Chapter Title: RECIRCULATION AND REGENERATION OF RESOURCES (CIRCULAR ECONOMY)

Book Title: Global Green Shift
Book Subtitle: When Ceres Meets Gaia
Book Author(s): JOHN A. MATHEWS
Published by: Anthem Press. (2017)
Stable URL: http://www.jstor.org/stable/j.ctt1kft8m1.20

CHAPTER 14

RECIRCULATION AND REGENERATION OF RESOURCES (CIRCULAR ECONOMY)

There is a story that every school child in Australia is familiar with – Norman Lindsay's *Magic Pudding*. The thing about the magic pudding is that no matter how often it is eaten, it always re-forms to be whole again. The pudding itself is a character in the story, along with heroes Bunyip Bluegum the koala, Bill Barnacle the sailor, and Sam Sawnoff the penguin. The heroes have to battle pudding thieves who are out to acquire the wonderful culinary creation for themselves.

There is something of the 'magic pudding' about the circular economy, where the issues of note are not limits to growth (as highlighted in the famed Club of Rome report of 1972) but the regeneration of resources, either as such (recycling or reusing) or more significantly as extracted from a flow of waste materials. Through 'urban mining' the resources can be extracted and utilized once again in manufacturing processes – and then again, and again – for as long as the material sustains such reuse and regeneration.

The central idea of the 'Limits to Growth' with its insistence that the only known source of resources would be virgin deposits that are increasingly exploited until the limits are reached, is one that has held sway for decades. This is not the way the world is moving however. Instead the world is moving towards a view of resources that sees them as being regenerated via closed loops, or circular flows, through such practices as 'urban mining'. These processes of urban mining are instances of manufacturing where again scale economies can be reaped as efficiencies improve through learning curves. Enhancement of resource security is the driver, where manufacturing processes take over from minerals extraction. It is a way of turning resources into an industrialized 'magic pudding'.

ENHANCING RESOURCE SECURITY

For countries like China and India the task of building energy security is one important aspect of their creation of a new kind of industrial economy. The other important aspect concerns resources. Here too we find a critical situation emerging that can only be resolved by radical measures – in this case a restructuring of the economy along circular lines. Again, we find that China presents the biggest problem and the most radical solution.

China, by the second decade of the twenty-first century, has become the world's largest producer of industrial commodities and world's largest consumer of resources, which are sourced from all around the world. China already produces 46 per cent, 50 per cent and no less than 60 per cent of the world's aluminium, steel and cement, respectively.[1] This gives it an enormous resource appetite and footprint. At the same time China is growing its waste output, leading many scientists to assert that waste production must peak within a few short years.[2] These problems have arisen, and are now reaching crisis point, because China adopted at first the linear model of industrial production – the one perfected by the West and now passed on to emulators in the East. In the linear model resources are sourced at one end of a chain of production and wastes accumulate at the other end. Resources are mined (extracted) from the earth at one end, and wastes are dumped at the other end. The linear model assumes the existence of a planet of infinite proportions that can go on supplying virgin resources at one end and absorb wastes dumped at the other end, seemingly without limit. This is not a very realistic assumption.

Of course the limits are now being reached. China cannot afford to breach geopolitical constraints on resource extraction around the world; it cannot afford to indulge in wholesale plunder of continents like Africa or South America in search of endless quantities of raw materials. It has to find a way to 'internalize' its quest for the materials needed by its gigantic industrial system. So it is in China – where the limits are being felt acutely in the form of resource dependence and waste disposal pollution of crisis proportions – that the most radical solution is being sought in the form of the *circular economy*. Indeed, the solution is simplicity itself – just as the solution to energy issues lies in the simple expedient of shifting to renewable sources that are manufactured. The circular economy proposes to turn outputs into inputs – just as in natural cycles the wastes of one organism are turned into food by another organism.

1. See Mathews and Tan 2015, Table 3-6, p. 68.

2. See Hoornweg, Bhada-Tata and Kennedy (31 October 2013). *Nature* 502: 615–617.

But turning the simple idea into practical examples proves to be exceedingly difficult – for the reason that it calls for companies to cooperate in sharing resources and discovering resource loops that can be closed. This is as difficult in China as it is anywhere else.

China's appetite for resources is immense. Its overall consumption of commodities rose fivefold over the two decades 1990 to 2010, from 5.4 billion tons to 25.2 billion tons (according to the OECD). That means that China's consumption by 2010 exceeded that of all the countries that are members of the OECD. Yet China's efficiency in utilizing resources is low. OECD countries consume half a kilogram of material resources for every dollar generated (that is they have a material intensity of around 0.5kg per US$ GDP). But China's material intensity is five times worse, at around 2.6 kg per US$ GDP.[3] The target under the twelfth five-year plan (FYP) was to reach around 2.2 kg per US$ – better than the current level, but still far from the average for the OECD (Figure 14.1).

China's economic boom of the past decade and a half means that it has already had a big resource impact on other countries, particularly in Africa and Latin America. Copper from Chile, or soybeans from Argentina, or iron ore and processed pig iron from Brazil now flow to China in vast quantities, causing great material destruction. Kevin Gallagher in his new book *The China Triangle* documents much of this destruction being wrought in Latin America by Chinese resource interests. In a review of the book, Margaret Myers describes a 'path of environmental destruction and social conflict' traced throughout Latin America on account of the rise of China.[4]

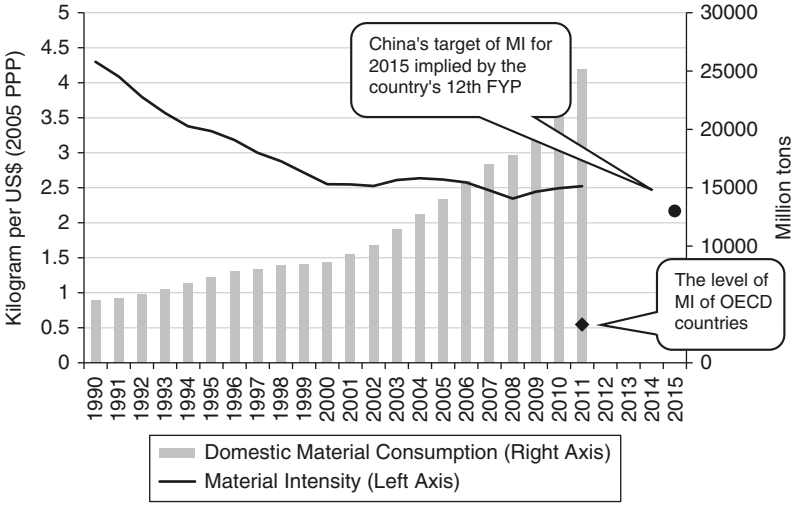
China's treatment of wastes is likewise a source of growing problems. In 2014 the country generated 3.2 billion tons of industrial solid waste alone, of which just over 2 billion tons were recovered, by recycling, composting, incineration, or reuse. By contrast the total waste generated by economic activities and households in the 28 EU countries accounted for 2.5 billion tons in 2012, in which almost 1 billion tons was recycled or used for energy recovery.[5] China's municipal solid waste is expected to reach 23 per cent of the world total in 2025

3. China requires 2.5 kg of materials to produce one US$ of GDP (in 2005 US$ adjusted for Purchasing Power Parity) compared with 0.54 kg in OECD countries (http://stats.oecd.org/viewhtml.aspx?datasetcode=MATERIAL_RESOURCESandlang=en).

4. Margaret Myers (10 March 2016). China in the new world (review of *The China Triangle*, by Kevin Gallagher), *Nature*, 531: 109–110.

5. See http://ec.europa.eu/eurostat/statistics-explained/index.php/Waste_statistics#Further_Eurostat_information.

FIGURE 14.1. China: Material intensity trends, 1990–2015.



SOURCE: Mathews and Tan 2016; Source of primary data: UNEP (2015). http://www.unep.org/roap/Activities/ResourceEfficiency/IndicatorsforaResourceEfficient/tabid/1060186/Default.aspx

(Hoornweg et al. 2013) – in line with its share of world manufacturing activity. The municipal solid waste going to landfills or incinerators more than doubled in China during the period between 2004 and 2014, from 73 million tons to 160 million tons. But there are significant limits to such disposal solutions, as illustrated by the landslide in a waste disposal site in Shenzhen which killed no less than 69 people (and led to the official involved taking his own life), as well as a number of protests turning into riots by local residents over enforcement of waste incineration projects during recent years.[6]

The toll of this extreme dependence on mined and extracted raw materials at one end of the linear economy, and of waste generation and disposal at the other, is extreme. Tragedies continue to occur, underlining through their toll on human life that minerals extraction cannot cope with this surging level of demand for commodities from China, India and elsewhere. A recent calamity involved the collapse of a tailings dam in Brazil in an iron ore mine

6. On the Shenzhen incident and its aftermath, see: http://www.scmp.com/news/china/society/article/1895516/shenzhen-landslide-aftermath-official-who-rubber-stamped-waste.

in 2015, resulting in flooded villages and the loss of many lives.[7] Conservative news outlets like the *Wall Street Journal* are now pointing to the alarming risks associated with vast mining operations and the unstable structures being created to hold the 'tailings' or mining wastes.[8] There are also soaring costs of waste disposal and the terrible environmental consequences that flow from these practices. Clearly this kind of situation of rising depredations and rising risks leading to a regular succession of calamities cannot be allowed to continue.

CHINA'S CIRCULAR ECONOMY INITIATIVES

China feels the brunt of rising levels of waste being accumulated and the social resistance to measures taken to deal with it, such as incineration. And it is not surprising then that China is taking radical action to deal with these enormous problems of resource insecurity created by growing dependence on imports of resources from dangerously unsafe operations in sometimes dangerous parts of the world. China's efforts to create an alternative in the form of a Circular Economy (CE) date back at least to the release of the 2005 'white paper' from the ND&RC, on 'Opinions on Accelerating the Development of the Circular Economy'. This paper advanced a number of taxation, fiscal, pricing and industrial policy measures that have since been enacted to support the diffusion of circular flows of materials (or closed loops). The 2005 document also signalled that carriage of the issue at national level would be moved from the State Environment Bureau to the ND & RC – a considerable upgrading in political influence, and marking the shift in China to the promotion of the Circular Economy (CE)as a national development strategy.[9] This shift was followed by further developments, including targets for the shift to a Circular Economy in the 11th FYP (covering the years 2006 to 2010) and a whole chapter devoted to the CE in the 12th FYP (covering the years 2011 to 2015). The 2005 policy statement was followed by the passage of the Circular Economy Promotion Law of 2008, which called on local and provincial governments to take resource circulation issues into consideration in their development

7. See the news report at: http://www.theaustralian.com.au/business/news/brazil-community-flooded-after-dam-burst-at-bhp-and-valeowned-iron-ore-mine/news-story/ed5795af50d455eb3a76d2d5a02c90c1.

8. See the *WSJ* article at: http://www.wsj.com/articles/brazils-samarco-disaster-mining-dams-grow-to-colossal-heights-and-so-do-the-risks-1459782411.

9. On this strategy, see Mathews et al. (2011).

strategies. There were also sectoral targets enacted for the electronic and IT sectors as well as the chemical and petrochemical sector.

Financial measures have been taken in China to accelerate the uptake of Circular Economy initiatives. Pilot CE projects all around the country are being promoted, particularly in existing industrial parks and export processing zones where companies are already operating next door to each other and are able to see where they might have interests in common in sharing resources such as heat, water or steam.

According to a policy jointly issued by the ND&RC in 2010, the Central Bank of the PRC, the China Banking Regulatory Commission, the China Securities Regulatory Commission as well as state-owned banks are being encouraged to provide loans for CE projects. It is notable that CE-related industrial parks and enterprises are being given priority for their financing needs in the capital markets (e.g., the stock and bond markets) as well as through contingent loan facilities from state-owned banks. This has been an important financial underpinning of moves towards a Circular Economy, complemented by similar moves to utilize green bonds as tools for greening the Chinese economy.

During the decade from 2005 to 2015, there have thus been numerous attempts in China to upgrade the significance of the Circular Economy as a national development goal, involving tax policy, bank lending policy as well as specific measures to accelerate the conversion of traditional industrial parks (clusters of related activities) to eco-industrial parks with an emphasis on greening. The case of the *Suzhou New District* as an exemplary such conversion is discussed below. In the 12th FYP several objectives were set for achievement by 2015, including reaching a comprehensive resource utilization rate of 72 per cent for industrial solid waste, and an improvement in resource productivity of 15 per cent. The 12th FYP laid out a three-pronged 10/100/1000 strategy (applying to 10 major CE programs, 100 CE demonstration sites and cities, and 1000 CE demonstration enterprises or industrial parks) for accelerating the shift to a Circular Economy.

URBAN MINING

The great urban futurist Jane Jacobs argued in her classic work *The Economy of Cities* that instead of viewing cities as sources of increasing mountains of waste they should instead be viewed as sources of materials in themselves: cities should be viewed as the new mines. As an example she cites a coal-burning power plant in Pennsylvania where a trial was run to capture sulphur dioxide

from the smokestacks and convert it to sulfuric acid. Based on the facts that costs of extraction were $7 a ton while the market price for the delivered material was $8 to $10 a ton, she reasoned that 'the process amounts to a new way of mining sulphur for sulfuric acid' (1969: 109). This simple but far-reaching insight is the basis for a vast new industry – urban mining.

Jacobs was heavily criticized in her time as being naïve and unduly technologically optimistic, for example, by Stein Weissenberger in his response to Richard Sennett in the *New York Review of Books* (12 March 1970) where her proposals for 'mining' cities to recover valuable materials in wastes, and simultaneously eliminating heat pollution and conserving fuel by recycling the hot water from power plants, not only reveal her characteristic combination of self-confidence and naiveté […] but also 'demonstrate an implicit and unwarranted faith in the ability of technology to solve all possible problems'.[10] But Richard Sennett's reply buttresses Jane Jacobs' point that cities and countryside complement each other. Cities support efforts to reconcentrate and cluster productive and exchange activities – exactly as called for by Jacobs. The Chinese megalopolises of today are the logical end result of this process. But they need complementary policies designed to recycle and rechannel the flows of materials that threaten cities' well-being.

As supplies of resources come under increasing strain (at one end of the linear economy) and waste generation accumulates to unsustainable levels (at the other end) the traditional model of linear resource throughput is coming up against physical and geopolitical limits. Urban mining presents itself as a viable solution – one that goes back to the industrial recycling practices of the nineteenth century and the growing concentration of manufacturing activities in cities in the twentieth century.

Consider the case of electrical and electronic waste – or e-waste. Just in China new statistics reveal that upwards of 30 million cell phones are discarded each year, along with 4 million refrigerators and 5 million TV sets – along with PCs, printers, scanners, fax machines and microwave ovens. It adds up to around 3,000 tons of e-waste alone.[11] And then the e-waste from the Western world also finds its way to China, where southern towns like Guiyu in Guangdong province have become centres for 'informal' recycling – that

10. See Stein Weissenberger, with reply by Richard Sennett, 'How cities grow', *New York Review of Books*, 12 March 1970, at: http://www.nybooks.com/articles/1970/03/12/how-cities-grow/.

11. These data are cited in 'The problem of e-waste', *China.org.cn*, 8 January 2008, at: http://www.china.org.cn/english/China/238544.htm.

is to say, unregulated dismantling and recycling that ignores environmental hazards. But the rewards of recognizing this increasingly gargantuan flow are themselves large.

As an illustration of the power of urban mining, in China a ton of discarded mobile phones can yield as much as *280 grams of gold*; by contrast only about 4 grams can be extracted from a ton of ore in South Africa. The concentration of valuable metals in e-waste is such that 'mining' these waste flows is becoming a sound business proposition – especially if there are government incentives provided in the form of subsidies on recycled materials and taxes on virgin materials or unused waste. That same 1 ton of mobile/cell phones will yield also 140 grams platinum and palladium – not to mention as much as 140 kilograms copper. The plastic and glass in the phone can be extracted and processed into pure forms of the materials.[12] This is what is meant by *urban mining* – the extraction and processing of metals from streams of waste such as e-waste in an urban setting, where the recovery rates are superior to those obtained in the extraction and processing of virgin ores. Jane Jacobs was prescient in her vision of cities being the mines of the future.

A visit to the Chinese e-waste processor Huaxin Environmental is an eye-opener. This Beijing firm is one of 49 national demonstration sites for e-waste recycling and metal recovery – or 'urban mining'.[13] Huaxin runs a website that means literally 'banana peel' as a means of encouraging consumers to re-cycle their mobile phones, PCs, printers and even household white goods like cookers, microwaves and refrigerators. Consumers can log on to the 'banana peel' website and have the discarded items collected, to be channelled to the disassembly lines at Huaxin's Beijing plant. China is now reaching the point that it has large flows of electrical and electronic goods being discarded – so-called EEW (electrical and electronic waste) or e-waste. Huaxin has long lines for disassembly of all electrical and electronic goods, followed by sophisticated processes involving magnetic separation, chemical dissolution to produce the mined raw materials in various levels of purity.

Of course it is not just recently that such urban mining prospects have become apparent. The nineteenth century industrial leaders in both Europe and the United States enjoyed plenty of 'waste recycling' as spontaneous industrial initiative. The volumes involved were impressive – and it is a shock

12. See the estimates provided by 'Cell phone recycling – the gold in your cell phone', 12 June 2008, at: http://www.pacebutler.com/blog/cell-phone-recycling-gold/.

13. I visited the Huaxin e-waste recovery plant in Beijing in October 2016; my thanks to Professor Jinhui Li of Tsinghua University for organizing the event.

for observers in places like China where waste flows are greatest today to rediscover the inter-firm recycling linkages that knitted together the industrial districts of former times. Industrial ecology was alive and well in these past industrial districts – a long time before the concept was developed in the late twentieth century.[14]

Indeed it is arguably environmental regulation that has prevented spontaneous creation of inter-firm waste disposal linkages. Under this kind of regulation, 'waste' became identified with 'pollution' and came to be viewed as something to be controlled in itself. Emissions standards, which are the hallmark of environmental standards in the linear economy, actively dissuade firms from viewing their waste streams as sources of profit – even if alternative uses for the 'waste' can be found. It is in places like China where the waste flows are becoming unsustainable and unmanageable that a circular approach makes abundant sense, and is being implemented rigorously. The theme of urban mining as an essential aspect of the Circular Economy has been taken up by Chinese scholars themselves; Li Jinhui for example argues that 'wastes could be resources and cities could be mines'.[15]

So the idea behind urban mining is one that overturns traditional attitudes towards 'waste' and its control. Early essays in industrial ecology tended to see the built environment itself as source of metals and materials; this was doubtless what Jane Jacobs herself had in mind when referring to 'cities as mines'.[16] It is now instead the flows of recycled electronic and electrical goods that provide the main source for urban mining – one that needs to be recognized in policy prescriptions that reward recycling and punish supplies of virgin materials through subsidies and taxes. This is all an essential aspect of the green shift – a reshaping of what Paul Brunner calls the urban metabolism.[17]

---

14. For scholarly investigation of the prevalence of inter-firm industrial recycling linkages, see Desrochers (2002a; 2002b).

15. See the exposition by Li and his Tsinghua University colleagues in Li et al. (2015).

16. Scholars today likewise tend to favour the built environment as primary source for urban mining, not recognizing the scale of the flows of 'waste materials' in manufacturing centres like China. Krook and Baas (2013) for example refer to 'mining the technosphere' as a generalization of urban mining – but they seem to have in mind stocks of materials and landfill as the target, rather than waste flows themselves.

17. Paul Brunner is widely regarded as founder of the discipline of material flow analysis (MFA) which underpins activities such as urban mining. See his summary expositions in Brunner (2007; 2011).

WHAT HOLDS BACK THE DIFFUSION OF THE CIRCULAR ECONOMY?

Despite discussion of the need to switch away from the linear economy, with all its resource insecurity and waste disposal problems, it has proven to be extremely difficult to make progress in the West. There have been isolated examples of best practice, such as Kalundborg in Denmark, Yokohama in Japan, Ulsan in Korea and Kwinana in Australia.[18] But they are all limited in their scope and have not sparked much emulation. The difficulty is getting individual firms to cooperate along supply chains, so that one firm could discover that it could share resources (e.g., energy, water, heat) with other firms in the same supply chain – particularly if they are co-located in the same industrial zone or city.

China has been able to break through this 'reverse salient' (to use Thomas Hughes' graphic phrase) by focusing its CE efforts on existing industrial parks and export processing zones. It is a telling fact that over half of China's manufacturing activities are concentrated in industrial parks and export processing zones (an example of the power of industrial clustering); these then constitute an obvious target for CE initiatives.

In our article published in *Nature* in March 2016, Hao Tan and I referred to this issue and gave the example of the *Suzhou New District* (SND) as a case in point. This new industrial agglomeration is a vast complex with around 16,000 firms engaging with each other, of which around 4,000 are manufacturing firms. Many of these are involved in high-tech activities such as IT and electronics, as well as advanced machinery and biotechnology. There are waste flows generated by all these activities which, in a traditional linear economy, would constitute a big problem and call for undesirable 'solutions' such as incineration. Instead, through its local CE initiatives, instigated under the auspices of the SND administration, the firms in the Suzhou park are enabled to find common cause and thereby turn outputs into inputs. In the terms utilized in the discipline of industrial symbiosis, this is known as 'closing the loop'.

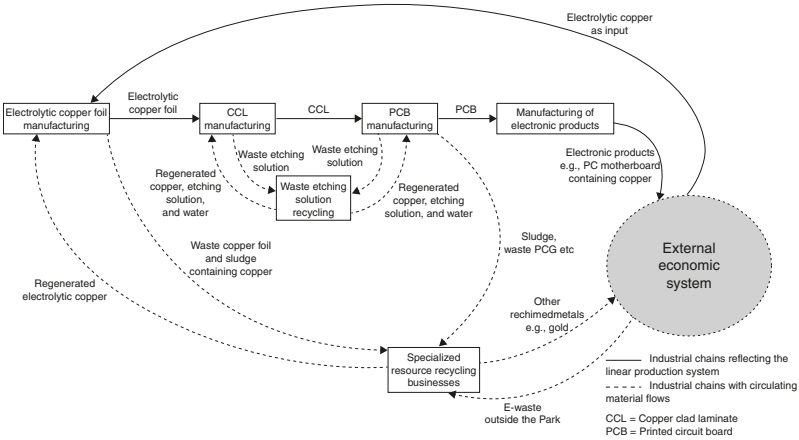
Take the recirculation of copper. Many of the IT and electronics firms in the SND produce printed circuit boards, where connections between transistors are laid out by printing with copper rather than linking them with wires. In the traditional linear economy, the copper would have to be sourced from virgin materials, mined somewhere on the planet by a large mining concern like BHP-Billiton or China Minmetals. This creates a strain on existing resources and

18. See my paper co-authored with Hao Tan published in the *Journal of Industrial Ecology* (Mathews and Tan 2011) for details.

triggers potential geopolitical conflict. (The shocking war in Katanga in the then Belgian Congo comes to mind, where controlling copper was a principal driver of the breakaway province.) It also creates a major waste disposal problem when the PCBs are discarded along with their IT products. Recycling components and seeking to build them into remanufactured IT products can only go so far in resolving the waste generation problem, and the firms that pursue such a business inevitably remain as marginal producers earning paper-thin profits.

Instead, in the CE initiatives instigated by the SND administration, the issue of copper extraction from waste flows is viewed as a major problem (reverse salient) and action is taken to 'plug the gap' in the *copper regeneration loop*. An initiative was taken resulting in the formation of a venture involving Dowa Metal in Japan in forming an advanced metal recycling business in Suzhou. As described by Hao Tan and myself, waste etching solution generated in copper laminating and PCB manufacturing is treated chemically and returned to other firms in the SND park. The role of firms like Dowa is to reclaim the copper and water from sludge and recirculate it; it is literally 'urban mining' where the mining is performed not in a virgin location but on industrial waste flows. Based on work reported by Wen and Meng, we pictured the process as in Figure 14.2 (while space considerations precluded

FIGURE 14.2. Copper regeneration in Suzhou New District.



SOURCE: Mathews and Tan, based on Wen and Meng (2015) and the websites of companies involved.

its being carried in our *Nature* article, it is carried here with permission of my co-author Hao Tan).

These initiatives of closing loops like that involving copper recirculation in the SND are now being taken all across China. Clearly there are moves afoot to shift from a linear industrial economy, with its costs to the earth in terms of extracting virgin resources at one end and dumping wastes at the other end, to a circular economy with its closed loops. Again the driver is going to be reducing costs – as the cost of virgin resources rises and waste disposal becomes more expensive financially and in terms of land, while the costs of 'urban mined' resources can only be expected to fall, given their foundation in manufacturing processes and their learning curves. In this way, resource regeneration is emerging as a central feature of ecomodernization – with China as a principal player. It is the country with the biggest resource insecurity problems and the country with strong state agencies that are prepared to intervene in the economy to make the changes needed. This is a powerful driver of the green shift.