Bio-, nano- and converging technologies for green innovation

Some other important technologies may also allow progress on environmental performance. Like ICTs, biotechnology and nanotechnology may also develop into "general purpose technologies" since they can be applied in a broad range of sectors. Individually, advances in these technologies are already a source of both radical and incremental innovations that provide technological solutions to GHG emissions and other global challenges.

Biotechnology as a source of radical innovation

Many areas of biotechnology have the capacity to spur green innovation and help entire industries to reduce their GHG emissions as well as reduce dependence on fossil fuels. Examples include the use of bio-based plastics and next generation biofuels such as cellulosic biofuels, derived from wood, grasses, or the non-edible parts of plants and alga biofuels. According to a recent study, "the full climate change mitigation potential of industrial biotechnology ranges between 1 billion and 2.5 billion tons of CO2 equivalent per year by 2030, […]" (WWF Denmark, 2009). Biotechnology also offers opportunities for "greening" individual industries such as the chemicals industry (responsible for about 16% of direct industrial CO2 emissions), materials and energy sectors. Estimates suggest a 13 to 16% improvement in energy efficiency for energy and feedstock use is achievable if best available technologies are applied.

Besides the environmental benefits from the use of biotechnology in primary production and industrial processing, biotechnology can be applied in the environmental services sector to repair or monitor environmental conditions in areas such as environmental remediation, especially in the clean-up of heavy metals and chemicals; pre-treatment for chemicals or fuels to reduce the presence of certain harmful compounds; wastewater and water purification for waste management and bio-monitoring (OECD, 2009a). However, despite the important potential of environmental biotechnology, there is very little public and private R&D in this area and levels of public sector funding remain low. One of the challenges for policy makers to promote further investment in biotechnology is adapting the current configuration for basic research funding and pre-commercial development. There is a large amount of high technology development in the biotech pipeline but translating the pilot projects into new products, process or services is held back by the lack of follow on investment. One of the problems behind the lack of investment for development and deployment is the lack of economic frameworks to assess the socio-economic benefits of new biotechnologies that are still in the R&D or pilot phase.

Another challenge relates to the need for technology platforms for enabling technologies like synthetic biology or genomics that can lead to radical innovation. By targeting research around platforms rather than specific technologies, the markets pick the most successful product. This implies a need for co-operation and co-ordination of these activities across different research agencies as well as the underlying soft and hard infrastructure, much of which must be built involving public-private partnerships, including at international level.

Environmental biotechnology can also play an important role in "green growth" owing to its significant potential in such areas as environmental remediation, especially in the clean-up of heavy metals and chemicals; pre-treatment for chemicals or fuels to reduce the presence of certain harmful compounds; wastewater and water purification for waste management and bio-monitoring; and delivery of value-added biomass as well as more potentially far reaching applications such as carbon sequestration and other environmentally friendly biotechnologies.

Nanotechnologies for green innovation

The application of nanotechnologies also offers substantial potential to contribute to green growth (see below). The range of applications is extremely broad including clean car technologies and materials, to environmental sensing and remediation, batteries, building materials and technologies and water purification. Nanotechnologies are developing rapidly and are increasingly used in a variety of products and industries, and are influencing environmental protection and socio-economic development.

Nano-enabled applications may directly address environmental challenges such as water purification and renewable energy production/storage or indirectly deal with environmental targets by improving ecoefficiency. For example, nanotechnology is emerging as an important enabling technology in water systems. Indeed, nanotechnology has been in use as a conventional approach to water treatment for many years. Notably, nanotechnology can enable more radical innovation for the outgrowth of new companies and industries, especially when it converges with other technologies such as ICTs and biotechnology.

Nevertheless, it is important to consider that the wide range of applications of manufactured nanomaterials also have a variety of unquantified and unverified risks (e.g. environmental, health and safety risks from the release of nanoparticles into the environment and health concerns for workers and consumers). The OECD is working with regulators to clarify the risks.

Examples of nanotechnology applications contributing to green innovation (OECD, 2009b):

- **Environmental sensing**: nanotechnology-based environmental sensors, sensors/detectors used to trace or identify nanomaterials in the environment.
- **Clean car technology**: nano-catalyst particles in novel dispersions, electrochemical reactors for NOx and PM decomposition, clean power generation by fuel cells.
- **Cellulose nanofibers**: bacterial cellulose as a building block for novel materials, bionano composite.
- **Site remediation**: nanoscale Zero-Valent Iron used for site remediation (soil/ground water).
- **Better batteries enabled by nanotechnology**: CNTs for lithium-ion batteries as additives, nanostructures, zero-emission advanced battery manufacturing for electric vehicles.
- **Agricultural nanotechnology**: sensors in many applications (bacteria in food, plant health monitoring, soil quality and pollution identification), filtration/purification for air/water applications, energy storage and PV, fibre production, soil stabilisation, slow release nanofertilizers, encapsulated pesticides.
- **Greener nanoproducts**: light-emitting diodes (LEDs), self cleaning and longer-lasting coatings, nano-coatings for energy conservation and generation, nano-coatings in buildings.

The role of green chemistry: Combining biotechnology and nanotechnology with chemistry

Green chemistry is another area of innovation which can spur green growth. Green chemistry aims to promote the design, manufacture and use of efficient, effective, safe and more environmentally benign chemical products, materials and processes throughout their life-cycles. This includes important technologies such as nano- and biotechnologies which are giving rise to a number of applications with more environmentally efficient outcomes in the areas of energy production, consumer goods, agricultural crops, and information and communication technologies, which have the potential to address major environmental concerns or help to adapt to changing environmental conditions (e.g. due to climate change). The trend towards a green chemistry also stimulates innovation across all sectors to design and discover new chemicals, materials, crops, production processes, and product stewardship practices that will provide increased performance and value while meeting the goals of protecting and enhancing human health and the environment.

It also aims at assessing the potential risks that new chemicals and materials could bring (i.e. use of potentially toxic nanomaterials) and identifying applications of new materials which will lead to environmental benefits.

Based on a recent survey of patent data, some tentative conclusions as to the role of public policy in inducing innovation in selected areas emerge; however, caution should be taken at this time in identifying a firm causal link between public policy and innovation trends. In some cases, like TCF pulping, it appears that public concerns about chlorine bleaching may have led to changes in technology before regulations took effect. In other cases, the effect of new policy seemed to have a more obvious impact, such as following the introduction of the German packaging ordinance in 1989 and the subsequent take-off of patents of biodegradable packaging.

A survey of barriers and drivers of sustainable chemistry innovation in industry is currently under way and should help to put these tentative findings on a firmer foundation as well as identifying further mechanisms that support sustainable chemistry innovation that could be used in policy making. An important aspect of the work is to explore applications involving the use of nanomaterials from the perspective of life cycle assessment, that is to say, the implications of the use of such nanomaterials from their production and use through to waste disposal.

Technology convergence and the challenge of system complexity

In the longer-term, however, the true potential of these GPTs for green innovation will come from the convergence of nanotechnology, biotechnology and ICT. Most technological progress over the next century will require the use of converging technologies. Not only does convergence provide opportunities for wider applications of general purpose technologies but it also potentially increases the returns to public and private R&D. Therefore, from a policy perspective, setting the right incentive mechanisms to stimulate investment and the diffusion of these new emerging and converging technologies will be crucial to meeting the global challenges of climate change, energy, water or food security while generating positive spill-overs for society.

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