens are facilitated in self-organising of participatory technology assessment (as illustrated in the case of the GM Nation? public debates in the UK in 2003) large amounts of data and information can be gathered for relatively little expenditure. If incentives for participation were effectively constructed, similar 'self-organised' pTAs might be possible in developing countries, with co-ordination and data collation taking place online or through mobile telephone networks.

GLOBALISATION AND OPPORTUNITIES FOR INTERNATIONAL TECHNOLOGY ASSESSMENT

In the early 1980s, Oldham and Kaplinsky discussed the idea of an "early warning system" to investigate emerging technologies, their potential benefits and possible future negative

impacts. This task has to some extent been taken forward by UNCTAD and by NGOs such as the South Centre, however their activities are limited and a permanent observatory does not exist. The increasing number of sources of innovation (Ely and Scoones 2009) and the ever-increasing pervasiveness of technologies and their impacts means that the need for global co-ordination and governance has never been greater. Despite this need, existing governance questions and limits to the accountability of international organisations raise continuing questions about the workability of technology assessment institutions working at the global level (Van Zwanenberg *et al.*, 2009).

The Rockefeller Foundation-supported work on 'pro-poor foresight' and scenario thinking around the future of technology and development (Bezold *et al.*, 2009) illustrates that international engagement and thinking is necessary not only to derive useful data for policy, but to foster greater understanding across geographical, cultural and political contexts.

Transnational technology assessment has been common within Europe under the Commission's STRATA programme and through the activities of STOA. However, expansion beyond these regional (and OECD-focussed) networks is now increasingly required. Emerging economies such as India and China are rapidly becoming sources of innovation, especially those forms of technology that might serve poorer users (Kaplinsky, 2011). Some private sector actors in emerging economies are already utilising nanotechnologies in products serving the poor in so-called 'bottom billion' markets (for instance, in response to more expensive filters made in OECD countries, the Indian firm Tata Chemicals has developed the Tata Swatch – an inexpensive water filter capable of serving a family of five without energy or running water). With similar patterns of expanding innovation activity in China and Latin America, it is appropriate for a broader range of international partners to participate in technology governance, with a shared agenda around global challenges.

One of the few examples of a participatory transnational technology assessment is the Worldwide Views on Global Warming initiative, co-ordinated by Teknologirådet, the Danish Board of Technology. This sought input from diverse groups of citizens in 38 countries on policy responses to global warming. It was timed to feed into the UN COP15 climate negotiations in Copenhagen in December 2010 and involved a number of public events in which 1000 citizens were provided with "balanced and scientifically-based information" on climate change and allowed to deliberate for several hours prior to voting on pre-defined (standardised) questions and putting forward their own, qualitative recommendations. This concerted initiative for the first time provided input from diverse groups of citizens across the world to a key moment in international policy-making. It illustrated the shared conviction of like-minded participants on several issues and on these provided policy-makers with a clear and resounding mandate to act.

The Worldwide Views initiative (as well as the IAASTD exercise outlined in Box 1) illustrate the potential of transnational technology assessment for development and suggests a role for similar exercises. At the same time, cost and co-ordination challenges must not be underestimated, and flexibility and networked activities are key to efficient use of financial and human resources.

LESSONS FROM THE CASE STUDIES

We now provide a brief review of our case studies, focusing on the extent to which they both enabled a 'broadening out' of inputs to the TA exercise in question and an 'opening up' of outputs to wider policy debate. We also discuss the consequences of these shifts for the nature of the TA process and for subsequent policy decision-making processes.

BROADENING OUT THE INPUTS TO TECHNOLOGY ASSESSMENT

Boxes 4 to 6 discuss the extent to which, and how, in each of our three main case studies, participation was extended so as to enable a greater range of perspectives and knowledge to be brought to bear on the assessment process. The boxes also highlight some of the consequences of that broadening out.

Box 4. Broadening participation through a multi-stakeholder process in the IAASTD

The IAASTD, right from the outset, was intended to be much more inclusive and participatory, in both design and process, than traditional global expert assessments. An international multi-stakeholder steering committee established the scope of the assessment - and the processes and procedures by which it would be conducted and governed – following consultation with over 800 participants from diverse sectors and locations. The assessment itself was overseen by a multi-stakeholder Bureau – comprising representatives from government, the private sector and civil society. The Bureau selected 400 scientists, from a range of disciplines, and institutional settings, to author the report, and the drafts were subjected to two independent peer reviews by assessors from government, civil society, industry and specialist research institutes.

There was no direct representation of farmers or their organizations in the Assessment, whether at the early consultation stages or subsequently, and limited funds meant it was not always possible for the authors of the reports to consult, as they had been encouraged to do. Some commentators regarded this as a fundamental design flaw of the whole process, undermining the legitimacy of the effort as a whole; others saw this as a necessary consequence of convening such a process, but one which allowed space for (indirect) representation by NGOs and other civil society organisations.

The inclusion of private sector and civil society representatives, from diverse geographical locations, had several important consequences. First, it meant that perspectives that might not otherwise have featured within the Assessment were at the very least voiced, and on occasion found their way into the overall report. As one participant noted: "perhaps for the first time, those advocating sustainable agriculture and indigenous knowledge had been given a place at the table, and got (some of) their views acknowledged." Second, it meant that a whole range of viewpoints, perspectives, arguments, assumptions and types of evidence were brought together in one place, producing frequent tension, especially between the more conventional production-oriented analyses, and those emphasizing environmental, social and political issues and the multi-functionality of agriculture. This was considered by some commentators as unhelpful, but for others it was the result of effective inclusion, where controversies were dealt with and compromise sought. One of the key findings of the IAASTD is that there are diverse and conflicting interpretations of the past and current role of agriculture science and technology in development, which need to be acknowledged and respected.

(Sources: IAASTD, 2009, Scoones, 2009)

The cases illustrate how there are a range of practical ways in which to capture the values, priorities and knowledge of stakeholders and citizens. These range from the use of specific methods, such as the MCM and citizens juries, to the adoption of particular ways of organising TA, such as the multi-stakeholder approach of the IAASTD. The cases also show how these approaches have enabled the key value-laden aspects of TA - such as questions about the nature of the problems to be addressed, the choice of effects or impacts to assess, and the relative importance of those effects - to be exposed to broader stakeholder and/or citizen deliberation. In some cases, (eg the IAASTD) the outputs of these deliberations then informed more traditional analytical expert-based assessment. In others (eg the MCM) the assessment as a whole was conducted by particular stakeholder/citizen actors.

Box 5. Broadening participation in the Zimbabwe Nanodialogue

The Zimbabwe stakeholder workshop involved a broad range of stakeholders and deliberately attempted to 'broaden out' the inputs to the debate. Academics from the Zimbabwean Academy of Sciences, the University of Lancaster in the UK and NorthWestern University in South Africa also provided technical inputs. Policy makers from the Ministries of Science and Technology, Environment, Health, Agriculture the Zimbabwean National Water Authority, as well as decision-makers at sub-national levels. It also included users from two communities, rather than seeing them as a uniform group experiencing similar challenges.

It is possible to identify a number of ways in which the outputs of the Technology Assessment benefitted from the broadening out of the inputs. The inclusion of two communities and the exploration of their different problems enabled attention to be paid to a diversity of contexts in which nanotechnologies might be employed – with issues such as control and ownership (which might otherwise have been neglected) put forward as key issues for consideration. The broadening of inputs to include perspectives from the communities also illustrated some of the problems with previous technology-based solutions, and allowed scientists and policy makers to extend these to the ways in which nanofilters might fit within the practical situations in which the communities found themselves. The community members' responses to previous technologies, and the difficulties those raised (eg around availability of parts or expertise for maintenance and repair, leading to unsustainable interventions by NGOs), were useful insights provided by their participation. This inclusive approach also allowed community and scientist responses to the key issues to be compared, drawing attention to the differences between them and highlighting otherwise implicit assumptions. For example, community members highlighted access issues as the main hindrances to society's uptake of new water-related technologies, whilst scientists pointed more to community empowerment and involvement in the development process.

According to the organizers of the event, including policy-makers and other innovation actors among those present at the workshop led to improved understanding and capacity within those groups than would have been the case if a technology assessment had taken place without their participation.

The stakeholder workshop approach illustrated by the Zimbabwe nanodialogue was also utilised in a similar exercises, again co-ordinated by the international NGO Practical Action, that investigated potable water provision in Peru and Nepal. The emphasis at a seminar (November 2007) and workshop (April 2008) in Peru was on identifying a key problem/need: mercury pollution from small mines in the Andes. These events led to the establishment of a Spanish language website and network across the Andean region, and an ongoing linkage with nanotechnology researchers in the UK.

Box 6. Broadening participation using a specific method: Multi Criteria Mapping and Maize Innovation Pathways

MCM exercises are intentionally designed to capture and illustrate the perspectives of different groups of stakeholders. In the Kenya maize MCM, potential innovation pathways, or options, were initially identified through discussions with farmers, plant breeders, policy-makers, extension workers and executives in commercial seed companies. These stakeholder groups were then invited to assess each option, on the basis, importantly, of their own chosen criteria. Many conventional technology assessment processes focus on a relatively small number of criteria to assess a technology or series of technological options (such as human health or economic cost, or biodiversity damage) and this tends to mean that the full depth and diversity of different viewpoints about which criteria are relevant (i.e. which kinds of impacts matter) are not fully recognised. MCM exercises allow stakeholders to choose as many different criteria as they wish, and to weight them, in their own terms, in order of importance.

Thus, the Kenya MCM exercise allowed researchers, in this case, to identify the range of different ways in which, for a given problem, different groups, selected potential technological and policy options, decided on the kinds of impacts that were relevant, weighted those impacts by importance, and then actually assessed the extent to which those impacts might be positive or negative for each option.

What differences did this make as compared to a traditional expert-led assessment? First it is unlikely that a top-down expert led assessment would have identified the same kinds of options as were identified through the stakeholder discussions. Second, the kinds of impacts that were deemed relevant in assessing the options, from the perspective of the stakeholders, as well as the relative importance of the different impacts, could not have been anticipated by a centralized expert group, because those preferences are predominantly value-based. As a consequence of this broader input, and sensitivity to how different groups' subjective understandings inform assessment, the Kenya MCM exercise produced a range of interesting, and even counter-intuitive, findings. For example, quite different groups of stakeholders – maize farmers, the biotechnology industry, and public sector researchers – were all more optimistic about the performance of the option of promoting alternative dryland crops in response to climate change, as compared to other options such as commercial, public sector or locally-driven improvement of maize varieties.

Another event, on 26 May 2009 in Kathmandu, focussed on developing a design brief for an arsenic sensing device. Around 1.4 million people are at risk from arsenic contamination in the Terai region of Nepal (UNICEF 2006), and it is also a problem elsewhere in South Asia – wells dug by foreign aid agencies in the 1970s and 80s have led to severe health implications in some parts of Bangladesh (Clarke 2001). The workshop brought together multiple stakeholders including scientists and representatives of communities, together with the Department of Water Supply and Sewerage, Government of Nepal. Discussions and outputs focussed on characteristics of the testing equipment human factors, data management and the introduction of new methods (Grimshaw 2009).

The design brief delivered a number of specifications that would not have been obvious without the particular methodology used and the broadening out of participation eg different perspectives around the degree of accuracy required, a preference for numeric rather than colour-coded displays amongst villagers, capabilities (and trust amongst peers) required by local users, attention to variable levels of arsenic at different points of the year, cultural issues with the marking of wells, availability of maintenance support and a

requirement for up to 45° operating temperatures. The costs associated with this workshop, delivering this and other context-specific data which feed into the design brief were around £10,000 (at that point approximately \$16,000) (Grimshaw 2009).

Box 7. Broadening the range of options for consideration in the Zimbabwe Nanodialogue

DEMOS approached Practical Action with a proposal for a community engagement exercise around the defined problem of potable water provision, therefore the technology assessment in this case was not focused on a technology per se (Interview with Practical Action Zimbabwe, Nov 2010). The Zimbabwe Nanodialogue devoted a whole day towards exploring the underlying problems of potable water provision, from the perspectives of the community members and multiple stakeholders present. The broadening out of discussions around technological options meant that the exercise was not limited to nanotechnological applications but also involved alternatives (including wells, rope and washer/ treadle pumps, chemical treatment, boiling water, eco-san, sand abstraction, water divining).

Boxes 7 and 8 focus on the second, closely related, aspect of 'broadening out' discussed earlier: namely the extension of the scope of assessments to include a wider range of issues and options. The boxes discuss how, for two of our main case studies, the assessments were focused around a well-defined problem, rather than on the attributes of a particular selected technology.

As the cases illustrate, broadening the scope of assessments allows contending technological and policy options to be explicitly considered, including those that are not favoured by dominant actors or under prevailing market forces. A further example, drawn from Argentina, illustrates why this is important. The case concerns an assessment of technology and policy options for small cotton farmers after the introduction of GM cotton seeds. This group of farmers cannot afford the new seeds, and conventional seeds are no longer available. Instead small farmers obtain copied GM seeds in informal markets, which whilst more affordable, are often of poor quality and uncertain identity. As part of a UK-funded research project, a series of scenarios were constructed based around different options for supporting small cotton farmers' livelihoods, given their problems over access to quality seeds, and covered a range of linked regulatory, technological and policy strategies. Those options were then subject to a formal assessment of their feasibility and their potential disadvantages and disadvantages by experts in government, the seed industry, universities and public sector research organisations. As a consequence the scenarios exercise generated a far wider range of options, and informed views on their feasibility and desirability, than had previously been considered within Argentinean policy processes.

Box 8. Broadening the range of options with a problem-focused remit: the IAASTD

The scope of the IAASTD extended well beyond agricultural science and technology with a decision by the IAASTD steering committee that the scope of the assessment should encompass not only science and technology but also other types of relevant knowledge (eg, knowledge held by agricultural producers, consumers and end users) and that it should also assess the role of institutions, organizations, governance, markets and trade. One consequence of the multi-dimensional nature of the Assessment, and the simultaneous assessment of knowledge and technologies with institutions and policies, was that the agenda was ambitious and wide ranging. The findings ranged from issues such as the system of agricultural subsidies in OECD countries, trade rules and intellectual property law, to traditional and local knowledge and community-based innovation. For some, this was too broad: "...if you propose everything, then you don't prioritise anything," suggested one commentator. Others suggested that the publication of iconoclastic ideas is in itself a triumph. An IAASTD spokeswoman argued that "Even changing perceptions of farming is quite a shift from the past 50 years, and they should drive the agenda for the next 50."

The ambitious scope of the IAASTD (combined with the broadening of voices) has managed to stimulate debates in diverse circles, from community groups working on agriculture and development to discussions at the G8. Debates about issues such as unequal access to food, water and agricultural opportunity have, as a result, been brought further to the foreground of policy debate.

Source: Coghlan, A. (2008) How to kickstart an agricultural revolution, *New Scientist*, 5th April 2008

OPENING UP THE OUTPUTS FROM TECHNOLOGY ASSESSMENT

Boxes 9 to 11 discuss the extent to which, and how, in each of our three main case studies, the outputs from the technology assessment in question were opened up.

In cases where TA outputs were at least partially opened up, such as in the IAASTD, considerable efforts were made on the part of stakeholder participants to provide evidence and arguments about different technological and policy options. This suggests that where stakeholders are confident that their perspectives and arguments would be communicated in outputs, they are willing to invest considerable energy in the process.

As outlined above, methods for broadening out and opening up technology assessments are multiple and diverse. One such method, multicriteria mapping (MCM)⁵ was developed within SPRU-Science and Technology Policy Research at the University of Sussex and has been applied in a number of policy areas in Europe – around transgenic crops, obesity policy, medical strategies for kidney failure and options for the hydrogen economy 0. Using a computer-assisted, interview-based approach, MCM provides a structured means for exploring perceptions among a broad range of actors – and provides opportunities for them to identify the criteria upon which they appraise options themselves.

⁵ <http://www.multicriteriamapping.org/>

Box 9. Opening up outputs in the IAASTD?

The IAASTD process was, for some commentators, beset by a key tension. On the one hand it sought to encourage a plural inclusive process that genuinely tackled normative and political issues and that opened up debates and options on agricultural science and technology issues. On the other hand, it expected that uncertainties could be resolved by rational, objective, scientific debate among expert peers, and that common understandings and visions for the future could be reached, based on the ideal of consensus and an appeal to science and expertise. That tension was successfully managed in part, often through informal debate and argument rather than allowing different political and value positions to be explicitly acknowledged. And the IAASTD did seek to identify where there was consensus on what was well known and where there was uncertainty, and to discuss minority points of view that could not be discounted. Furthermore, it did not make recommendations, only options for action, on the basis that different stakeholders who might wish to act on those options have different sets of priorities and responsibilities, and operate in different socioeconomic and political circumstances. Yet, on particularly contentious issues, such as that of GM crops, consensus was unobtainable; and the underlying world views and perspectives on that issue, and as a consequence the kinds of evidence considered relevant and irrelevant, were not made explicit.

(Sources: Scoones, 2009; IAASTD Steering Group Report)

In developing country contexts, in addition to the MCM exercise described in Boxes 6 and 10, the STEPS Centre has also used MCM in a study of peri-urban sustainability and water provision in India. A researcher used the software to conduct 17 interviews in Ghaziabad and Delhi with members of the peri-urban community, academics, activists and government officials focussing on 6 different scenarios for water management. These included three public initiatives, two private initiatives and one public-private initiative (Public provision of piped water supply and sewerage systems; public provision of piped water supply and sewerage systems with addition measures to support poorer users; public provision of integrated water supply and waste management with addition measures to support poorer users; legalisation of private water vendors; regularising existing means of informal access, water use and waste management; and commercial supply and waste water management).

By comparing these scenarios the MCM exercise emphasised the diversity of water provision options in peri-urban slums in India, and opened up discussion of the pros and cons of different possible options (STEPS Centre peri-urban sustainability project⁶).

⁶ <http://www.steps-centre.org/ourresearch/urbanisation,%20asia.html>

Box 10. Opening up outputs using a specific method: Multi Criteria Mapping and Maize Innovation Pathways

MCM exercises allowed interviewees to choose as many different criteria as they wish when assessing options, and to weight them, in their own terms, in order of importance. It therefore emphasises the diversity of different perspectives, rather than artificially combining these into a single picture, or 'best' option. It helps reveal the ways in which different preferences depend on underlying views about which criteria (i.e. the impacts of a given option) are relevant. In principle, then, it can therefore help decision-makers see the range of choices available to them, what different actors' preferences for those choices are, and their underlying reasons.

In the Maize assessment, nine distinct innovation pathways were identified that farmers in semi-arid regions of Kenya might pursue in response to climate change (ranging from reliance on maize as the key crop to diversification out of maize; and from reliance on internal inputs to external inputs). The pathways were then assessed during group interviews by different groups of farmers, both male and female, some wealthier some poorer, and by national and local government officials, agricultural researchers, plant breeders, donor organizations and agricultural input suppliers. 147 different and unique criteria were defined by informants to evaluate the pathways. These ranged from economic issues such as resource costs, access and availability and market aspects, to stress tolerance issues such as water use and pest and disease resistance, to social, political and cultural issues such as food security and availability of knowledge and skills. Interviewees scored each pathway using their chosen criteria, using both an optimistic and a pessimistic score, were allowed to weight criteria by order of importance. Figure 2 below provides an example of the aggregated, weighted optimistic and pessimistic scores for all the pathways against all the options for farmers in general, and for low income and high income subsets. Each horizontal bar represents one option, the positions of which represent the magnitude of the scores, and the width of which represent the differences between their optimistic and pessimistic scores.

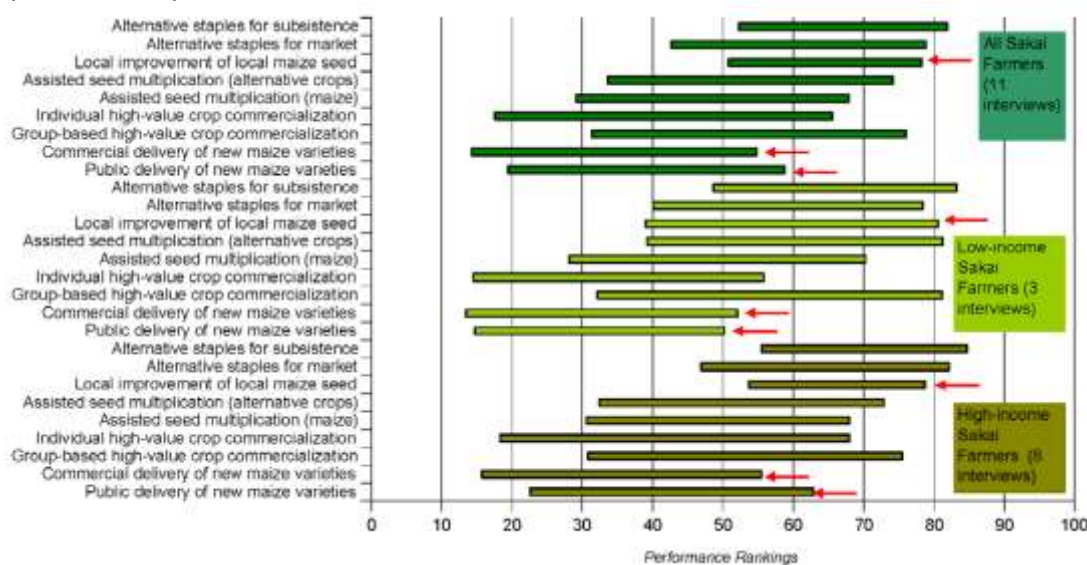


Figure 2. Optimistic and pessimistic scores from different groups of farmers assessing innovation pathways in and out of maize in Kenya

The relevant point here is that this MCM exercise allowed different stakeholders to assess different technological options on the basis of their own chosen, and weighted criteria. In the example above, the MCM exercise illustrates, among other things, that local improvement of maize is favored over commercial or public delivery of new maize varieties, according to farmers' own criteria, and perceptions of uncertainty.

As the boxes illustrate, in addition to MCM, various techniques were adopted across our core cases to allow a broader range of stakeholder and/or citizen input, to more explicitly consider different options, and to open up outputs of assessment to wider debate. The boxes also illustrate how this often had a substantive – and largely positive – impact on the assessment itself. Of course, there also emerge difficulties of implementation. But none of these negate the general validity of this main conclusion. In each case, it is very unlikely that similar findings would have emerged using conventional narrow input/closed output TA approaches to the same technology-related issues. The cases therefore show how assessment can help capture the underlying preferences and values of different stakeholders, including at times technology users – preferences and values that are an integral and necessary part of any TA. We have seen how those broader citizen and stakeholder values and preferences subsequently influenced the definitions of the problems subject to TA (eg the IAASTD, the Zimbabwe nanodialogue), the selection of technological options (the MCM exercise), the choice of impacts to be assessed (eg the IAASTD & the MCM exercise), and the kinds of knowledge considered relevant (the IAASTD).

Box 11. Opening up policy discussions in the Zimbabwe Nanodialogue

The fact that the consensus was generated after the first two days “there is no real water quality issue that cannot be solved with existing technologies” illustrates that promotion of nanotechnological solutions was not at the heart of the process in Harare. The discussions at the end of the third day raised a large number of further questions, including those targeted at scientists, about the possibility of additionally using nanotechnologies, the conditions under which these might be favourable and the timeframe for implementation. Including these ambiguities and uncertainties in the project report, as well as more narrow issues and recommendations, provided a broad basis for future societal discussion. It may not have helped bring about a direct policy change or investment (for a number of reasons discussed above), but the process highlighted the complexities and alternatives to the new technologies.

POTENTIAL IMPACTS IN SPECIFIC DOMAINS

Based on the experiences and evidence presented above, what impacts might be expected on specific sectors (in particular agriculture, health and energy/climate change) from an increased adoption of new models of technology assessment in developing countries and at the global level?

Agriculture

MDG 1c (halving the population suffering from hunger) requires a concerted global effort, which builds capabilities for innovation as well as making technologies available to producers in developing countries. The International Assessment on Agricultural Knowledge, Science and Technology (IAASTD) illustrates that broadening out the inputs to technology assessment, whilst not claiming an objective or singularly authoritative outcome, allowed new issues such as the role for diverse kinds of indigenous/ traditional knowledge to enter the mainstream discourse. At the international level, this indicates the importance of national policies and international programmes that contribute to the conservation of this diversity, accelerating the diffusion of useful knowledge and supporting communities to

harness it and experiment with novel combinations, including those that integrate traditional knowledge with innovations derived from formal scientific research. If the IAASTD had been able to adopt a fuller range of characteristics associated with 'new models of technology assessment' (eg citizen participation, open engagement using virtual platforms), a broader range of outcomes might have emerged, with further detail articulated through wikis and online fora and relative preferences/priorities identified among different geographical and societal groups through online/mobile voting platforms.

At national and sub-national levels, the STEPS 'Pathways in and out of Maize' MCM experience in Kenya illustrates the value of structured engagement process at multiple levels, and points to a potentially scalable tool (MCMapper and Analyst software) through which it is possible to explore the perceptions of selected participants at a workshop or in individual interviews. To date, the potential of this tool for online engagement has not been realised. Although the outputs of earlier forms of pTA around agriculture in developing countries were not directly taken on by governments (Pimbert *et al.*, 2001), they have had an impact on discourse within civil society, which has increasingly begun to mobilise around technology as a legitimate site for democratic debate.

Health

Millennium Development Goals 4 (reduce infant mortality) and 6 (combat HIV and AIDS) require not only new technologies, but governance approaches that open access to existing treatments, currently hampered by economic and political relationships (see MDG 8e). 'Health technology assessment' is an activity distinct from technology assessment and often draws upon quantitative economic approaches to identify the most cost-effective technology investments within health systems (eg disability-adjusted life years or DALYs, which WHO defines as the sum of years of potential life lost due to premature mortality and the years of productive life lost due to disability). Conventional technology assessment approaches can also highlight qualitative impacts not only of technologies but also social changes, and various characteristics of new models of technology assessment can also be applied to this end in the health domain. Here we present a series of possible implications if they were to be applied in specific areas.

Broad, networked technology assessments, for example on options for the prevention and control of orphan diseases, could fulfil an important role not only in identifying candidate technologies but also in building the partnerships so crucial to health innovation (exemplified by PATH MVI, IAVI, and BVGH). In addition, with respect to the challenge of moving beyond standardised, scalable solutions (such as a focus on vaccines), networked participatory assessments could provide context-sensitive information and perspectives from various geographical regions, but, if appropriately designed to be scalable and linked, could also highlight shared concerns that need to be taken into account in determining directions of technology development. Scaling up is a political as well as a technical process (Bloom and Ainsworth, 2010), and new models of technology assessment are better equipped than traditional ones for facilitating the creation of networks that can then go on to act as constituencies advocating and co-ordinating between geographical and institutional domains.

A number of innovative policy instruments are emerging around technology in the health domain. One such instrument that is being trialled is the 'advance market commitment'. Advance market commitments focus on leveraging markets to drive innovation in directions that deliver public goods that are otherwise unlikely to emerge under existing arrangements. A specific example (the first 'pilot' AMC) is that funded by five countries (Canada, Italy, Norway, Russia, the United Kingdom), and the Bill & Melinda Gates Foundation to the tune of

US\$1.5 billion to develop a pneumococcal vaccine against pneumonia and meningitis. The possible use of participatory technology assessment to examine the characteristics of the technological solution being sought (eg a vaccine meeting/ exceeding the 13 requirements specified by the Independent Assessment Committee in the pneumococcal vaccine case) might point to more diverse approaches and enable ongoing democratic accountability.

Beyond investments in new technologies, innovation in business models (Hwang and Christensen, 2008) can make a vital contribution to health provision in developing countries and combinations of social and technological innovations are prevalent in recent work on impact investing (Thornley *et al.*, 2011). Involvement of societal actors in the ways envisaged in new models of technology assessment leaves the door open to non-technical as well as technical innovations, and the possibility for social changes to alter the rules and incentive structures that drive current directions of innovation.

Energy/ climate change

The problem of sustainable energy in the face of climate change – by definition a global challenge – calls for ever more co-ordinated responses and continuous learning and innovation – both technological and non-technological. The ‘Worldwide Views on Global Warming’ initiative represents a pioneering global, networked and participatory example of technology assessment. One of the strengths of the initiative was that it fed directly into a high-level discussion (the climate summit at Copenhagen, 2009). It also allowed qualitative and quantitative inputs, and, although it adopted a similar approach in all geographical locations, was flexible enough to allow diverse messages to emerge from diverse contexts. Although not focussing only on technology, the initiative delivered strong messages from citizens across the world to the policy makers at Copenhagen. The response by leaders was perhaps disappointing, but similar events in the future could maintain pressure and, along with other parallel efforts, catalyse action at the highest levels.

Technology needs assessments (under the UNFCCC) that involve stakeholders and users more closely might be expected to yield a greater understanding and demand for the technologies identified beyond those actors directly responsible for the needs assessment. At the same time, they are likely to build understanding across networks in the countries where they are based, contributing to building vital innovation capabilities that are to some extent neglected by existing approaches to technology transfer.

The Global Energy Assessment (<http://www.iiasa.ac.at/Research/ENE/GEA/>) is an international initiative to redefine policy discourse around energy led by the International Institute for Applied Systems Analysis (IIASA). Like the ‘Worldwide Views’ initiative, it goes beyond technology to look at a broad range of challenges around “energy services for sustainable development, whilst ameliorating existing and emerging threats associated with: security of supply; access to modern forms of energy for development and poverty alleviation; local, regional and global environmental impacts; and securing sufficient investment”. Although involving a number of stakeholders, it does not represent most of the characteristics of new models of technology assessment. Integration of perspectives through participatory exercises might contribute to some of the questions around poverty alleviation and access, as well as highlighting non-technological options that are currently used in developing countries and may offer alternative pathways for energy systems in other parts of the world.

Emerging technologies

Emerging technologies generate controversies and citizen engagement that can be thought of as informal technology assessment (Rip, 1986) and, in some cases, welcomed as a tool in generating robust knowledge. Structured fora that allow this engagement to be harnessed to influence the directions in which innovation emerges could deliver more equitably distributed and environmentally sustainable technological (and other) outcomes, and the interest that emerging technologies can engender can provide a fertile basis for citizen engagement.

Nanotechnologies are one such area of controversy. Although put forward by some as a key component of the new 'green economy' (Lux Research, 2010), other commentators have pointed to the potential for negative impacts of such technologies on communities and ecosystems, including in developing countries (Arnall, 2003), and various groups have since looked into the potential uses of nanotechnologies in development, as well as the impacts of those and others on developing countries. A prominent UK report that began to investigate such issues stated: "It may also be important to look beyond the perspective of Western industrialised societies, to take account of the ways in which people in developing societies might respond to developments in nanotechnologies and their impacts" (Royal Society & Royal Academy of Engineering, 2004). The Zimbabwe nanodialogue initiative, and Practical Action's other related activities, are rare examples of a nanotechnology-focussed technology assessment-type exercise in 'developing countries'.

These activities can be compared with a host of other similar initiatives, primarily in OECD countries which have used a diversity of approaches to engage citizens in discussions around this emergent field (Lafitte and Joly, 2008). As part of the 'Global Dialogue on Nanotechnology for the Poor,' a similar, international workshop was held in Chennai, India in October 2006 (again focussing in the water domain); there are however no other examples (to our knowledge) of new models of technology assessment being used with respect to the use of nanotechnologies for water provision in developing countries. At international levels, regulation of nanomaterials has been the subject of continuing discussion within the International Conference on Chemicals Management, which in 2008 highlighted the need for regulation, and there is reportedly concern amongst workers' unions as well as FAO, WHO and ILO (who will take up the focus on nanoparticles at its XIX World Congress on Safety and Health at Work in Istanbul in September 2011) (ETC Group, 2010). The global debate continues, but although the case studies above have provided unique inputs, they promise to be isolated islands within a sea of information driven from the global North.

An absence of transparent engagement around these technologies can leave policy-makers, research institutions and firms susceptible to disruption by grassroots organisations, sometimes informally networked (Shirky, 2008) campaigning for greater democratic control of innovation. At the same time, the capital intensity associated with their development means that they are perhaps less likely to be applied to problems of development, driven instead by private sector investment in large markets. The absence of a forum at which these emerging technologies, and associated issues of direction, distribution and diversity represents a democratic vacuum worthy of focussed attention by the international community. Especially under circumstances where future technological trajectories are largely driven by a small number of countries and firms, emerging nations like China and India (Ely and Scoones, 2009), with development challenges of their own, are increasingly demanding a seat at the table.

What do the potential contributions outlined above, and the lessons from the case studies tell us about how TA might be improved to foster development outcomes in future years?

THE FUTURE OF TECHNOLOGY ASSESSMENT FOR DEVELOPMENT

Technology assessment is at a crossroads. Whether or not the United States commits to a new investment in building TA-related capabilities, the interconnectedness of the planet and the pace of innovation of different kinds demands co-ordinated information-sharing and action. The design and implementation of such TA processes would do well to address a number of the lessons outlined above. Specifically, there are a number of key findings that help illuminate the conditions under which TA may best help deliver technologies that contribute to long-term development and sustainability goals.

- Technology assessment processes should symmetrically encompass on divergent views of pros, cons and associated uncertainties across alternative dynamic *directions* for interlinked technological / socio-technical change. This is by contrast with a narrow asymmetric focus on the attributes of some particular selected technology under a specific view expressed with minimal uncertainties, assessed in isolation from alternative options or diverse and changing social and environmental contexts.
- Technology assessment exercises are best viewed broadly – as a crucial part of ‘social appraisal’: the general array of social processes through which knowledges are gathered and produced in order to inform decision making and wider institutional commitments (Stirling *et al.*, 2007). The key role of TA, therefore, is not to undertake the entire task of justifying technological decisions, but to catalyse, inform, enable and strengthen these broader social and political processes.
- There are synergies – not just tensions – between new and old approaches to technology assessment. Participatory elements of the new models are often most usefully focused on the ‘framing’ of technological choices: the problems to be addressed, the questions to be asked, and the criteria by which technologies are to be assessed. Where appropriate, the outputs of these processes can usefully inform more traditional expert-based analysis. For example, the Practical Action nanodialogue led to an understanding of complex and inter-related factors that together led to insufficient provision of potable water in two areas of Zimbabwe, raising a number of crucial questions for expert analysis.
- Criteria and options for assessment should be identified on the basis of a process of multi-stakeholder deliberation. They should aim to take into account the immediate *distribution* of costs, benefits and risks arising from socio-technical change, rather justifying inequitable impacts by assuming post-hoc redistribution.
- Technology assessments should focus on maintaining and enhancing the diversity of social and technological approaches to addressing specified challenges. Potentially negative impacts of those new technologies that particularly threaten these diverse solutions should be especially guarded against.
- There is a need to move beyond a series of unconnected, isolated technology assessment experiments to a co-ordinated and networked approach that allows pTA to be scaled up across diverse regions of the world. The focus should therefore not be on the individual TA exercise in a particular setting, but on broader cross-national programmes – enabling cumulative distributed learning both about the process of TA, as well as the specific technological challenges.

Broadening out the inputs and opening up the outputs of technology assessments in the ways described in the earlier sections of this report can deliver new models that better respond to the needs of developing countries. However, there are certain constraints to their effectiveness that cannot be ignored:

- Though internet infrastructures are improving in many of these contexts, a reliance on Web 2.0 or other 'virtual' models is not realistic where the necessary infrastructures do not exist. This is evidenced, for instance, by much recent work pointing to the continued challenges of internet access in developing country settings.
- Capacity in the methodologies associated with 'new models of technology assessment' are often lacking in many developing countries. In these cases pooling resources between countries may, where appropriate, enable more effective TA activities.
- Data and statistics that can inform technology assessment activities in more developed contexts, as well as levels of understanding and language required for meaningful citizen engagement in debates about some technologies, are less often present in developing countries. However, established statistics in even the best documented innovation systems are often not sufficient for the kinds of question about technological directions addressed in new models. Either way, methodological innovation is required.
- Resources and capacity may not be available to act on TA outputs and subsequent political decisions. Where possible this must be communicated in advance to avoid disillusionment and raising false hopes. Nevertheless, in these circumstances, new models of technology assessment can generate tacit learning within the innovation system, even if their outputs do not go on to guide concrete investments. As such, rather than presenting an additional burden, these innovative models can offer ways to help address these challenges and build new capacity.

Bearing the above factors in mind, there is a need to identify technology assessment tools and methodologies with the potential for scaling up in diverse, developing country contexts. There emerge from the above general findings, the following more specific list of fifteen operational methodological questions/ criteria, under which any given exercise may readily be appraised. These are clustered around five thematic sub-headings:

Broadening out inputs to technology assessment – participation and expertise

1. Is the method equally conducive, without inherent bias, to eliciting all relevant perspectives?
2. Are different perspectives afforded a role in design as well as implementation of appraisal?
3. Is there due attention, not just to technological, but also social and institutional aspects?
4. Are all relevant technology and policy options compared in inclusive and symmetrical ways?
5. Are there any inherent or circumstantial limits on the kinds of issue admissible in appraisal?
6. Does the method allow balanced attention to positive as well as negative consequences?
7. Is there flexibility for different actors themselves to define their own key options and issues?

8. Are certain kinds of issue unduly privileged over others (eg. quantitative over qualitative)?

Dynamic social-technological-environmental pathways

9. Are different options addressed in a dynamic way, eg. attending to contrasting scenarios?
10. Are issues around diversity and interactions between options also fully considered?
11. Is there consideration of issues of flexibility and reversibility, to allow learning from surprise?

Opening up outputs to technology assessment – promoting accountable decisions

12. Are conditions made clear under which contrasting assumptions yield different conclusions?
13. Is full attention given to uncertainty ranges, without artificial reduction to probabilistic risk?
14. Is it explained how this individual exercise relates to others and to wider political debate?
15. Have sponsors committed to respond in detail to findings, even if these are not agreed?

Open, responsive systems of governance, and strong linkages between technology assessment processes and policy-makers, are among the systemic requires for effective TA. These kinds of new models of technology assessment place the responsibility for decision-making on democratically accountable leaders, and at their best enable an ongoing political debate around scientific and technological investments and policies. As a first step, governments, funders or other 'targets', 'audiences' or 'beneficiaries' of technology assessment exercises should commit formally to responding in detail to the outputs of technology assessment, so that a transparent and verifiable 'audit trail' exists that justifies decisions made in relation to TA (as demonstrated in the 2003 government decisions following the GM Nation? Public debate in the UK). Rather than seeing this dependence on reflexive institutions and audiences as a hindrance to their potential impact (i.e. a negative point), we see new models of technology assessment themselves as a positive contribution towards more democratic systems of governance.

The positioning of technology assessment within the process of policy-making and technology development is illustrated in figure 4. Importantly, this process is seen as ongoing, with iterative cycles of problem identification, technology assessment, decision-making and monitoring and evaluation to ensure continuous improvement. Ideally, each of these activities involves communication with internal and external stakeholders. The core technology assessment role is one of co-ordination, rather than the conduct of TA in its entirety. Obviously this requires core resources and capabilities; however, in comparison to the wide-ranging technical expertise and costly research budgets demanded by conventional approaches, 'new models' may be co-ordinated by a relatively small group of well-trained and networked staff.

There are obvious areas where resources and capabilities are currently lacking. For instance, there is an urgent need for methodological capacity-building for technology assessment in developing countries. Many of the examples covered in this report are of external groups entering developing countries and co-ordinating TA activities. If developing country citizens and stakeholders are to speak for themselves, they need to be empowered to co-ordinate broad, open and rigorous technology assessments, drawing on and adapting new models to suit their local contexts.

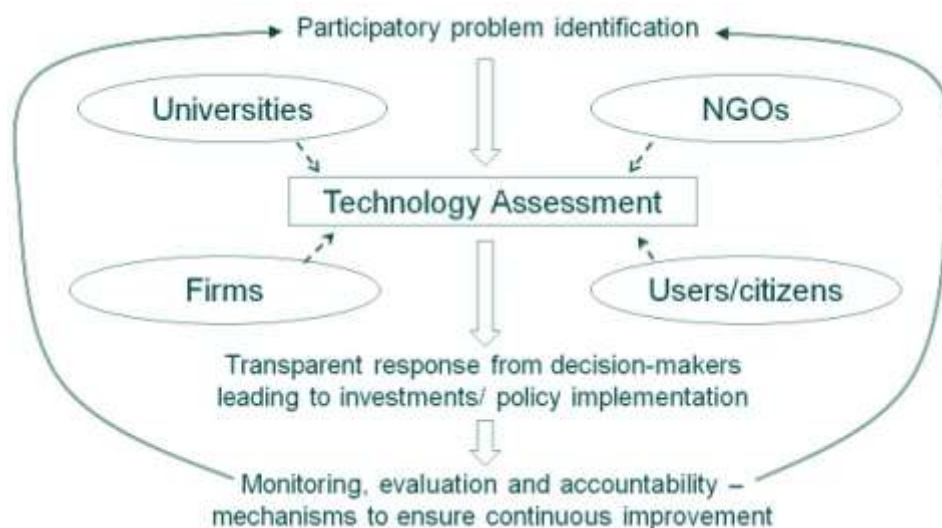


Figure 4. Positioning technology assessment within the policy-making/ technology development process

Taking these ideas further, we can envisage a role for a global network of regional centres with key capabilities in technology assessment methodologies (see Figure 5). These may be NGOs, academic institutions, firms or intergovernmental organisations. The STEPS Centre's New Manifesto project (<http://anewmanifesto.org>) proposed a Global Innovation Commission that could act as an international forum for reporting, analysing and discussing investments and policies in the innovation domain. Linked to this idea, but with a more prospective role, there is a clear need for a global technology assessment network. Such proposals are not new (and there are a number of organisations that already conduct technology assessment-like activities with a development focus); only recently, however, have information and communication technologies made the possibility of a virtual, networked approach to international TA possible. Such a network could provide multi-stakeholder assessments like those seen in international examples like the IAASTD (or national examples like the UNFCCC TNAs), whilst at the same time developing the participatory aspects of assessment so that user and citizen perspectives could also feature. The outputs could be enhanced by being more focussed on well-bounded, strategically-defined problems with implications for poverty alleviation and environmental sustainability, and being targeted at key decisions around policies or investments.

A prototype would be an arrangement of regional nodes, each co-ordinating national or trans-national assessments and sharing data, methodologies and TA outputs with similar nodes across the globe. Technology assessment 'problems' could be highlighted, drawing on citizen or stakeholder inputs at local, national and regional levels on the basis of core development challenges or emerging issues identified by practitioners or citizens' groups. At the same time, international challenges identified by inter-governmental organisations could feed in to complement and co-validate these 'bottom-up' framings. Other participating organisations could be selected on the basis of familiarity with candidate technologies and non-technological interventions.

Such a 'network of networks' could provide an important forum for knowledge exchange across diverse contexts, and feed into international research networks collaborating on development challenges and thus build the innovation system linkages and efficacy of what Wagner (2008) terms the 'New Invisible College'. While it may be that insights from technology assessment are most urgently needed from developing countries and regions, nodes in OECD countries will be important to enable links with leading research institutions in these areas.

These links could influence public and private research priorities in wealthier countries and discourage the establishment of restrictions to the diffusion of knowledge and technology (eg patent arrangements) that are in conflict with development outcomes.

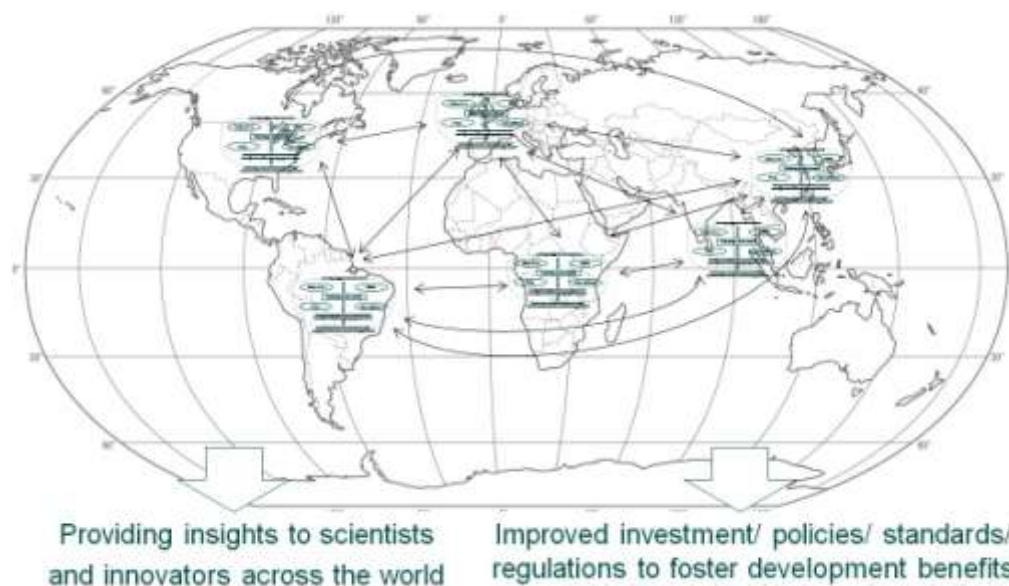


Figure 5. A prototype international 'technology assessment' network involving (inter-)governmental, non-governmental, private sector and academic institutions and open to scrutiny from citizens (the distribution of the network nodes is illustrative, rather than based on a detailed consideration of relative benefits).

At the same time, outputs from these networked technology assessment processes could provide an important resource for policy-making at national and international levels, and offer opportunities for international co-ordination in the spirit of the STEPS Centre's 'New Manifesto' recommendations. Obviously, the potential for impact from such a network will depend on the governance structures within which it is embedded, but it will nevertheless provide a mechanism for generating relevant knowledge on new technologies and technological investments, and, through its direct engagement with citizens and stakeholders, democratising their development. Capacity and resources will be a perennial challenge and the absence of baseline statistics will continue to be a hindrance to the poorest countries.

As explained early on in this report, a clear understanding of the impact of technology assessments on policies and innovation pathways represents a research challenge that spans years or decades. In order to inform the future of technology assessment for development, baseline studies and longitudinal investigations are required, especially in developing countries. Preliminary proposals for an international technology assessment network have been made above, but there is a prior need for further research into the potential actors and architecture of such a body, and further consultation amongst possible participants, audiences and beneficiaries.

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