Policy Instruments for Environmental Innovations: The example of resource use in ICT products

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1. Introduction

The current use of resources exceeds a sustainable level. Besides economic constraints, such as foreseeable scarcities in some critical minerals, economies also face ecological limits: detrimental environmental effects stem from increasing land consumption from mining activities, emission of greenhouse gases or the disposal of an ever growing body of end-of life products. These limitations are not sufficiently reflected in market allocation mechanisms to incentivize market actors to use scarce resources more efficiently and to reduce these negative environmental effects. Global trends in primary metal extraction show a steady increase throughout the last decade. There are no signs of even relative decoupling of resource use from economic growth (Jackson 2009:74).

Resource use is increasingly embedded in globalized patterns of production and consumption. However, transboundary supply chains and product life cycles contribute to unequal distribution of benefits from resource use and detrimental environmental and social impacts. Structural change in industrialized countries towards the service sector and the increasing import of raw materials, components and finished products lead – besides a decrease in CO_2-emissions – to a relocation of environmental intensive production stages to industrializing and developing countries. This is also true for the disposal of an ever growing amount of end-of life products (Umweltbundesamt 2007). Thus, most of the enhanced resource efficiency in industrialized countries can be ascribed to this effect, and burdens of resource use tend to be shifted to developing countries. This makes resource use a prime example of global environmental change. At the same time, the increasingly globalized character of resource flows renders existing political instruments – most of which still focus on the national state – inadequate.

Information and communication technology (ICT) products are a prime example for globalized production chains and the spatial divergence of consumption and environmental (and social) impact. Since a whole range of market failures and obstacles are connected with their consumption, ICT product life cycles are indicative for unsustainable resource use patterns. Thus, the paper exemplarily explores causes of these market distortions that lead to inefficient use of resources. Consequently, the paper proposes a policy mix which complements existing approaches by focusing on the input side of the product life cycle. Choices which are made during the product design phase define the environmental effects of a product to a great deal. It sketches a three-pronged policy mix that aims at inducing strong environmental innovations by generating necessary information for efficient resource use, accelerating innovation by using public procurement to foster environmental innovations and by introducing dynamic standards to mainstream them in mass markets.

The aim of this paper is not to provide a sophisticated and encompassing solution to the world's growing hunger for resources. The specific case of more resource efficient ICT products is too limited in its scope in order to reach an absolute decoupling of resource use and economic growth. Rather, using ICT products as an example, the study explores where obstacles to resource efficiency are located, which instruments might be employed by governments of industrialized states (beyond the existing supply side measures such as R&D funding for new technologies) and how demand-side instruments might contribute to a more resource efficient economy and society. In this context it is important to note that the proposed policy mix is not confined to ICT products and the use of secondary metals but can in principle be extended to other product categories and material flows.

2. Trace metals in ICT supply chains and their environmental impacts

An essential component of many electronic components of computers (PCs, laptops, netbooks) are so-called "trace metals" or "high-tech metals" such as tantalum, indium, or platinum group metals (UBA 2009). They are installed only in very small amounts of mostly less than 1% built into the devices. Their sum however rises, for example in Germany, to about 60 million units, which brings about considerable quantities of material (Chancerel 2010). Only around 1% of these crucial high-tech metals are recycled, with the rest discarded and thrown away at the end of a product's life (UNEP 2010a). The dissipative use of trace metals in ICT products and technical trade-offs between the recovery of different trace metals demands sophisticated recycling technology so that most trace metals are not recovered (Chancerel 2010).

The demand for trace metals is growing. In case of e.g. gallium, indium or germanium the main driver is the on-going technological change with emerging technologies like thin layer photovoltaics, displays, fuel cells or lithium-ion batteries. It is predicted that in 2030 the worldwide technology-induced demand for trace metals will significantly rise: for gallium will be 4 times higher than its total present world production. For indium, a 3.3 times higher demand is predicted (AHWG 2010). These metals with technology-driven demand are of paramount importance for future technology development and utilisation.

In case of e.g. platinum metals, tantalum or silver the world economic growth adds as the second dominant driver (Angerer et al. 2009).
Compared with metals produced in large quantities, trace metals have high environmental impacts per unit. Hence, for ICT products, the input of trace metals is particularly relevant. Environmental impacts of metals in general are related mostly to the mining, extraction and refining stages, which are very energy intensive and can be the cause of substantial air, water and soil pollution (UNEP 2010b). Because these stages are mostly located in countries outside of OECD countries, the environmental burden of using these materials is shifted to these sites and the impact increases with rising demand (Schütz et al. 2004).
Because recycling and re-use requires often much less energy than primary production, a larger share of secondary resources can reduce the emission of greenhouse gases significantly (UNEP 2010b). Furthermore, impacts on water resources, biodiversity and soils are reduced compared with producing and using primary metals from mines.

3. Barriers for resource efficiency and the necessity for policy intervention

The production of ICT devices is associated with particular forms of market failure that lead to inefficiencies in the use of resources and warrant policy interventions. This is especially true when not only market prices are considered, but also the social costs of material use are taken into account. Most important causes of inefficient resource use can be grouped into 5 broader categories:

3.1. Information deficits

Economic theory's basic assumption that market actors have full information leading to an efficient allocation of resources cannot be upheld for resource markets. ICT products are manufactured in complex supply chains. Comprehensive information about the specific components of products and pre-products, about the origin of resources etc. are hardly available, neither for producers nor for regulators. The spatial and temporal segregation of resource use and its impact make environmental effects of consumption less conceivable and attributable and contribute to a lack of knowledge about consequences of consumption. However, sufficient knowledge is a pre-condition for effective allocation and regulation.

3.2. Lacking and asymmetric internalisation of negative external effects

As described in Chapter 2, the production stages with the most severe environmental impacts are often located at the beginning of the life cycle in developing countries with weak environmental governance structures (Cf. Iles 2004). These phases include mining and processing of ores, and the manufacturing of components and pre-products. Increasingly also dismantling, recycling and disposal of end-of life products take place in non-European countries. Negative external effects e.g. from the use of cyanide in gold extraction tend to be insufficiently internalized in these countries.
The use of recycled metal is one means to reduce the environmental impact of ICT products. However, existing legislation in most OECD countries does not offer positive incentives for recycling. Producers are held responsible for financing the environmentally sound disposal of 'their' end-of life products in many OECD countries. Yet, the consequence of this system is that the recycling of end-of life products is mostly perceived as a financial burden instead of a source of secondary material. Additionally, owners of end-of-life devices are not compensated for returning these to collection points while household waste offers a 'cheap and easy' option to get rid of old products. These devices disappear, leave negative environmental impacts and their resources are lost for recycling and re-use. While most industrialised countries attempt to internalise costs from the disposal of e-waste, there are no such regulations in developing countries. This creates a situation in which, despite an export ban under the *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal*, end-of life products are illegally exported to developing countries where they are exploited and disposed under questionable conditions (Sander and Schilling 2010). Besides detrimental health effects for workers and negative environmental impacts from disposal, the primitive technologies employed contribute to losses of secondary material.

3.3. Deficient price signals for consumers and lack of incentives for producers

Scarce metals are often used in minor quantities per unit. Their price in relation to the overall product price is insignificant, also because of lacking internalisation of negative externalities. Therefore, scarci-

ties and environmental impacts of specific materials are not mirrored adequately in product and production prices – and neither consumer, nor producer demand is influenced.
Higher resource efficiency does not translate into lower operating costs for consumers, as is the case for energy efficient products. Thus, there is no economic incentive for customers to demand resource and material efficient products and the emergence of an autonomous, demand-based trend towards higher resource and material efficiency is unlikely.
Company decision-making is often significantly influenced by short-term investor expectations, which makes it harder to address longer-term issues, such as declining stocks of scarce resources or negative externalities of production.
Since trace metals are often used in hardly separable components such as circuit boards, and their concentrations in ICT products per unit are very low, their recovery requires sophisticated recycling technology, which only few recyclers can afford. To reach positive returns, both large quantities of end-of life products are as input and a strong demand for secondary material are needed.

3.4. Rebound effects

ICT products are especially prone to rebound effects: they tend to be technically outdated and replaced rapidly. Possible efficiency gains, e.g. from miniaturisation, are offset by increasing volumes and further diversification of products offered. A typical example are netbooks, which are manufactured with relatively less resources (miniaturisation), but often do not replace conventional computers but are used as an additional device.

3.5. Lack of enforcement

While there exists a lack of government capacity in developing states to control the adherence to environmental regulations, there is also a lack of capacity in EU states to verify the export ban under the Basel Convention (Sander 2010)..

This short review suggests that the neoclassical assumption that scarce resources are efficiently allocated through the price mechanism does not apply here. The results are avoidable costs that are borne by the public in the form of environmental and health damages. This clearly mandates policy intervention to govern the use of some resources and materials. The goal of resource policy therefore is to provide a framework in which economic incentives and prices direct actors towards more sustainable and efficient use of resources. After chapter 4 outlines motivations for an ambitious resource efficiency policy, chapter 5 sketches a specific policy mix that addresses said problems and pushes innovations for more sustainable ICT products. Emphasis will be on demand side-instruments and the introduction of minimum standards which are intended to supplement existing supply-side approaches in innovation policy, such as R&D financing.

4. Access points for regulation in the EU

Because most stages of the life cycle of ICT products take place outside the EU, possible interventions of EU states are confined to market access, consumption, and disposal and recycling. Most existing legislation deals with the end-of life side of the product life cycle (e.g. the WEEE Directive or the Basel Convention) – with questionable success as Chapter 3 has demonstrated. The proposed a policy mix complements existing waste legislation by focusing on the input side of the product life cycle. A great deal of the environmental effects that a product will exert during its life cycle are mostly determined during its design stage Hence, the aim of the instruments is to foster both process and product innovations and their spread into mass markets. The availability of information is a pre-condition for deploying such instruments. One example for input regulation is the RoHS Directive which regulates the use of certain hazardous materials in electronic products. However, since the directive forms part of hazardous substances regulations, it is not directly applicable to the use of resources.

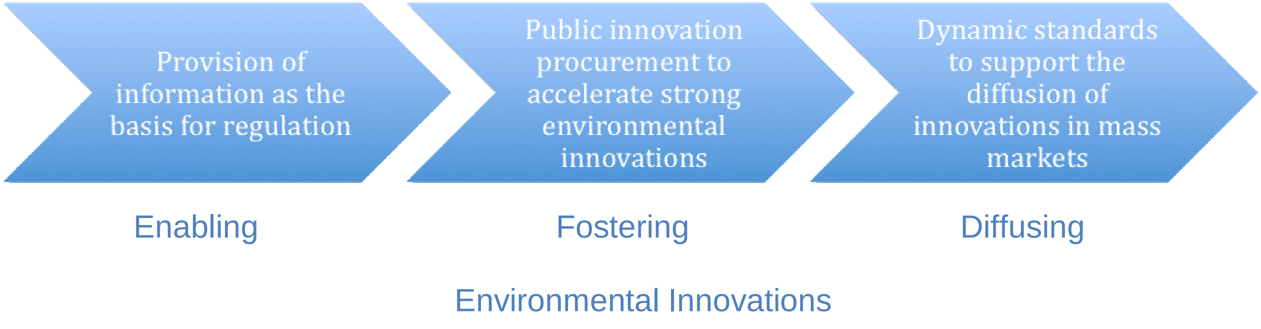
5. Opportunities for innovations and greater resource efficiency

The reduction of resource consumption has not only environmental, but also microeconomic benefits: It can boost the competitiveness of organizations by reducing costs, abating external effects and triggering innovations (Porter & van der Linde 1995). On a macroeconomic level, it contributes to the security of supply. Further, resource efficient economies are more competitive than others – whereupon cause and effect are still not clarified (Steger & Bleischwitz 2009). These multiple benefits – in addition to the simple fact that the EU cannot supply the resources it uses on its own – are the reason why the

European Commission has adopted a strategy on sustainable resource use and made it a priority theme in its "Europe 2020 Strategy" (European Commission 2005; European Commission 2010).
In order to reduce environmental impacts of resource use, an absolute decoupling of economic growth and resource consumption needs to be achieved (Schütz & Bringezu 2008). An only relative decoupling – which means that resource use may increase at a lower rate than economic growth (or, resource use remains constant while the economic output increases) (Schütz & Bringezu 2008) – would not be sufficient. For that, 'strong' environmental innovations are needed: these are 'radical' in leading to both substantial environmental improvements and a high degree of market penetration (Jänicke & Lindemann 2010). Normally, absolute decoupling is rather expected from system innovations than from product innovations (Machiba 2010). But also the latter one can principally lead to significant environmental improvements, if a high market penetration is reached (Jänicke & Lindemann 2010). Especially for ICT products with their growing markets and increasing consumption absolute decoupling requires 'radical' product innovations in order to overcome the counterproductive effects e.g. of decreasing product's durability.
Because of the named barriers (cf. chapter 3), firms in competitive markets often produce only incremental innovations towards higher resource efficiency. Beyond that, eco-innovations in general suffer from a constraint named 'Valley of Death': the move from a test-series of products to production of commercial volumes of a product requires significant investment, and this risk coincides with the stage in the innovation process when public support usually ends (European Commission 2009).
'Radical product innovations', therefore, require an active role by government in order to overcome the 'Valley of Death' to develop innovative technologies and foster their diffusion in mass markets. Policy intervention should not describe particular technologies, but be based on performance-standards. Governments lack the necessary knowledge to determine companies R&D decision in the invention phase of an innovation cycle. However, it can support R&D activities of firms to foster resource efficiency by procuring innovative technologies in the innovation phase. Thus, governments can use the dispersed knowledge of market actors to find potentials for greater resource efficiency and base its innovation procurement decision on the rate of technological progress of the most resource efficient market actors. While the government should not and is not picking winners in this way, it is giving companies economic incentives to accelerate the innovation cycle.
In order to achieve radical efficiency improvement through product innovations a well-designed policy mix is needed that accelerates both the competition between firms for technological leadership as well as requirements for products in mass markets.

6. An innovative policy mix for more resource efficient ICT products

The analysis of deficits has shown that command and control approaches like the Basel Convention or the introduction of minimum recycling quotas for e-waste do not suffice in order to reduce negative externalities in global resource flows. Reasons for inefficient use of resources are manifold and differ according to region and actors. Since most of the consumption of ICT products still takes place in OECD countries, the focus of this paper will be how these states may act in order to minimize environmental effects of their consumption. Moreover, OECD markets have a higher potential to act as lead markets for environmental innovations (Jänicke & Jacob 2004).
Thus, the following chapter explores a combination of instruments (policy mix) which the EU and its member states can introduce to deal with the identified shortcomings in existing resource governance arrangements. The chapter proposes a combination of information generating instruments, public procurement, and regulatory measures (minimum standards), which are based on one another:



6.1. Enabling strong innovations through information obligations

A significant obstacle to an effective resource policy is the lack of information about material flows as well as environmental impacts in global supply chains. Attempts to regulate on the level of nation state are insufficient – much more, a global life cycle assessment of ecological and social impacts would be necessary. While the European Union's resource strategy outlines such an approach, they haven't been translated into practical results (Cf. European Commission 2005).
To address this problem we propose an information-creating policy instrument: Resource Information and Certification Obligations in Supply Chains (RICOS).
RICOS combines attempts for self-regulation, information gathering and legal instruments and contains three elements: 1. *information* 2. *substitution* and 3. *certification* obligations. The goal is to generate knowledge about material streams and to reduce their negative externalities. It further builds the foundation for other resource policy instruments.
At its heart, it requires producers to provide *information* as a precondition for market access ("no data, no market"). This obligation covers environmentally relevant materials embodied in a product as well as its environmental impacts. They begin at the point of extraction (the beginning of the supply chain), but would also gather information on recycled materials. The decision which resources are most relevant varies between different product categories. For ICT products, the scarce metals discussed in chapter would be such resources. We propose to collect the following pieces of information for each metal:

- Amount used (direct material input (DMI))
- Ecological rucksack (ER) and other environmental impacts
- Total material requirement (TMR) as the sum of DMI and ER
- Origin of the resource (e.g. which mine; recycler)
- Share of secondary material in the product

In order to protect company secrets, detailed information is kept confidential in internal databanks of the regulating authorities and only aggregated environmental data are published on each product's data sheet.

Based on this information, the regulatory authorities will determine and constantly update a list of materials that are considered "specifically problematic". This list could be the basis for two additional mechanisms: The listed materials could be subject to a *substitution* obligation – that means they are to be checked whether there is a substitute available with a smaller environmental impact. For scarce metals that are considered "specifically problematic" and cannot be substituted there could be a *certification* requirement. The goal is to gain information on which places of extractions, which mines, have the least environmentally damaging impacts and to foster the reduction of these externalities. The certification is given to materials whose ER and other environmentally impacts are below a certain threshold that is to be determined on a case-by-case basis. Further, it is combined with the obligation for continuous reduction of harmful impacts.

RICOS would be applied to ICT products such as computers in a gradual process to allow for stakeholder involvement. The time between each the three elements of RICOS will further allow companies to a) take action on their own to provide solutions that might make regulation unnecessary, e.g. by voluntary substitution of certain materials, or b) to prepare for the requirements of the instrument.

The implementation of the instrument can be built on the information requirements of the European Union's Eco-design directive (and its regulations) that will – according to current plans – from 2013 on be applied to all kinds of products. That being said, the specific design of such a information-generating policy instrument will need to be based on pilot projects and feasibility studies to develop specific criteria for regulation. Also, the policy's development and its execution should be open to benefit from input by stakeholder groups.

6.2. Fostering strong innovations through public procurement

Chapter 4 discussed the valley of death as an important barrier for European companies to transform eco-innovative inventions into products and commercialise them (European Commission 2009, 2).

Asymmetric information on inventions' potentials for application in mainstream products inhibits finding private financing, which leads to a situation in which "technological values does not lead inevitably to commercialization" (Marklund, Vonortas & Wessner 2009: 124). In recent years, the demand-side of innovation policy instruments has received greater recognition both in research, as well as on the EU's policy agenda (Cf. Aschhoff, Sofka 2008; Edler, Gheorgiou 2007; Edler 2009; European Commission 2007; European Commission 2009; Rolfstam 2009).
In order to overcome this 'valley of death' phase and support the mainstreaming of strong environmental innovation, public procurement can be used to support these not-yet-commercialised technologies. This paper adapts the broad concept of "innovation procurement policy" that contains all forms of market initiation procurement (direct, co-operative, catalytic and pre-commercial procurement) (European Commission 2009, 4). The impact of innovation procurement is multifaceted: a) by procuring products that are not yet commercialised, the government is partly carrying the company's R&D investments in the invention stage; b) the procured product's learning curve is accelerated and it faster reaches the point where it can compete with conventional products in the market and c) the lower environmental impact of products reduces negative external effects.

The EU's framework directive on public procurement (2004/18/EC) gives member states the opportunity to include criteria beyond the lowest price in their awarding decisions. Germany or the UK have adopted provisions to foster innovations by their procurement decisions.
Based on the information generated by RICOS, public procurement can be used to specifically foster innovations in resource efficiency. Public procurement makes up for a significant share in the ICT market. Public tenders would incorporate resource-efficiency-based criteria that producers have to fulfil to be considered like the amount of specific trace metals, the ecological rucksack and/or the share of secondary material. Procurement criteria would be performance-based and dynamic so that the most resource-efficient products are eligible for public procurement. Each year, this threshold would be increased based on the pace of innovation of the leading companies. Thus, the economic incentive to gain access to public innovation procurement markets spurs the competition between companies to increase resource efficiency and reduce environmental impacts.
The UK's public procurement system has already adapted such aspects and gives a practical example on how such a dynamic innovation procurement can be put in practice. In order to help procurement officials identify sustainable products, there is a "greentick" label for those products that meet the requirements of a product category under the government's sustainable procurement policy. In addition to that, two further labels indicate that an ICT product fulfils the best practice criteria of its product group ("greentick plus"), respectively that it reaches the "class leader" standard ("greentick double-plus").[1] The UK's example provides one example on how public procurement can be designed to provide incentives for environmental innovations in ICT products.

6.3. Diffusion of strong innovations into mass markets through minimum standards

While public innovation procurement aims at inducing innovation, the introduction of minimum standards for products targets the diffusion stage of the innovation cycle. Building on information requirements (RICOS), producers have to prove the resource efficiency of their products before gaining market access. In order to avoid interference with world trade law, standards have to be met both by domestic and foreign producers.
Overall aim of the regulation is the reduction of resource intensity of products. In order to build on the market push by public procurement, the minimum standards should adopt the same criterion respectively criteria. The paper will illustrate the mechanisms of this instrument by exemplarily using an input quota for secondary material in new ICT products. As mentioned before, the substitution of primary material for secondary material is one means to enhance material efficiency of products and is explicitly mentioned as one possible indicator for implementing measures under the Eco-Design Directive. However, an expansion to other product categories or material flows is possible in principle.

Reasons to start with a minimum input quota for secondary material in new products comprise:

- There exist huge potentials for enhancing efficiency through better take back of end-of life devices and better recycling technology (process innovation and technical innovation).
- Secondary metals normally have a lower material intensity (measured in TMR) than primary material.

[1] Cf. http://www.buyingsolutions.gov.uk/aboutus/sustainability/sustainable-solutions/quickwins/

- o Enhancing the use of secondary material bypasses the problem of substitution through other, potentially even more problematic primary materials.
- o The expansion towards other materials, as already provided for under RICOS, is possible.
- o The Eco-design directive explicitly mentions the share of secondary material as one possible indicator for implementing measures.

The introduction of a minimum input quota for secondary material is a product regulation. Other than the existing legislation for e-waste (e.g. the WEEE Directive), the instrument targets the input of material into new products, and not the disposal of end-of life devises.[2] A minimum input quota for secondary material aims at lowering the material intensity of ICT products. However, while primary materials are relatively cheap due to lacking internalisation of environmental damages, the recovery of trace metals from end-of life products requires sophisticated recycling technology. The augmented demand for secondary material strengthens the market for recycled material, making investments into recycling technology financially viable. It also aims at assigning a positive value to end-of life products which are considered a financial burden under the current producer responsibility schemes.

Since the average material composition of ICT products changes over time, not only the standard level, but also the metals selected for regulation need to be adjusted on a regularly basis. In order to ensure acceptance (legitimacy), the identification of most relevant metal flows take place in a participatory process. Stakeholders that would be represented at the panel include producers and importers, recyclers, but also environmental and development NGOs and consumer rights organisations. In case the accomplished standard under the public procurement seems insufficient, the panel retains the possibility to tighten the respective standards.

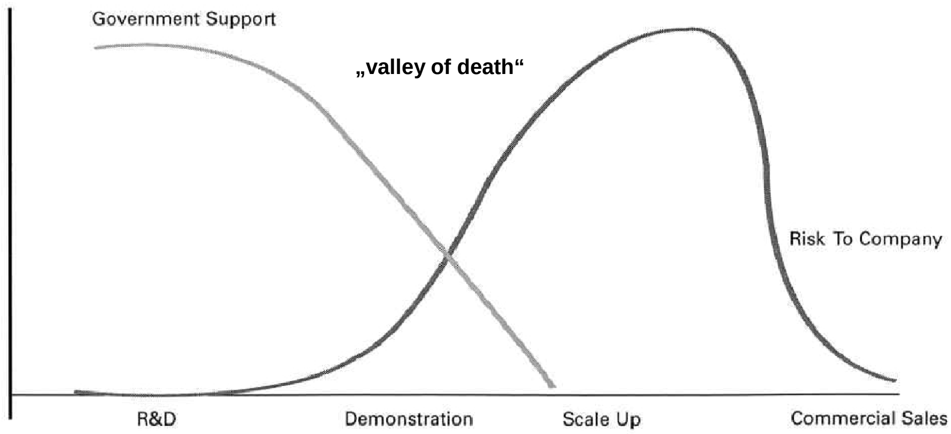
In order to foster innovation, the minimum standard needs to be tightened regularly. The introduction of minimum standards targets the diffusion stage of the innovation cycle and aims at spreading resource efficient products. Best performers of one product group can be taken as reference point; their technological standard has to be met within a certain time frame by all new products that enter the market. All products that do not meet the standard (the “dirty end”) will no longer be allowed on the market.

6.4. The policy mix

The three mentioned policy instruments work together and present a policy mix which enables, fosters and diffuses strong environmental innovations in the field of resource efficiency. The following table and figure illustrate the interaction between them and their assignment to the three phases of an innovation cycle and how they contribute to overcoming the “valley of death”. The instruments complement public and private investments in research and development and sustain these. By providing for greater transparency about the use of resources, RICOS on the one hand contributes to better information of industry actors and on the other hand serves as a foundation for the other proposed instruments (public procurement and dynamic standards).

By making public procurement decisions on RICOS-based performance criteria, procurers are not arbitrarily picking winners and the pace of innovation is determined by the most innovative companies in the market. By buying innovative, but not yet marketized products, public procurers accelerate the products’ learning curves and drive down the costs of innovative technologies in order to diffuse them in mass markets more quickly. Finally, Dynamic regulatory standards aim exactly at the diffusion of innovative products and technologies in mass markets to realize environmental benefits from the greater efficiency in use in large sections of the market. Again, the standards are not determined arbitrarily but by the most innovative and efficient companies in the market whose performance standards will have to be met by all suppliers in a given time span. As such, industrialized countries can act as lead markets for a global diffusion of resource efficient products.

[2] One exception is the RoHS-Directive that regulates the use of certain hazardous materials in new products. However, the RoHS-Directive is part of hazardous substances law and thus cannot be used as basis for a resource and material efficiency policy (cf Ch. 4).



Graphic adapted from European Commission 2009: 25

Instrument/ Phase	Invention	Innovation (market launch)	Diffusion
Informational instruments		***RICOS***	
Direct support instruments	Direct support for research and development	***Public Procurement of eco-innovative technologies***	
Regulation			***Dynamic regulatory standards***

7. Conclusion

The example of ICT products has shown that market forces do not suffice to take negative externalities into account and to allocate scarce resources efficiently. One source of these inefficiencies is grounded in globalized production and consumption patterns that contribute to a lack of information about resource flows, their origins, and connected environmental impacts. However, adequate information is a precondition for targeted policy intervention that aims at fostering strong environmental innovations. The combination of public procurement and dynamic standards provides a consistent policy frame to commercialise eco-innovative technologies and diffuse them in mass markets. Such a policy mix might be used as one means to avoid environmental effects of consumption that appear outside the “own” state territory. Therefore, the enabling, fostering and diffusion of strong environmental innovations has the potential to mitigate the shifting of environmental burdens from the “industrialized” to the “developing” countries. The presented policy mix does not target to cap supply chains and to threaten the income of mining and recycling workers in developing countries, but to enhance the environmental and health conditions of their work. A proper design of the policy mix therefore can contribute to more environmental justice regarding resource use and product consumption.

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