Part 3: Technical Innovation and EPR Policies

Chapter 1

EXTENDED PRODUCER RESPONSIBILITY AND INNOVATION

by

Candice Stevens, Head, Industry Division
Directorate for Science, Technology and Industry, OECD

1. Introduction

Extended producer responsibility (EPR) is defined by the OECD as an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle. *Innovation* is defined as the first use of a new product, process or system in a commercial context. Innovation occurs overwhelmingly in private firms in reaction to external signals. It is distinguished from *science,* which is the search for knowledge, and *invention,* which is a new technical idea.

This paper develops an analytical framework for examining the interaction between EPR and innovation. Innovation comes in many degrees and types, but the ultimate EPR innovation goal is the redesign of products towards sustainability. Better product design would mean less waste, more durable goods, and more reuse and recycling of products and their components.

2. Analytical framework

A framework for analysing the relationship between extended producer responsibility and innovation is presented schematically in Table 1. The framework consists of three components: *i)* the stimulus of environmental policy, which can take a variety of forms; *ii)* a range of possible innovative responses; and *iii*) firm-level and sectoral-level contextual variables which can

mediate the effects of environmental policies on innovation. This paper first discusses the innovative effects of different environmental policy instruments - of which extended producer responsibility is one type. It then extends this analysis to different types of EPR instruments and their potential effects on innovation as mediated through firm- and sectoral-level variables.

Table 1: Framework for analysing EPR and innovation

Policy instruments	*Innovative responses*		*Contextual variables*	
	Degree	*Type*	*Firm Motivation*	*Sector*
Regulations/ Standards	No innovation	Product change	Regulatory response	Packaging
Economic instruments	Incremental innovation	Process change	Cost savings	Automobiles
Information disclosure	Radical innovation	Resource use change	Reduced liabilities	White goods
Voluntary agreements	Continuing innovation	Managerial change	Enhanced image	Computers
Extended producer responsibility	Technology diffusion	Consumer behaviour	Patents and licensing	Mobile phones

In this framework, environmental policy instruments encompass a number of approaches, including regulations and standards, economic instruments, information disclosure, voluntary agreements and extended producer responsibility. Of course, these instruments overlap in their categorisation and their effects and are usually combined in policy implementation.

The innovative responses of firms differ in both in degree and type. In some cases, environmental policy may produce no innovative changes at all. Radical and incremental innovations represent different degrees of change, the latter denoting smaller improvements along a given trajectory, and the former, major departures from the technical *status quo*. The need for innovation to satisfy environmental policy may be continuing or it may be satisfied by a single technological modification. Technology diffusion succeeds innovation, as subsequent users adopt, often with adaptations, the technology pioneered elsewhere.

These degrees of innovation can take different forms. Most often, they are changes to either products or production processes to incorporate environment-related improvements. Innovation may or may not be embodied in a change in the type or level of resource inputs. More far-reaching innovations

relate to both the organisation and management of enterprises and to consumer behaviour, which can become more oriented to environmental considerations as an integral part of operational thinking.

The contextual variables show the set of boundary conditions which can limit the innovative responses to environmental policy. Enterprises have varying motivations for making environmental investments and introducing environment-related innovations. These include the desire to be in regulatory compliance, to realise cost savings and efficiency gains, to reduce future financial liabilities associated with possible damages or accidents, to enhance their public image and expand their consumer base, and/or to patent and sell a new technology. Lastly, the innovative response of a firm will depend to a large degree on the economic sector and particular product in question. The dynamics of these and other conditioning factors to the links between environmental policy instruments and innovation are analysed below.

3. Environmental policy instruments and degree of innovation

Table 2 summarises and compares findings concerning the probable innovative responses of firms to different types of environmental policy instruments: no innovation, radical innovation, incremental innovation, continuing innovation and/or technology diffusion (OECD, 1999). These policy instruments can have more than one type of effect.

Product standards are regulatory requirements that specify the environmental and/or safety characteristics of consumer and industrial products. Generally, such standards are imposed on products already in the marketplace. In the past, product standards have resulted in quick substitution of an existing technology, not true innovation. Lead and solvent-based paints, urea formaldehyde foam insulation and small engines are examples of products for which technology to solve environmental problems was moved "*off the shelf*." The effects of product standards may thus be characterised as incremental innovation, although this may be widely diffused throughout the industry.

Pre-market approval generally involves government review and approval/denial of new products, including pharmaceuticals, pesticides and toxic chemicals. Studies show that pre-market approval systems tend to lengthen the period of research and development for products and increase the cost of R&D. There has been some concern that this type of regulation could actually retard the rate of product innovation. Generally, it results in incremental innovation to meet expected standards or specifications but not to exceed them.

Table 2. Environmental policy instruments and degree of innovation

	No innovation	Incremental innovation	Radical innovation	Continuing innovation	Technology diffusion
Product standards		X			X
Pre-market approval		X			
Product bans		X	X		
Performance standards		X		X	
Technology specifications	X				X
Facility permits	X				
Charges and taxes		X	X	X	
Emissions trading		X		X	
Subsidies		X	X		
Information disclosure		X			X
Voluntary agreements		X			X
Producer responsibility		X	X	X	X

Source: OECD, 1999.

Product bans are one of the most severe regulatory commands and have been applied almost exclusively to chemical products. PCBs, phosphate detergents, asbestos, DDT, leaded gasoline and CFCs are the main examples. Product bans always result in a change in technology. The nature of this change can range, however, from simple substitution of readily available products, processes or components (*e.g.* aqueous cleaning replacing CFCs) to incremental innovation (reformulated detergents or gasoline) to radical changes that restructure an industry (PCB substitutes produced by new firms which totally displaced the sole US producer).

Performance standards are widely used to implement process controls for air pollution, water pollution and hazardous waste management. Their advantage is that they combine a clear technological demand with flexibility in solving it. However, most performance standards are based on assumptions about what the best available technology can achieve. They thus require little or no technological changes from firms already at the state of the art. At best, performance standards lead to continuing incremental innovation rather than any radical changes.

Technology specifications are regulatory commands to use a particular technology. Such specifications foreclose the possibility of an immediate innovative response, since they are based on already available technology. Specifications do furnish a compelling force for technology diffusion. Since they are typically based on the best technology in use in leading firms, one effect is to force laggards up to the state of the art.

Facility permits allow regulators to review industrial technology, ensure compliance with applicable laws and involve various parties, particularly local citizens, in environmental decision-making. Permits do not lead to any appreciable innovative responses. Some observers believe such permits may have negative effects on innovation, causing the regulated industry to postpone the installation of new equipment to avoid scrutiny. However, from a public point of view, it is one way of gathering information about and influencing the technological decisions of firms.

C*harges and taxes*, and other economic instruments, can have significant effects on technological change, since in theory one of their major advantages rests in dynamic efficiencies. While regulation tends to provide a strong single stimulus to technological change, economic instruments may give a continuing impetus to innovation. At present, the level of charges and taxes is not sufficiently high in most cases, so that the tendency is towards incremental innovation, with radical improvements dependent on the marginal tax rate.

Emissions trading is focused on "efficient" pollution abatement, since it gives lesser-cost abaters (or situations) the ability to transfer their savings to higher-cost circumstances. Being tested for air pollution, water effluents, and CFC phase-outs, such trades tend to be more a balancing device within overall emissions targets than a stimulus for technological change. Trades take place largely among industry insiders which also limits the competitive stimulus for change. Continuing incremental innovation, rather than radical change, is the most likely result.

Subsidies are generally considered to be environmentally–damaging by discouraging the internalisation of costs into prices and encouraging the over-consumption of resources. However, most OECD governments give supports to firms - directly through grants and indirectly through tax incentives - for both environmental investments and for research and development. Some governments have combined these to give grants or fiscal incentives to R&D for the environment. Such research, which is taking place more often within the context of public/private partnerships among firms and universities/research institutions, can lead to incremental and/or radical innovations, although these may be one-off rather than continuing.

Information disclosure covers a range of initiatives pertaining to public disclosures of environmental performance and also monitoring requirements. To the extent that information systems are holistic and range across various environmental media, they can stimulate true innovation rather than end-of-pipe, medium-specific fixes. However, this is not often the case. Beyond the impact on polluting firms, information policies help to create markets and diffuse monitoring and control technology as well as new process approaches.

Voluntary agreements assign the initiative for specifying change to the party with the knowledge to design it and the means to implement it - *i.e.* the firm. Other major virtues include flexibility and realistic time-frames, all of which should in principle promote technological responses. However, there is as yet no evidence of major technological changes or radical innovations arising from voluntary agreements. The absence of reporting and monitoring requirements in most voluntary agreements is one obstacle to assessing their impact on environmental innovation.

Extended producer responsibility can lead to far-reaching design changes of benefit to the environment. EPR generally changes the time-frame and range of factors that appear in the design space of an engineer. It can be an important force for environmental innovation, particularly among companies which would, in the traditional regulatory model, have been the major targets of *ex post* product standards, as well as among younger firms willing to experiment with new approaches. Certain EPR instruments can lead to continuing innovation and broad adoption of technologies across a sector. However, the innovation effects depend on the stringency of the EPR instrument.

4. Environmental policy instruments and type of innovation

Table 3 indicates the different types of innovation which may be engendered by various environmental policy instruments. Here, they are classified into product changes, process changes, modifications to resource use, changes in firm-level organisational and managerial approaches, and alterations of consumer behaviour. In cells of the matrix, + or - signs indicate the tendency (positive or negative) and magnitude (single or multiple signs) of the effect on innovation (blank cells are neutral).

Table 3. Environmental policy instruments and type of innovation

	Product change	Process change	Resource use change	Organisational/ Managerial change	Consumer behaviour
Product standards	+			+	+
Pre-market approval	-			+	
Product bans	++				++
Performance standards		+	+		
Technology specifications		+			
Facility permits		-	+		
Charges and taxes	+	++	++		++
Emissions trading		++	++	+	
Subsidies	++	++		-	-
Producer responsibility	++		++	++	++
Information disclosure	+	+	+	+	
Voluntary agreements		+	+	+	

Source: OECD, 1999.

The table can offer conclusions by reading horizontally or vertically. For example, reading horizontally, it shows that *product standards* may have mild positive effects on product change, management attitudes as well as consumer behaviour. *Product bans* would have much more radical effects on innovation involving products as well as on consumer choices. Economic instruments - charges and taxes and emissions trading - have the potential for significant positive impacts on production processes and resource use. Subsidies can lead to product and process innovations, but may actually have passive or negative effects on managerial and consumer attitudes. Information disclosure and voluntary agreements may invoke some valuable innovative responses. Achievements in eco-efficiency in terms of redesign of products, reduced resource use, and development of managerial and consumer environmental awareness may best be stimulated through extended producer responsibility. EPR may thus have the most potential for innovative change across a range of economic actors.

5. EPR instruments and innovation

Extended producer responsibility encompasses a range of approaches, which are analysed here in terms of their innovative effects (Table 4). While other policies target a single point in the production-consumption-waste chain,

EPR seeks to integrate signals throughout the chain. As a general concept, EPR allocates the physical and/or financial responsibility for the environmental externalities of products along this chain to the producer, with attendant costs and benefits.

Two main types of instruments can be used to implement EPR policies: *i) regulatory instruments* (take-back requirements) and *ii*) *economic instruments* (deposit/refund schemes, advance disposal fees, materials taxes, pollution charges, subsidies, combined schemes). Other instruments can be complementary to these: product standards (minimum recycled content), information instruments (eco-labelling), and voluntary approaches, which often include aspects of the other instrument categories. Each of these EPR approaches has different effects on innovation, which will also vary according to other firm- and sectoral-level factors.

The goal of EPR in terms of innovation is to encourage producers to alter the design of products so that they will lead to reduced or less polluting waste streams. With regard to product redesign, various EPR approaches could lead to no innovation, incremental innovation or radical innovation. Both incremental and radical innovation may decrease energy and materials consumption as producers have incentives to make less wasteful and more recyclable products.

It is difficult to distinguish between what constitutes incremental or radical innovation in terms of product design. EPR-related innovation could encompass product simplification, standardisation of components, modifying components for reuse, standardisation of material types, easily detachable parts, reduction in number of pieces requiring dismantling, fewer material types, etc. Separately, all of these could lead to less waste and lower costs of waste management and disposal, but would probably be termed incremental innovation.

More radical innovation would be in the holistic approach of "design for the environment". Green product design includes a variety of techniques and strategies which aim to increase a product's recycled content, eliminate problematic ingredients, or create a system to take-back a product or its packaging for reuse, refurbishing or recycling at the end of its useful life. This includes designing products in their entirety that can be easily upgraded, rather than replaced when they become outmoded, or that can be easily disassembled for reuse or recycling.

EPR-driven radical innovation can have far-reaching effects on enterprises which invest in product-oriented environmental management systems and re-conceptualise the design process so that environmental factors are an "integral" part. Firm-level managerial and organisational changes could lead to

the development of "*inverse engineering*" which thinks backwards from the environmental consequences of wastes to the initial design problem. In the long-term, EPR could prompt changes in the behaviour of consumers, who would base their purchases to some degree on environmental criteria relating to a product's waste effects.

5.1 Regulatory EPR instruments

Take-back requirements are the primary EPR regulatory instrument. These require the producer and/or retailer to take back the product or its packaging after use. They are often associated with targets for collection and recycling and have been applied to a range of products, but most often packaging. When regulated by law which assigns take-back responsibility to producers, they are one of the purest forms of EPR. Such requirements can encourage firms to redesign products for easier recycling, recovery and re-use of components as well as reduction of hazardous materials. In the long-term, they can be one of the strongest incentives to green product design.

Table 4. EPR instruments and type/degree of innovation

	No product innovation	Incremental product innovation	Radical product redesign	Modified material use	Managerial organisa-tional change	Consumer behaviour change
Regulatory instruments						
Take-back requirements			X	X	X	X
Economic instruments						
Deposit/ refund schemes	X			X		X
Advance disposal fees	X					
Materials taxes		X		X		
Product charges		X		X		X
Subsidies		X	X			
Tax/subsidy schemes	X					
Leasing		X			X	
Other instruments						
Labelling		X				X
Product standards		X		X		
Voluntary schemes		X		X	X	

5.2 Economic EPR instruments

Deposit/refund schemes require a payment to be made when a product is purchased which is fully or partially refunded when the product is returned to a dealer or specialised treatment facility. These schemes have primarily been used for beverage containers. Since in current practice, most responsibility is assigned to the consumer and dealer rather than to the producer, they have had limited impact on innovation in product design. Their function is primarily to realise reduction in materials use through encouraging reuse and recycling.

Advance disposal fees are fees levied on certain products upon sale to finance collection, treatment and recycling. They are often used for longer-life products such as tires, refrigerators and cars. Since consumers and dealers assume most responsibility, as in deposit/refund schemes, they have had limited

impacts on product innovation. An alternative is to require producers to pay the fees, but they may then have the incentive not to redesign products but to reduce the fees they pay. Advance disposal fees may push manufacturers away from new materials towards heavy metals that are more easily recycled.

Materials taxes are intended to reduce the use of virgin materials (or materials that are difficult to recycle, contain toxic properties, etc.) in favour of secondary (recycled) or less toxic materials. Special taxes may be levied on particular materials or those deemed to cause pollution or create a hazard. When set at the optimal level (where marginal costs of the tax equal the marginal treatment costs) and when treatment/recycling responsibility is delegated to the producer, materials taxes can stimulate product redesign. At a minimum and even when set at lower levels, they can contribute to beneficial modifications in materials use.

Product charges are payments applied to products that create pollution when consumed or discarded, such as the sulphur and carbon content of fuels, fertilisers, pesticides or batteries. Product charges can influence the types of materials used although they may not stimulate radical innovations. In raising product prices, product charges have more effects on consumer behaviour. For example, some countries have introduced product charges to shift consumers away from harmful substances such as PVCs.

Subsidies - in the form of direct payments to producers to redesign products to minimise adverse environmental effects - can lead to innovation. Due to allegations of government involvement in "picking winners", most environmental R&D subsidies are now allocated to public/private partnerships, such as for the design of "clean cars". Studies show that subsidies may induce one-off investments resulting in either incremental or radical innovation, but not continuing changes in the innovative behaviour of firms or consumers.

Tax/subsidy schemes combine a tax paid by producers combined with a related subsidy to fund waste treatment. When levied by weight on particular materials, the tax would have the same effects as a materials tax. If the subsidy is paid to local authorities rather than to producers, there would be few incentives for product redesign. Innovative effects would only be realised when producers were required to pay the tax and were also given the subsidy as well as responsibility for post-consumption treatment.

Leasing is when the government requires a firm to lease its equipment to users rather than sell it, thereby assigning whole-life responsibility to the producer. For example, some OECD governments are proposing that public procurement of office equipment, etc. should be oriented to leasing rather than

purchasing to obviate government responsibility for end-of-life treatment. Some leasing programmes have been implemented voluntarily by firms, for example for computers. However, leasing is not practical for many products. Still, it could lead to incremental innovation in the greater reuse and recycling of parts so as to reduce treatment costs to firms.

5.3 Other instruments

Labelling or seals of approval transmit information about the environmental characteristics of products, their recyclability or recycled content to consumers. For example, product durability labels can increase pressure on firms to improve their environmental record regarding the durability of products while enhancing the environmental awareness of consumers. The transmission of signals to producers for product redesign would depend on the extent to which consumers base their purchasing behaviour on the information transmitted. However, the creation of markets for green products is often difficult given their generally higher prices. More difficult, though, is finding ways of reducing inputs and waste in the absence of green demand.

Product standards can be considered an EPR instrument, particularly when they pertain to minimum recycled content and specify a minimum amount of secondary materials per product. These can stimulate product innovations as well as increased recycling and reuse of products and have been used most frequently to date with regard to paper products, glass containers and plastic beverage containers. In being specifically directed to EPR goals and concerned with both design and waste management, these standards can lead to innovation as well as modified materials usage.

Voluntary schemes. Most of the instruments discussed above have been implemented on a voluntary basis by firms, sometimes in co-operation with governments and under varying degrees of commitments. These include computer recycling programmes, automobile recovery programmes, packaging take-back schemes, etc. If the degree of compulsion involved is close to that of a mandatory instrument, the stimulus to innovation in terms of product redesign will be similar to that of a regulatory standard. However, most often, enterprises implement these schemes in order to ward off new laws, regulations or taxes relating to waste management. Still, voluntary agreements and initiatives can induce incremental innovation in giving firms flexibility in devising new approaches and reducing administrative costs. They can lead to new managerial attitudes and approaches. Producers may also be more willing to share information about their innovative responses to specific environmental problems, thereby spreading technologies farther and faster than would otherwise have been the case.

6. Firm Motivations

The innovative actions of firms are not simple responses to the pressure of government regulations and other policy instruments. Firms undertake environmental investments for a variety of motives relating to finances, markets, image and other factors. Enterprises may act because they do not want to be perceived as polluters, they are concerned about future liability claims, or they seek to realise financial gains through market expansion or technology sales. The enterprise response to EPR policy instruments will be moderated through firm-specific factors relating to their motivations. This will also temper the degree of the innovative response, whether incremental or radical. In most cases, only radical change will generate future profits. EPR instruments need to build on other drivers to lead to radical innovation in terms of product design.

Regulatory response - Compliance with government regulations and policies remains the most forceful driver of corporate environmental performance as it requires firms to take mandated actions, or meet certain standards, in the absence of which fines or other measures are likely to be imposed. The stringency of the regulation is an important determinant of the degree of innovation. Firms are also motivated by the desire to get a jump on government regulations and thus save time and expense or gain a market edge. For example, some multinational enterprises headquartered in the United States are currently complying with EPR mandates in Europe. They see company-wide product responsibility initiatives as an opportunity to adapt early to European mandates and potential state-level regulations in the United States.

Cost savings - Many technologies producing environmental benefits are adopted by firms for the normal business reasons of reducing costs and enhancing product quality. Firms that give priority to resource productivity and product innovation can often achieve significant performance gains at lower cost. EPR is one approach that can yield benefits to enterprises by improving the efficiency with which they use energy, water and other natural resources. Greater use of recycled materials can yield significant cost-savings. An EPR-focused approach to the life-cycle management of a product can be cost-effective in the long-term once initial investments are made.

Reduced liabilities - Enterprises may be motivated to redesign products to reduce longer-term financial liabilities associated with hazardous wastes, toxic materials and other repercussions from poor waste management. Assuming total product responsibility could reduce potential environmental hazards associated with storage, shipping, handling and disposal of products. Financial institutions and insurance companies are now looking at potential environmental liabilities when lending to and insuring companies. Unforeseen liabilities and

environmental problems associated with production and distribution can be minimised through EPR approaches.

Enhanced image - Corporate image is an important aspect of a company's marketing strategies and can be a significant driving factor for improving environmental performance. For some firms, developing and selling greener products and adopting a greener corporate image is a pro-active sales strategy. The introduction of innovative product designs can enable the firm to brand itself in a way which allows it to capture market share from environmentally-conscious consumers. Companies that can creatively and strategically meet this goal without compromising product performance and price will have a marketing advantage with discriminating consumers.

Patents and licensing - Some firms realise that there are significant opportunities to gain the competitive advantage that accrues to early movers in the environment area. In addition to expanding markets, firms can develop entirely new product designs and technologies which it can then patent and sell to other market actors. EPR can make it attractive for companies to research and specify environmentally-sound materials, to design products to have multiple life spans, and to eliminate unnecessary parts of the product or packaging in the design phase. Small entrepreneurial firms can build on market niches in innovative, environmental product designs based on EPR.

7. Direction of innovation

Product considerations are important when assessing how EPR policy instruments can influence the direction of innovation in terms of product design and waste prevention. Some products and waste streams may be better candidates for EPR intervention than others. Important factors include the primary objective (*e.g.* waste prevention, waste management, design for the environment), the structure of the industry and size of producers, and the costs of EPR relative to potential profits In general, EPR may be most effective in the case of products where the primary objective is total product redesign, producers are many and diversified, and potential profits may outweigh costs.

7.1 Sector/product examples

Packaging - EPR has been widely applied to packaging in the attempt to reduce waste and improve its management. Because redesign of packaging is likely to generate costs to industry rather than profits, voluntary schemes and other approaches have not been effective in promoting radical innovations. These instead have led to incremental innovations in the form of package lightweighting, elimination of unessential packaging, and increased use of

concentrates and refill packs. There has been some shift from difficult-to-recycle composites and plastics to more recyclable materials such as paper. As seen in the case of plastic packaging in Norway, EPR in the form of recycling fees has resulted in few new solutions that go beyond incremental improvements in dematerialisation (Roine and Brattebo, 2001). Packaging take-back requirements have been somewhat more successful in prompting innovation. There have also been related process innovations. For example, German companies have developed new sorting and recycling technologies based on infrared and laser beams, which they are now licensing to other firms.

Automobiles - Because vehicles are already among the most highly recycled products, the EPR innovation goal here is total product redesign. About 75% of vehicles by weight consists of metals which are usually recycled. The EPR target is the remaining 25% consisting of mixed materials such as plastic, rubber, glass, textiles, paint, etc. which are difficult to recycle, may be contaminated with hazardous substances, and are usually landfilled. Incremental changes in auto design have been realised through increased recycled content and labelling of components. Take-back requirements or assigning responsibility to producers for end-of-life vehicles could lead to more innovation. Some producers are aiming at complete automobile redesign for total recycling of parts and materials (*e.g.* the *US Vehicle Recycling Partnership* including Chrysler, Ford and General Motors). These firms are anticipating possible EPR requirements relating to end-of-life vehicles as now exist in some European countries. However, when the target industry consists of a few large firms as in vehicles, the likelihood of diverse, radical solutions will be less than in a highly entrepreneurial business environment. Radical redesign of automobiles may originate only in subsidised research partnerships with governments. In addition, as automobile producers become more service-oriented, EPR regulations could lead to managerial and organisational innovations in this sector through modified relationships between producers, assemblers and dismantling/recycling operators (Zoboli, 1998).

White goods - White goods - large household appliances such as refrigerators, ovens and washing machines - have aspects in common with automobiles. About 75% of their metal content is recycled. They generally enter the scrap metal feedstock along with other products such as vehicles for processing in local shredding facilities. Like automobiles, the white goods industry is a high-volume, mature sector somewhat resistant to major change. Total product redesign to address the 25% of non-recyclable materials could be stimulated by take-back requirements which require manufacturers to accept products for disposal at the end of their commercial lifespan, but this would be very costly to producers. Assigning households some role and cost at the time of disposal can also influence and encourage changes in consumer behaviour

both in terms of encouraging purchases of more durable products and promoting proper care and maintenance. In Japan, the *Household Appliance Recycling Law*, which combines manufacturer obligations to recycle their products with disposal fees paid by consumers, is expected to lead to significant changes in product design and recycling practices (Tanaka, 1998).

Computers - In the case of computers, innovation has led to shorter lifecycles and greater waste management problems. While the miniaturisation of computer equipment may reduce the volume of waste, it makes collection, repair and recycling more difficult. Although this sector is dominated by large established firms, there are also many smaller entrepreneurial ventures in the information technology industry. Cost-effective computer recycling will require product design changes that reduce disassembly time and increase the reuse and recyclability of components as well as eliminate hazardous materials. This is the direction of the draft EU *Directive on Waste from Electrical and Electronic Equipment* (WEEE) which prohibits the use of mercury, cadmium and other chemicals in all electrical goods by the year 2004 and puts full financial responsibility on producers to establish collection systems. Although it is left to individual EU countries to implement this directive, it could lead to cleaner computer product designs by companies seeking a green market niche. In addition, "eco-PCs" with easier dismantling and recycling may be cheaper to produce, providing an added incentive to innovation.

Mobile phones - Mobile phones are causing waste problems due to their short life-span (18 months to two years) and increasing numbers. Several policy instruments could induce incremental improvements in cell phone-related waste problems. Materials bans could reduce the use of toxic substances, particularly lead and brominated flame retardants. Financial incentives, such as deposit/refund systems, could encourage consumers to return mobile phones for recycling and reuse. Voluntary take-back schemes could be implemented, particularly for phone batteries. Eco-labelling and seals attesting to product durability - for what is a relatively low-priced product - could appeal to environmentally-aware consumers. Other instruments - such as product standards or charges - could lead to standardised design elements so that users are not forced to purchase a new phone when changing service providers or travelling abroad. Total redesign for disassembly, reuse and recycling of mobile phones may be induced by take-back requirements which put the burden on the producer. In this sector, there are smaller firms and potential new entrants who may develop innovative design responses and reap profits through enhanced company image and patenting new approaches.

8. Conclusions

Experience shows that many environmental policy instruments can stimulate incremental innovation in industry. Among the instruments which have the potential to engender more radical innovation are product bans, subsidies and extended producer responsibility, which are themselves more extreme policy approaches. These instruments primarily invoke changes in product design rather than in processes.

Several instruments can be used to implement EPR policies, whose ultimate innovation goal is complete product redesign to prolong the life of products and reduce waste. Many EPR instruments may induce incremental innovation in the form of simplifying products by reducing materials and components and increasing the recycling of parts. More radical innovation to completely redesign products to prolong their life, allow easy upgrading and reuse and/or promote complete recycling of components is more difficult to achieve. Take-back requirements, which assign full responsibility to producers across the product lifecycle, are the EPR instrument most likely to induce radical innovation.

Stringent EPR take-back requirements can produce technologically beneficial results over the long-term, provided the transient disruptions and costs can be sustained. Other EPR instruments - including taxes and charges, subsidies and leasing - can lead to beneficial but mostly incremental innovations in terms of products. They can also promote modified and reduced materials usage and changes to both firm-level managerial and organisational approaches (*e.g.* in the case of leasing and voluntary schemes) and consumer behaviour (*e.g.* in the case of deposit/refund schemes, product charges and eco-labelling).

Firms undertake environmental investments for a variety of motives, including government regulations and financial and image considerations. Depending on the structure of the industry and the product in question, certain firms may be motivated to redesign products to realise cost savings, market niches or patent earnings. Governments should tailor their EPR policies to take into account the potential range of responses in different industry sectors and the possibilities to profit from product innovation. It appears that EPR (particularly take-back requirements) may be most effective in diversified sectors where firms could realise longer-term benefits from related innovation. For this reason, case studies of the application of EPR to particular products and waste streams could be useful.

The innovative element of EPR - and thus the longer-term benefits - can be augmented by complementary industry-related policies. When introducing

instruments which allocate take-back and treatment costs to producers, governments may need to alleviate the short-term adjustment costs through financial or technical assistance. Governments can undertake R&D to provide generic technologies for product redesign as well as enter into partnerships with industry to advance EPR-related innovation (OECD, 2002*a*). Through green government procurement, more emphasis could be placed on leasing goods or purchasing products with beneficial design elements. Governments can also promote the patenting and licensing of EPR product innovations, increase the number of environmentally-conscious consumers, and expand markets for vendors of EPR-based products.

REFERENCES

JAFFE, A., R. NEWELL and R. STAVINS (2000), "Technological Change and the Environment", Resources for the Future, Washington, D.C.

OECD (1999), *Technology and Environment: Towards Policy Integration*, OECD, Paris.

OECD (2000), *Innovation and the Environment*, OECD, Paris.

OECD (2001*a*), *Encouraging Environmental Management in Industry*, OECD, Paris.

OECD (2001*b*), *Extended Producer Responsibility: A Guidance Manual for Governments*, OECD, Paris.

OECD (2001*c*), *Sustainable Development: Critical Issues*, OECD, Paris.

OECD (2002*a*), "Policies for Public-Private Research Partnerships", DSTI/IND(2002)19.

OECD (2002*b*), *Technology Policy and the Environment*, OECD, Paris.

ROINE, K. and H. BRATTEBO (2001), "Implementation of EPR in Norway: The Case of Plastic Packaging at National, Sectoral and Company Level", OECD Seminar on EPR: Programme Implementation and Assessment, Paris.

TANAKA, M. (1998), "Waste Management and EPR Practices in Japan," OECD Workshop: Extended and Shared Responsibility for Products, Washington D.C.

ZOBOLI, R. (1998), "Implications of Environmental Regulation on Industrial Innovation: The Case of End-of-Life Vehicles", European Commission Joint Research Centre, Seville.

TABLE OF CONTENTS