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Implications of Carbon Markets for Implementing Circular Economy Models

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Abstract

Carbon markets have become a prominent policy innovation to internalize the external costs of fossil energy use. Cap and trade schemes, such as the European Union Emissions Trading System (EU ETS, launched in 2005), allocate tradable emissions allowances to facilities; and offset programs, such as the Kyoto Protocol's Clean Development Mechanism, credit emissions reductions at the level of individual projects. In parallel, policymakers in various countries around the world are embarking on efforts to conceptualize and move towards closed loop "circular economy" models. This paper explores the implications of existing carbon markets for efforts to transform economies from a linear to a circular model, based on selected case studies that highlight issues related to achieving material, energy and water efficiency (e.g., end-of-life treatment of tires, incentive schemes for home appliances). Policy relevant insights are also presented.

With a "gigaton gap" between emission reduction pledges currently put forward by all countries and the reductions necessary to have a reasonable chance of keeping global warming below 2°C, it is imperative to find effective means of achieving the structural changes that will lead to a low-carbon economy in time. Ironically, the improbability that an effective and comprehensive global climate protection strategy for the period beyond 2012 will be adopted in the near future presents a valuable opportunity to consider how market based mechanisms can be designed to drive, rather than hinder, the transition to a circular, low-carbon economy, as well as for leading countries to experiment with related policy innovations.

Keywords: super-efficient home appliances, scrap tire recycling, resource efficiency, low-carbon economy, governance and policy coherence

1. Introduction

As population grows, standards of living improve and markets globalize, the need to decouple environmental impacts from economic growth is becoming an increasingly urgent global imperative. Whereas environmental policies on climate change already tackle some aspects of resource use, any progress is being overwhelmed by ever growing production and consumption volumes – and global greenhouse gas (GHG) emissions and waste heaps continue to mount.

Resource efficiency and sufficiency measures are not delivering the reductions required to reduce absolute emissions, and the overall environmental impact is increasing. A broader perspective is desperately needed.

2. Circular economy vision and carbon market reality

Carbon markets have been created largely by governments as a means of allowing regulated entities to achieve greenhouse gas emissions reductions cost effectively (see Table 1). They tend to consider only carbon dioxide or some combination of the greenhouse gases addressed by the UN Framework Convention on Climate Change (UNFCCC). Cap-and-trade schemes establish emissions quotas for individual GHG-emitting entities within a given political jurisdiction (such as the facilities under the EU ETS), and impacts up- and downstream of the regulated entity are typically excluded from consideration (with the exception of impacts due to purchased electricity), as illustrated in Figure 1. The use of offsets has typically been accounted for at the project level.

Circular economy thinking, in contrast, pursues different objectives and takes a more inclusive approach by drawing on life cycle assessment (LCA) methodologies. It has its roots in industrial ecology (Andersen 2006). As well as considering the environmental impacts of the processes within the direct control of an entity, attention is also given to the raw materials used, supply chains, product use, and finally the effects of disposal and possibilities for reuse or recycling. Cradle-to-cradle (C2C) thinking has begun to influence various types of policies in the European Union and other countries – including product policy, consumption & production policy, procurement policy, standard & label schemes, waste policy, natural resources policy, and innovation and technology policies – but there has been virtually no integration into climate mitigation policy.

Figure 1 illustrates the emphasis of carbon markets on greenhouse gas impacts of regulated entities (usually at a facility level) and individual projects, and Table 1 summarizes some of the important differences between carbon market mechanisms and circular economy thinking. Materials management is an approach to serving human needs by using/reusing resources most productively and sustainably throughout their life cycles, generally minimizing the amount of materials involved and all the associated environmental impacts. Independent efforts to address the issues of climate change, energy conservation, and water conservation miss opportunities for achieving maximum environmental impact, because they do not also consider broader approaches to managing materials more sustainably, and they fail to consider different supply chain perspectives that can help reveal impacts in a way that is helpful for considering the most effective policy options.

The following sections illustrate some of the shortcomings of carbon markets, based on case studies for two product categories familiar to individual consumers: major domestic appliances and automobile tires. The paper then discusses how climate change and life cycle materials management policies might be better integrated to yield more sustainable outcomes for the planet.

3. Major domestic appliances

3.1 Inputs

The German sustainability leader Bosch and Siemens Home Appliances Group has invested significant effort into carbon market development since 2008, including:

- Obtaining approval of two methodologies to quantify GHG emission reductions from appliance programs implemented under the Clean Development Mechanism (CDM): “Energy efficiency and HFC-134a recovery in residential refrigerators” facilitates refrigerator exchange programs, including state-of-the-art demanufacturing to capture industrial gases (CFCs, HFCs, HCFCs) used as refrigerants and foam blowing agents, while “Dissemination of energy efficient household appliances” relies on global benchmarks to estimate energy savings and emissions reductions;
- Developing plant oil cookstove technologies and methodologies to quantify the resulting greenhouse gas emissions reductions, as well as contributing to the Global Alliance for Clean Cookstoves;
- Preparation of a project in Turkey to obtain Verified Emission Reductions under the independent Gold Standard for manufacturing refrigerators that are more efficient than the market benchmark.
- Implementing a modal switch logistics project in Germany under the Kyoto Protocol Joint Implementation (JI) mechanism.

3.2 Outcomes

With the exception of the logistics modal switch program, the anticipated outcome of these efforts – the ability for BSH to generate carbon market revenues to incentivize low-carbon innovation across the value chain – has so far not materialized. The experience with the Clean Development Mechanism been particularly disappointing (Grammig, Arquit Niederberger & Shiroff 2009). Despite concerted attempts since 2008, BSH has failed to work through official UN channels to make it possible to generate carbon offsets for programs to disseminate energy- and water-efficient home appliances. Even when the CDM authorities approved appliance methodologies, they have invariably been fraught with known shortcomings that have so far prevented any appliance manufacturer or other entity from realizing any carbon revenues for manufacturing or disseminating efficient appliances (see Table 2).

The exception is BSH’s program to shift a large share of its goods transport from road to rail, which has been officially acknowledged as a climate protection project by the German Emissions Trading Authority (DEHSt) under the title "BSH Transportation Shift Project". BSH will receive European emission allowances (EUAs) from the German government as compensation for the reductions in carbon dioxide emissions it achieves by switching to low-carbon rail transport. This model could be readily adopted by other manufacturers.

Furthermore, the company has continued to voluntarily optimize the cradle-to-cradle performance of its products as part of its normal business practices, by adopting the International Organization for Standardization's (ISO) 14001 standard (environmental management systems) and environmental performance evaluation guideline 14031, undertaking product environment (life cycle) analysis (Otto, Ruminy & Mrotzek 2006), consumer education efforts, issuing and enforcing a code of conduct for BSH suppliers, and cooperation on development of voluntary recycling standards. These sustained and pioneering efforts have been recognized by various institutions over the past 20 years.

3.3 Insights

These experiences lead to a number of insights:

- Due to the large and growing number of major domestic appliances in service around the globe, industrial greenhouse gases in the appliance stock (e.g., CFCs and HCFCs used as refrigerants and trapped in insulation material) and the significant difference in consumption between the best and worst products available, the potential to reduce energy use and greenhouse gas emissions associated with domestic electrical appliances rapidly is considerable – and existing policies leave large savings "on the table".
- Major domestic appliances at the cutting edge of efficiency tend to be more expensive to manufacture, which is reflected in retail prices. The most efficient A+++ clothes washers, fridges, freezers and A++ tumble dryers sold in Germany in 2011, for example, were between €240 and €630 more expensive (and 25 – 55% more efficient) than "average" products in the categories A+ and B, respectively.
- Consumers are more likely to purchase the most resource efficient appliances in those markets where awareness of the issues is most prevalent and electricity and water prices are higher (hence faster payback through savings in utility bills).
- We have seen no evidence that carbon markets have contributed to product innovation; rather, corporate strategy and product development protocols of individual manufacturers, as well as voluntary corporate responsibility initiatives, have stimulated leadership. The carbon market has not created any tangible incentives for manufacturers to innovate on product design or for end users to purchase super-efficient domestic electrical appliances. Not a single BSH facility is subject to any cap under an emissions trading regime, nor has BSH managed to generate revenues or intangible benefits from carbon offset efforts (with the exception of the logistics effort highlighted above). One major barrier is a lack of viable methodologies to credit efforts to disseminate super-efficient domestic electrical appliances.
- The problem of existing banks of fluorinated compounds used as refrigerants and foam blowing agents in cooling appliances has yet to be satisfactorily addressed. This large potential source of GHG emissions falls though the cracks between the Montreal Protocol (which regulates only the manufacture of ozone depleting substances (ODSs), but not existing banks in the appliance stock) and the Kyoto Protocol (which only addresses GHGs that are not ozone depleting substances). As pointed out by the Montreal Protocol Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee in its latest assessment (UNEP 2007), total emissions from refrigerating appliances are dominated by end-of-life emissions – and there is no economic justification for recovering refrigerant, let alone foam blowing agent, at end-of-life. In the case of refrigerator programs, any mitigation effect of energy efficiency improvements can be nullified through ODS releases, if the existing appliance stock is not carefully demanufactured and the ODSs captured or destroyed. One elegant, perhaps unique, means of providing the right incentives is to allow such activities to generate carbon offsets. Whereas the California cap-and-trade program includes a compliance offset program under which ODS projects are eligible, attempts to credit reductions in ODSs outside of the project boundary due to a CDM project activity unfortunately have yet to be accepted by the CDM authorities, despite the fact that this would be consistent with the modalities and procedures adopted by the Parties to the Kyoto Protocol.

3.4 Potential

Significant energy and water efficiencies have already been achieved without any incentives from carbon markets (Figure 2). Future advances will be more difficult to achieve – and carbon markets could offer a welcome incentive to leading manufacturers. Despite the current low market price of carbon offsets under the CDM (under €1/t CO_2e on the spot market) several factors have the potential to leverage relatively modest carbon offset revenues to make such technology more widely available, including:

- Marketing value related to the generation of credits: In those markets where an increasingly large number of consumers are environmentally conscious, the ability to emphasize the green credentials of a given appliance provide a unique selling proposition. Moreover, even under the CDM, when carbon offsets can only be generated in eligible developing countries, the ability to tell the marketing story is viable in Annex I countries as well.
- Achieving greater economies of scale: The technology and feature differences between high-end and basic appliances is by no means solely related to resource efficiency. Consumers purchasing the lower end products are, however, far more price sensitive, and adding super-efficient technology to such products, even at relatively minimal additional costs, can drive the retail price high enough to no longer be a viable option for this class of consumers. As a result, the materials for such technologies are often not purchased in quantities that maximize price efficiency. Carbon revenue has the potential to change this dynamic in a virtuous circle. By marginally lowering the cost and increasing the potential market for such technologies, more super-efficient products can be made available to a larger target market.
- Planning and research and development (R&D): The availability of carbon revenues has the potential to significantly impact the manner in which product development and launching occurs. This can range from the acceleration and additional financing of R&D for resource efficient technologies to the earlier introduction of available technologies to markets that might otherwise not be considered mature enough to justify.

4. Vehicle tires

4.1 Inputs

The tire industry uses 70% of all natural rubber produced worldwide, and consumption is expected to double within the next 30 years (ETRMA 2012). Applications that recycle or recover rubber are therefore critical to preserve this valuable resource. Genan, a Danish/German group of companies, is the largest recycler of scrap tires in the world. The company recently commissioned independent analyses that compare the impacts of different end-of-life pathways for scrap tires:

- Material recycling: Recycling of tires to recover the rubber fraction for use as an ingredient in rubber asphalt (75% fine fraction < 1.4 mm) and for use as an infill in artificial turf (75% > 1.4 mm), the steel fraction to substitute for virgin production and a residual textile/rubber fraction that can be used as an alternative fuel by cement plants;
- Civil engineering applications: Shredding of tires for use as a drainage layer in landfills;
- Co-incineration: Combustion of whole tires as a source of energy and iron in cement kilns.

The LCAs were carried out by a team from the Copenhagen Resource Institute, FORCE Technology (Denmark), and the German IFEU Institute in Heidelberg, according to the ISO standards 14040 and 14044. They were peer reviewed by an independent, international team of three experts led by Gaiker, a Spanish Technology Centre. These studies demonstrate the potential climate mitigation and environmental benefits of recycling scrap tires to substitute for virgin materials, compared with other end-of-life options (disposal, civil engineering, energy recovery, feedstock recycling).

With respect to climate change impacts, these LCAs found that the material recycling route reduces potential greenhouse gas emissions by roughly 1.1 t CO_2e per ton of scrap tires recycled relative to the cement kiln co-incineration route and by 1.8 t CO_2e per ton, compared with civil engineering applications. Recycling avoids several processes, in particular, production of virgin polymers, which saves about 50 GJ per ton of tires, and the iron fraction eliminates the need for 400 kg of iron ore.

As in the previous example, the company is not subject to any emissions caps on its own installations, but it has been exploring the feasibility of offset generation activities:

- Genan conducted a study to determine whether it might be possible to generate carbon offsets for a first-of-a-kind tire recycling facility planned for construction in Texas.
- To make the prospect of constructing expensive, state-of-the-art tire recycling facilities in emerging economies and developing countries more attractive, the company has been interacting with the CDM authorities on appropriate methodologies, including commenting on existing methodologies and proposing a new methodology "Substitution of virgin by recycled raw materials recovered from scrap tires".

According to this methodology, the project boundary includes the scrap tire recycling facility, which will be constructed (or retrofitted/expanded) under the project activity. Emissions reductions are determined by taking into account project emissions (due to operation of the recycling facility), baseline emissions (which are zero, if the recycling plant is a greenfield facility) and the net change in leakage emissions outside of the project boundary, based on life cycle assessment results.

The mechanical tire recycling process yields the following marketable outputs for each ton of scrap tires: 503 kg fine rubber granulate, 180.5 kg steel, 167.5 kg coarse rubber granulate, and 140 kg textile fraction (which also contains residual rubber).

To simplify project validation and subsequent verification of emissions reductions, the proposed methodology assumes that the baseline scenario for the treatment of scrap tires at end-of-life is always co-incineration in a cement plant. This assumption is very conservative, because scrap tires are not widely used as alternative fuels in developing countries (UNEP 2010), but rather are merely discarded, used for civil engineering purposes or incinerated without energy recovery – all of which would lead to greater net emissions reductions outside of the project boundary than assuming co-incineration. This simplification means that a conservative result can be achieved, without any need to verify the source of scrap tires.

Figure 3 presents an overview of the system boundaries considered for the recycling and the co-incineration routes in the underlying LCA study "Comparative life cycle assessment of two options for waste tire treatment: Material recycling vs. co-incineration in cement kilns" (Genan 2009).

The proposed emission factor to be used to estimate net leakage from material recycling of scrap tires (-0.794 t CO_2e/t scrap tires) is based on the results of the same LCA study (Table 3). The only modifications are that the scrap steel factor has been reduced from 360 to 271 kg CO_2e/t scrap tires, taking into account the most recent scrap steel LCI value of 1.5 t CO_2e/t scrap steel (worldsteel 2011), and, to ensure conservativeness across host countries, the iron source in cement kilns is assumed to be 100% pig iron, rather than the mix of iron ore and scrap steel used in the original LCA.

Table 3 provides emission factors based on both the "consequential" and the "attributional" LCA approaches. In the draft methodology, we have used the values estimated under the former approach, because a consequential approach reflects the changes from one end-of-life treatment scenario (co-incineration in cement plant = baseline scenario) to another (recycling = project activity) and takes into account the market response to changes in demand, which is more appropriate for estimating leakage impacts under the CDM. Furthermore, the consequential approach yields more conservative net leakage values for the recycling route. The methodology adopts a set of conservative assumptions, with the intention of avoiding the need to obtain detailed local data, while ensuring that reductions in greenhouse gas emissions outside of the project boundary attributable to the project activity cannot be overestimated.

Genan is also engaged in stopping the practice of exporting partly worn tires to developing countries, because this results in three adverse outcomes: (i) the tires are often used much longer than originally prescribed by the tire manufacturer, causing traffic accidents; (ii) poor countries shoulder a disproportionate share of the waste burden, because they import tires with a very short remaining useful lifetime, while being stuck with all of the waste problem, and (iii) very often recycling technology is not available in developing countries, so the scrap tires are dumped or end up in landfills, which requires a lot of land and can lead to adverse health impacts (e.g., supporting mosquito breeding, spreading dangerous diseases like malaria, water contamination by tire compounds, uncontrolled burning).

4.2 Outcomes

Consultations with emission cap-and-trade scheme operators and regulators in North America led Genan to conclude that there was no basis to pursue generation of offsets from Genan's planned Texas facility, because the resulting emissions reductions would not be eligible for a variety of reasons:

- Regional Greenhouse Gas Initiative: The RGGI cap-and-trade scheme was the first mandatory, market-based CO_2 emissions reduction program in the United States, with an initial 2009 – 2011 compliance period. Scrap tire recycling is not among the five eligible offset project categories. Furthermore, all offset projects must be located within one of the RGGI participating states, and the planned locations of US plants (Texas, California) are outside of the RGGI region.
- California Cap-and-Trade Scheme: As an integral part of the California Global Warming Solutions Act of 2006, a cap-and-trade scheme will begin in 2013 for electric utilities and large industrial facilities, expanding in 2015 to ultimately cover about 600 facilities responsible for 85% of California's greenhouse gas emissions Only sources outside capped sectors may generate offsets and – although not explicit in the proposed regulation – according to principles of the California system, sectors capped in California would be ineligible to generate offsets anywhere in the US and Canada, even if the sector is not actually capped in that jurisdiction (such as in Texas). Since both the electricity and cement sectors are capped under the California scheme, offsets cannot be generated.
- Western Climate Initiative: According to the WCI definition of "real" emissions reductions or removals, these GHG impacts must take place at sources controlled by the project proponent. Furthermore, an explicit decision was taken not to include "avoided" emissions in the definition of offsets, "as the term often implies that no real reduction took place, which conflicts with the criterion "real" and is inconsistent with the ISO".
- Midwestern Greenhouse Gas Reduction Accord: The model rule finalized in May 2010 foresees that the emissions reductions must occur primarily within the participating jurisdictions, which excludes Texas.
- Joint Implementation: The Kyoto Protocol provides for carbon offsetting among Annex I Parties to the agreement. However, the USA has not ratified the Kyoto Protocol and is not likely to do so; therefore, no JI offsets can be generated from US-based operations.

It is too early to tell whether it will be possible to generate offsets for tire recycling under the CDM; the CDM authorities have been working on a suitable quantification methodology since early 2011, but have yet to approve one.

4.3 Insights

It is proving difficult to access carbon markets for recycling activities, for a number of reasons:

- Conceptually, life cycle assessments produce results that are inconsistent with typical criteria for offset quality, because LCAs assess potential impacts, whereas offsets are intended to represent "real" and "verifiable" emissions reductions that have been achieved. In capped sectors, all sources and sinks are already accounted for and attributed to power plants or industrial facilities, so offsets issued to reduce emissions within these sectors would represent "double counting", unless specific set-aside or accounting provisions are adopted.
- The carbon market, therefore, does not directly reward pure recyclers, because the service they provide results in avoidance of upstream greenhouse gas emissions reductions associated with raw materials needed to manufacture final products downstream, activities that are beyond the control of the recycling company. There is also no carbon market mechanism that makes manufacturers responsible for carbon embedded in the raw materials they use.
- Under the Clean Development Mechanism, there is no systematic framework for assessing climate mitigation impacts of activities across the entire cradle-to-cradle lifecycle of consumer products. There is no sectoral scope defined for recycling activities, which is not surprising, given that the industry is diffuse,

with a wide range of industries that may be classified as being engaged in recycling activities (e.g., hauling, manufacturing, processing, brokerage, refurbishment), with more or less vertical integration. Nor are the concept of "project boundary" and the guidance on accounting for greenhouse gas impacts outside of the project boundary (referred to as "leakage") applied consistently. This is critical for activities that prevent waste from being generated, because the largest greenhouse gas savings potential is not in making the recycling process itself less carbon intensive, but rather in making recycled materials available to displace production of virgin raw materials and/or combustion of fossil fuels by other industries.

- In some cases, project based offsetting has resulted in perverse incentives to create waste first and then mitigate emissions from it, rather than avoiding waste in the first place (i.e., landfill methane capture, fuel switch to alternative fuels in the cement industry).
- Carbon finance alone may be insufficient to overcome local barriers to tire recycling, such as the lack of national legislation to create a collection system for scrap tires.

4.4 Potential

The disposal options on a global level are retreading, recycling, incineration, civil engineering, and landfilling, with retreading being the most beneficial solution for the environment (although mainly practical for truck tires and of declining importance, because the relative cost of new tire manufacturing continues to decrease relative to retreading). The second best solution is recycling into the original components of the tire. The third best solution is incineration in cement kilns. And the worst solution is landfill, which is now banned in large parts of the world, including since 2003 in the EU under the Landfill Directive (1991/31/EC).

Beyond climate change concerns, promoting recycling offers other important economic and social benefits, including generating economic growth, fostering innovation, boosting employment, and helping secure access to critical resources. Taken together, these characteristics mean that recycling has an essential role to play in the shift to a green economy that generates prosperity, while maintaining a healthy environment and social equity for current and future generations (EEA 2011, Lean Energy Cluster 2012).

Based on the conservative quantification methodology suggested to the CDM authorities, a typical recycling facility with a capacity of 70 kt could avoid over 55 kt CO_2 emissions annually compared with the alternative of incinerating the tires in cement kilns (based on an emissions factor of -0.794 t CO_2e/t scrap tires). Were the estimated 1.25 million tons of scrap tires that were combusted as alternative fuels in Europe in 2010 (ETRMA 2012) recycled instead, roughly 1 million t CO_2e emissions could be avoided each year. Were the 240 million end-of-life tires that were generated in China in 2009 recycled, 1.9 – 4.3 million t CO_2e emissions could be avoided, assuming an average weight of 10 kg per tire and depending on whether energy recovery or civil engineering applications are assumed to be the baseline.

By adopting a sound methodological framework for material recycling, the CDM can support circular economy thinking, which will become increasingly vital. Although there are technical limits to how much waste can be incinerated in cement plants, plants in developing countries lag far behind on average – and are expected to do so for the foreseeable future (OECD/IEA & WBCSD 2009).

This situation represents an opportunity for the CDM to inform discussions about the best use of materials at end-of-life and reconcile circular economy and mitigation policies, so that valuable scrap tires are not incinerated in cement plants, when they could instead be recycled, with net mitigation benefits. Unlike the case of the European Union and the United States, where gate fees are payable to approved receivers of scrap tires (such as a tire recycling plant) to contribute to profitability, such incentives are largely absent in developing countries – creating a critical regulatory gap that could be readily addressed by carbon finance. In addition, incentives often reward co-incineration and recycling equally, despite far superior resource conservation and climate performance of the recycling route. The key is to provide either regulatory or market incentives that only reward quality recycling and maximize greenhouse gas emissions reductions relative to other end-of-life alternatives.

5. Rethinking market-based approaches

These case studies demonstrate the following shortcomings of carbon markets as a tool to stimulate the transition to resource efficient, low-carbon economy models:

- Carbon price signal is weak and not felt by end users and therefore has little impact on direct and indirect emissions from uncapped sectors. Cap-and-trade, where it exists, primarily affects the power sector and heavy industry. In Germany, for example, there is no evidence that passing the EU-ETS production cost increment – which is only a minor component of residential electricity price formation in Germany – through to households has translated into a discernable price signal that has encouraged households to purchase efficient appliances. And the market for high quality recycled rubber is challenging, because it is more expensive than virgin materials.
- Existing carbon markets have not stimulated efforts of manufacturers to adopt C2C practices. Most manufacturers are neither subject to carbon emissions caps, nor have they managed to generate revenues from offset activities. One of the greatest barriers has been the lack of suitable emission reduction quantification methodologies, embedded in a clear concept of which private sector activities should be rewarded with carbon finance, so as to stimulate truly additional efforts that best comply with circular economy concepts.
- A carbon price values global warming impacts over all other considerations and can therefore be distortionary and lead to suboptimal outcomes, including failing to reap maximum co-benefits. To avoid adverse outcomes, it would be valuable to adopt a comprehensive and systematic framework for sustainable resource management within which market mechanisms can be considered, such as that put forward by the US EPA (US EPA 2009), which defines three basic perspectives (summarized in Figure 4).

Not only would this help to identify priority materials, products and services that are having the greatest impacts – it would also help to determine the most effective levers to bring about change, to ensure policy coherence and to properly align (carbon) market signals to promote better materials management throughout the life cycle. All too often, carbon markets reward incremental improvements, rather than leap-frogging. For example, carbon credits can be obtained for making a natural gas-based fertilizer plant more energy efficient, but this only makes it more difficult for breakthrough technologies with lower carbon footprints (such as the production of organic fertilizer using biomass instead of gas as the feedstock, which saves roughly 2 t CO_2e per ton of fertilizer) to compete. There is competition for R&D money, carbon finance, concessional funding, and supportive policy frameworks for various technological solutions, so it is important for policymakers to consider sustainable development implications of technologies in a comprehensive framework. Otherwise, there is a real risk of suboptimal solutions crowding out "better" technologies (Ketola, Salmi 2010).

- Policymakers have many opportunities to establish market mechanisms that support sustainable life cycle materials management policies and programs and pushing the cleantech envelope. Only by blending the two can all of the critical barriers be addressed. Experiments taken now to integrate carbon finance into government programs and public-private partnerships can inform the UN climate negotiations going forward.
- Governance requires serious rethinking, on many fronts. As governance regimes emerged in the 1980s and '90s to address cross-boundary sustainability issues, the emphasis was on commitments by national governments with sovereignty over their natural resources for contemporary activities within their territories. The private sector and consumers were only implicated indirectly and in a piecemeal fashion (through regional, national and/or subnational regulatory frameworks). With the imperative of reversing the global growth in greenhouse gas emissions in the coming decade and dramatically reducing emissions thereafter, the current governance model is woefully inadequate. Transnational corporations (TNCs), in particular, are both major carbon emitters and low-carbon investors. TNCs can contribute to global efforts to combat climate change by improving production processes in their operations at home and abroad, by supplying cleaner goods and services and by providing much needed capital and cutting edge technology (UNCTAD 2010). It has been estimated that low-carbon FDI flows into three key low-carbon business areas (renewables, recycling and low-carbon technology manufacturing) alone amounted to $90 billion, not taking into account embedded low-carbon investments in other industries and TNC participation

through non-equity forms (UNCTAD 2010). Much more attention should be given to levers to enhance corporate contributions to climate mitigation (Arquit Niederberger, Gage & Saner 2011), keeping in mind that many technology breakthroughs are made by small companies without large marketing budgets.

6. Conclusions

There is a danger that climate change policies in isolation may inadvertently hinder (or at least fail to stimulate) transformational change in the way that consumer products are designed and treated at the end of their useful lifetimes. While policymakers appear to be converging around the aim of limiting the average global temperature increase to between 1.5 and 2°C above the preindustrial level, which would require global emissions to peak on a timescale of less than a decade, global emissions are growing at a rate of 1 – 2% annually, putting us on a trajectory that would at least triple the amount of warming. Given the ongoing discussion of the financial crisis that began in 2008, the tensions over exchange rate policies, the degree of political influence enjoyed by powerful corporations, and the failure of the UN Climate Convention process to agree a global climate governance regime, the time is ripe to consider effective governance to achieve low-carbon development pathways. Any new carbon market mechanisms should be designed from the outset to reward the most productive use of resources, rather than any incremental ton of greenhouse gases that might be reduced. We cannot afford to settle for suboptimal solutions, when better alternatives are available – and certainly not to create perverse incentives.

To rapidly reduce global greenhouse gas emissions to sustainable levels will require much greater attention to governance regimes and policies that can have the greatest leverage with the private sector, such as international governmental regimes (in particular, the WTO regime, economic governance, environmental markets); corporate governance (including voluntary industry (or individual corporation) self-regulation and global value chain relationships); multi-stakeholder partnerships; domestic governance regimes, from national to local level (particularly investment, taxation, product policies and standards), and civil society governance schemes.

References

Andersen, M.S. 2006, "An introductory note on the environmental economics of the circular economy", Sustainability Science, vol. 2, no. 1, pp. 133-140.

Arquit Niederberger, A., Gage, J. & Saner, R. 2011, Levers to Enhance TNC Contributions to Low-Carbon Development – Drivers, Determinants and Policy Implications, Centre for Socio-Eco-Nomic Development, Geneva.

EEA 2011, Earnings, jobs and innovation: The role of recycling in a green economy, European Environment Agency, Copenhagen.

ETRMA 2012, End-of-Life Tires – A Valuable Resource with Growing Potential, European Tyre and Rubber Manufacturers' Association, Brussels.

Genan 2009, Comparative Life Cycle Assessment of Two Options for Waste Tyre Treatment – Material Recycling vs. Co-Incineration in Cement Kilns, Genan, Viborg.

Grammig, T., Arquit Niederberger, A. & Shiroff, S. 2009, "Cool Carbon", EEDAL 2009 Conference Proceedings, 5th International Conference on Energy Efficiency in Domestic Appliances and Lighting, German Energy Agency (dena).

Ketola, T. & Salmi, T. 2010, "Sustainability life cycle comparison of biofuels: sewage the saviour?", Management of Environmental Quality: An International Journal, vol. 21, no. 6, pp. 796-811.

Lean Energy Cluster 2012, Less Energy – More Growth: Prosperity through Efficiency, Lean Energy Cluster / Monday Morning, Denmark.

OECD/IEA & WBCSD 2009, Cement Technology Roadmap 2009 – Carbon Emissions Reductions up to 2050, OECD/IEA and World Business Council for Sustainable Development, Geneva.

Otto, R., Ruminy, A. & Mrotzek, H. 2006, "Assessment of the environmental impact of household appliances", Appliance Magazine.com.

UNCTAD 2010, World Investment Report 2010, United Nations Conference on Trade & Development, Geneva.

UNEP 2010, Waste and Climate Change – Global Trends and Strategy Framework, United Nations Environment Programme, Osaka.

UNEP 2007, Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee – 2006 Assessment, UNEP Ozone Secretariat, Nairobi.

US EPA 2009, Sustainable Materials Management: The Road Ahead, US Environmental Protection Agency, Washington, D.C.

worldsteel 2011, World Steel Association Life Cycle Inventory Study for Steel Products, worldsteel, Brussels.

Table 1. Life Cycle Thinking vs. Carbon Market Approaches

	Carbon Market Mechanisms	**Life Cycle Thinking**
Paradigm	Flexibility in fulfilling GHG mitigation obligations → market forces identify least cost mitigation actions = reduced cost of climate protection	Shift from "waste management" → "resource management" = most productive use of resources
Ultimate objective	Avoid dangerous anthropogenic interference with climate system	Overall long-term sustainability
Targeted outcomes	Absolute emissions reductions or sink enhancement	• Less material inputs • Reduced toxicity • Recover more
Environmental impacts considered	(Selected) greenhouse gas emissions and their Global Warming Potential	Inputs & outputs from/to the environment (incl. use of materials, energy and water), plus multiple environmental impacts
"Currency"	1 ton CO_2e	Relative impact rankings, aggregated across multiple impact criteria (environmental impacts; material, energy & water use; material waste) and for different supply chain perspectives
Boundary considerations	Defined by territory (geographic), facility (ownership/management control) or project scope	Not geographically constrained; considers all life cycle stages of a material or product
Responsibility	Defined sources of GHG emissions: • Nations (for territorial emissions) • Capped entities (for their Scope 1 and 2 emissions), typically large energy users	All parties involved globally in the life cycle of a material or product, including consumers and manufacturers

Table 2. Selected Methodological Challenges for Appliances under the CDM

Challenges	**CDM Outcomes to Date**
Restrictive eligibility criteria	The CDM authorities often specify restrictive eligibility criteria that limit the applicability of approved methodologies to specific kinds of programs. For example, the refrigerator methodology AMS III.X. can only be used by programs that distribute appliances “at low or no cost to the end user” and which “replace existing, functional domestic refrigerators”.
High transaction costs	• Additionality has proven difficult to demonstrate to the satisfaction of validators; • Microscale additionality provisions are not yet operational – and may lead to increased transaction costs, since more projects must be validated to generate the same number of offsets; • Use of deemed savings (or default specific energy savings for appliances used intermittently, coupled with usage surveys) has not been accepted in appliance methodologies, although it has been for other types of project activities.
Unrealistic or overly conservative approaches to establish the baseline	• Project based emissions reduction estimation methodologies lead to high transaction costs, insurmountable data issues and uncertainty; • Benchmarking approaches have been accepted in theory, but have not become operational: – Use of national market benchmarks is allowed (e.g., using the refrigerator methodology AM0070), but applicability is practically limited by data availability; – Global benchmarking accepted from 2012, but benchmarks overly stringent for host country markets.
Lack of methodologies for appliances used intermittently	Several methodologies for refrigerators have been approved (including one developed by BSH, in partnership with GIZ), and there is a general methodology for efficient electrical end-use equipment, but methodologies tailored to the needs of domestic appliances used intermittently have been rejected (see http://cdm.unfccc.int/methodologies/SSCmethodologies/pnm/byref/SSC-NM069).
Addressing an appliance’s carbon footprint	Attempts to credit reductions in emissions outside of the project boundary due to appliance programs – such as reducing the amount of energy embedded in water used by dishwashers and washing machines or avoiding energy use needed to produce virgin materials when old refrigerators are demanufactured according to industry best practices and energy intensive materials are recycled – have been rejected by the CDM authorities, although the Parties to the Kyoto Protocol have stipulated that leakage (net change in GHG emissions outside of the project boundary) is to be taken into account.
Addressing banks of industrial greenhouse gases	Provisions proposed by BSH and included in Version 1 of AMS III.X. to require advanced demanufacturing of all old refrigerators taken back under refrigerator exchange programs was removed by the CDM authorities (and now only applies if credit is sought for reductions in HFC emissions). The CDM authorities have also not accepted accounting for reductions in industrial greenhouse gas emissions outside of the project boundary (e.g., CFCs, HCFCs).
Conservativeness	Extremely conservative assumptions are built into methodologies by the CDM authorities, which limits any financial incentive. One example is restricting crediting to only 10 years, when there is a significant body of literature that suggests a much longer useful lifetimes for major domestic appliances (Welch & Rodgers, 2010), particularly in developing country settings.

Table 3. Leakage Emission Factors

Scrap Tire Pathway	Fraction	Leakage (kg CO_2-eq/t scrap tires)	
		Consequential	*Attributional*
Tire Recycling	Coarse rubber recycling (infill)	-307	-278
	Fine rubber recycling (asphalt)	-1116	-1316
	Steel recycling	-271	-271
	Textile co-incineration (in cement plant)	273	273
	Use of alternative fuels in cement kiln	-405	-297
Co-Incineration in Cement Plant (avoided)	Whole tire co-incineration	-1896	-1896
	Use of alternative fuels in cement kiln	2657	1948
	Use of alternative iron sources	271	271
Net Leakage – Recycling		-794	-1566

Note: A minus sign signifies that emissions outside of the project boundary are reduced.

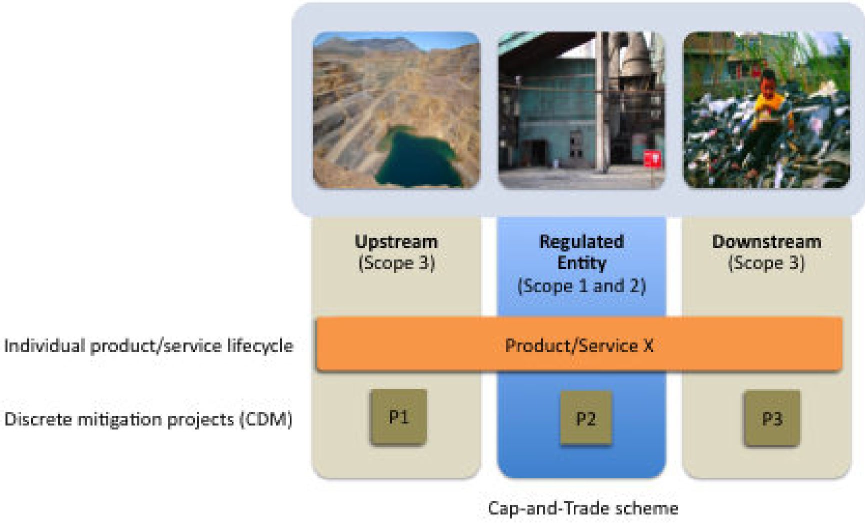

Figure 1. Impact Accounting Boundaries

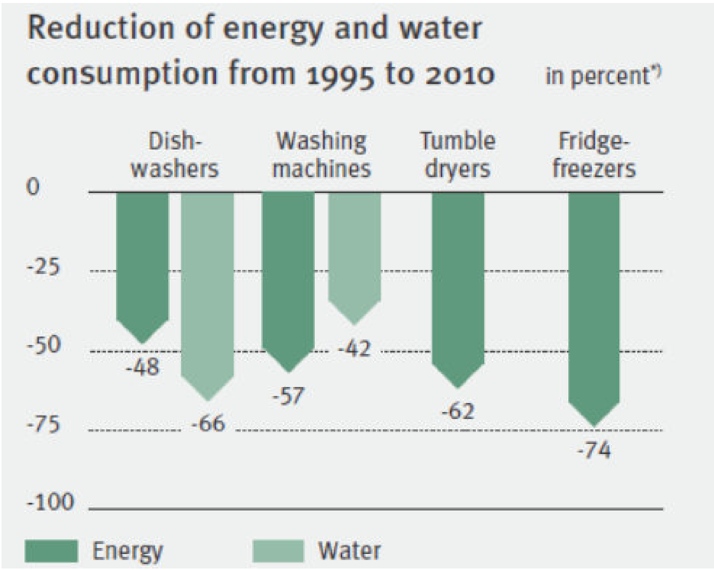

Figure 2. Reduction of Energy & Water Consumption

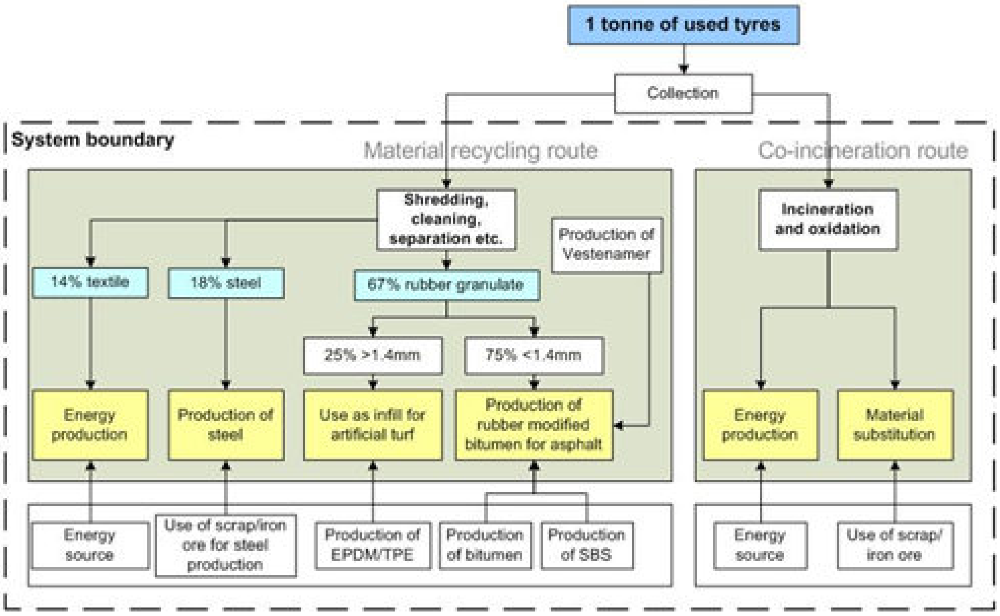

Figure 3. System Boundaries for Scrap Tire LCA Study

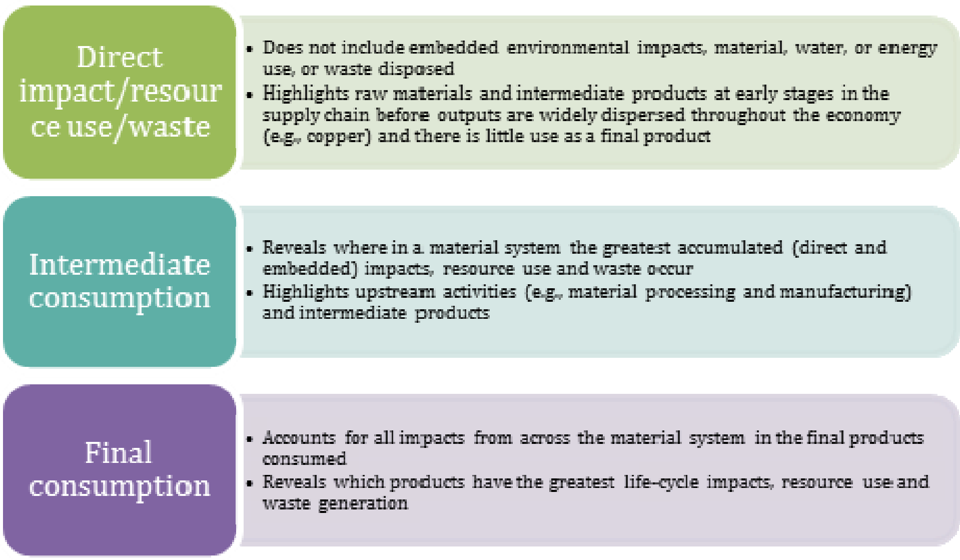

Figure 4. Impact Analysis Perspectives