Towards a Circular Economy with Environmental Product Policy

Considering dynamics in closing and slowing material loops for lighting products

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Abstract

A Circular Economy (CE) can help to achieve the sustainable development goal of responsible consumption and production. Product policies, in turn, can support CE objectives by promoting reuse of products, recycling of materials, and providing ecodesign incentives for more durable products. This thesis examined the role of product policies in meeting CE objectives in the EU, with specific focus on lighting products in the context of the Waste Electrical and Electronic Equipment (WEEE) and Ecodesign Directives. The research findings contributed to current policy questions, including how well WEEE systems have performed in closing material loops; the potential for closing loops for critical materials; and what trade-offs can occur in promoting longer lifetimes for rapidly developing products.

A theory-based evaluation was used to assess the performance of extended producer responsibility (EPR) policies for lighting products in the Nordic countries. While the WEEE systems were generally performing well, there were issues identified, including the downcycling and loss of many recycled materials and lack of ecodesign incentives. The research also found that the requirements of the WEEE Directive were a key enabler for closing loops for rare earth elements (REE) from lighting products, but that the recycling efforts in the EU face challenges with economic feasibility and complex transactions in the value chain.

The lifetimes of LED lighting products were examined from a consumer perspective through a life cycle cost analysis and an environmental perspective with life cycle assessment. From a consumer perspective, lifetimes much longer than the mandatory Ecodesign minimums were found to be optimal for LED products on the Swedish market. From an environmental perspective, longer lifetimes for LED lighting products can result in trade-offs between energy/climate impacts and resource depletion/toxicity impacts. However, in the context of a less carbon-intensive electricity mix, these trade-offs are minimised. The same is true if the product's energy efficiency improvements slow or mature.

The research suggested that more specific product and material targets in the WEEE Directive could be appropriate. While the findings indicated that more stringent mandatory lifetime requirements in the Ecodesign Directive may not be appropriate for products with rapid technological developments, dynamic trade-offs should be explicitly recognised in policy mixes and accounted for in policy planning.

Popular Science Summary

What really happens when we dispose of our lighting products? Critical raw materials in our lighting products have high value, but can that value be retained in Europe? LED lamps have many potential benefits over traditional lighting products, including longer lifetimes; but do long lifetimes mean we miss out on potential benefits of even newer technology?

Why do these questions matter? Our present system of production and consumption exceeds and damages the planetary systems on which it depends. That means we need to rethink the way products are produced, but also how they are consumed and what happens to them after use. Transitioning towards responsible consumption and production is a United Nations Sustainable Development Goal (number 12) and the aim of a Circular Economy. A Circular Economy encourages more efficient use of resources by closing material loops with recycling, and slowing loops by keeping products longer in a cycle; for example, through increased durability or repair.

However, there are challenges. Currently, high levels of consumption contrast with low levels of reuse and recycling, especially for critical raw materials. At the same time, decreasing product lifetimes further accelerate consumption. The EU's Circular Economy Action Plan, introduced in 2015, highlighted the need for enhancing current policies targeting products. This thesis focusses on policies for lighting products, a product group that exemplifies many of the current product policy issues related to slowing and closing material loops. The aim of this research was to address gaps in knowledge about the performance of existing product policies and potential improvements in relation to the EU's Circular Economy objectives.

The thesis evaluates the performance of extended producer responsibility (EPR) policies for lighting products in the Nordic countries. EPR policies intend to make producers responsible for the environmental impacts of their products throughout their life cycles (i.e. from production to end-of-life). In the EU, the Waste Electrical and Electronic Equipment (WEEE) Directive places responsibility on producers to set up systems for end-of-life management of lighting products. The WEEE Directive also aims to incentivise ecodesign, recover valuable materials, and close materials loops with mandatory targets for collection and recycling.

The evaluation of Nordic country EPR systems for lighting products reveals that collection and recycling of lighting products have improved with the introduction of EPR. Lighting products have been collected at a relatively high rate. The research suggest key factors for the high collection, including the convenience of the collection system and the high awareness amongst stakeholders of the risk from mercury.

However, there are still challenges with meeting some of the policy goals. The WEEE Directive's quantitative targets do not address the issues of downcycling (i.e. recovery of materials, but in low-value uses or products) or loss of valuable materials altogether in the current recycling processes. This loss of value and material is in conflict with the objectives of value retention and resource efficiency expressed in both the WEEE Directive and in the EU's Circular Economy Action Plan. There were also few indications that the WEEE Directive, as implemented in the Nordic countries (with producers sharing responsibility in collective organisations), is incentivising individual producers towards ecodesign that could make increased recycling and recovery of materials easier.

When the research for this thesis began in 2014, there was considerable concern about critical materials, which are important to the EU economy but face supply risks. There were few successful industrial-scale examples of recycling for critical raw materials in the EU – one was a company recycling rare earth elements (REEs) from lighting products. This case was analysed to understand the enabling factors

and potential for recycling REE from lighting products. Interestingly, the specific requirements in the WEEE Directive to collect and remove mercury from lighting products was one of the key enabling factors for the feasibility of REE recycling.

However, REE recycling from lighting products in the EU still faced competition from supply of REE from mining and processing in China. When the high prices of REE dropped after 2012 (due to a change in Chinese export restrictions), recycling initiatives in the EU struggled. Understanding the potential for REE recycling also involved examining the dynamics of complex global value chains. To better understand these dynamics, the research described the complex transactions in the governance structure of the value chain for REE recycling from lighting products. The research identified highly complex transactions and challenges for business actors in capturing social and environmental values.

Product policies for a Circular Economy aim not only to incentivise recycling of materials, but also to slow material loops through longer product lifetimes. In the EU, the Ecodesign Directive sets minimum energy-efficiency and functionality requirements for products, including minimum lifetime requirements for lighting products. However, since the introduction of the Ecodesign Directive in 2009, LED lighting products have been rapidly developing in terms of energy-efficiency and material design, which raises a question about whether longer lifetimes would result in increased costs for consumers and higher environmental impacts by locking in less efficient technologies.

The consumer perspective to the question of longer lifetimes was analysed with an assessment of life cycle costs of LED lamps on the market in Sweden. Lifetimes around 25000 hours (much longer than the current policy-mandated minimum lifetimes) were found to be optimal. However, the optimal lifetimes of LED lamps would be lower for the consumer in the context of higher electricity prices and increasing efficiency of replacement LED lamps.

From an environmental perspective, life cycle assessment results showed longer lifetimes for LED lamps could be better in terms of energy and climate impacts but worse in terms of resource depletion and toxicity impacts. However, context matters. When the electricity mix considered is cleaner, the climate and energy-related impacts from using LED lamps lessen overall, and in relation to impacts from production of the lamps. This means that in contexts like Norway and Sweden, with relatively clean electricity mixes, longer product lifetimes (and using products longer) are preferable when considering all environmental impacts. In all contexts, trade-offs between different impacts are minimised when energy-efficiency improvements of new products slow or mature.

While further research would strengthen the findings, some preliminary implications for policy can be drawn. The research suggested that continued improvement in collection of lighting products could be motivated by a collection target set specifically for lighting products and other small electronics. Recycling targets in the WEEE Directive could specifically target critical raw materials. There is a need to explore how policies can capture the environmental and social benefits of the recycled materials, also in utilising the recycled materials in products, e.g. through voluntary green procurement criteria or mandatory ecodesign requirements for recycled content.

While the findings indicate it may be appropriate at the EU level not to implement longer lifetime requirements for products with rapid technological developments, trade-offs should be discussed. Product development, and the push of product development by minimum standards, should inform a timeline for implementing appropriate lifetime measures. For contexts with low-carbon electricity mixes, it is already preferable to promote longer lifetimes for all products.

The findings of the research have broader implications for the transition towards a Circular Economy. A holistic approach needs to be taken in considering priorities for environmental policies. At times resource efficiency aims may undermine climate mitigation aims. However, trade-offs are also dynamic and often temporary, necessitating understanding of policy targets and roadmaps from both areas in order to optimise policy synergies.

List of Papers

Paper I Richter, J. L., & Koppejan, R. (2016). Extended producer responsibility for lamps in Nordic countries: best practices and challenges in closing material loops. *Journal of Cleaner Production, 123,* 167–179.

Paper II Machacek, E., Richter, J.L., Habib, K., & Klossek, P. (2015). Recycling of rare earths from fluorescent lamps: Value analysis of closing-the-loop under demand and supply uncertainties. *Resources, Conservation and Recycling, 104, Part A,* 76–93.

Paper III Machacek, E., Richter, J. L., & Lane, R. (2017). Governance and Risk–Value Constructions in Closing Loops of Rare Earth Elements in Global Value Chains. *Resources, 6*(4), *59.*

Paper IV Richter, J. L., Van Buskirk, R., Dalhammar, C., & Bennich, P. (2019). Optimal durability in least life cycle cost methods: the case of LED lamps. *Energy Efficiency, 12*(1), 107–121.

Paper V Richter, J.L., Dalhammar, C., Tähkämö, L. (2019). Trade-offs with longer lifetimes? The case of LED lamps considering product development and energy contexts. *Journal of Cleaner Production, 226,* 195-209.