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Twelve theses on the greening of capitalism: Is China driving the process?

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Abstract

Transition from one sociotechnical regime to another is currently under way. The process of industrialization is diffusing around the world, and is now encompassing industrial giants like China, India and Brazil, creating a ?great convergence?. But as these countries follow the same fossil-fuelled and resource-intensive pathway pursued earlier by the presently advanced world, so they come up against limits imposed by energy and environmental security: the ?business as usual? model will not scale to encompass billions more people. The paper makes the case through twelve theses that the green development model fashioned by China and implemented in complementary fashion with the ?black? fossil-fuelled pathway provides a feasible way forward. Such a pathway involves new rules for energy, resources and above all for finance, and calls for strong state intervention to break the grip of ?carbon lock-in?. The insights that can be generated from sociotechnical analyses of regime shifts are examined and utilized.

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Abstract

Transition from one sociotechnical regime to another is currently under way. The process of industrialization is diffusing around the world, and is now encompassing industrial giants like China, India and Brazil, creating a 'great convergence'. But as these countries follow the same fossil-fuelled and resource-intensive pathway pursued earlier by the presently advanced world, so they come up against limits imposed by energy and environmental security: the 'business as usual' model will not scale to encompass billions more people. The paper makes the case through twelve theses that the green development model fashioned by China and implemented in complementary fashion with the 'black' fossil-fuelled pathway provides a feasible way forward. Such a pathway involves new rules for energy, resources and above all for finance, and calls for strong state intervention to break the grip of 'carbon lock-in'. The insights that can be generated from sociotechnical analyses of regime shifts are examined and utilized.

Keywords: greening; diffusion of industrialization; China, India, Brazil; renewables; learning curve; state intervention

Introduction`

In the industry and innovation literature there is increasing attention paid to eco-innovation dynamics (Kemp and Oltra 2011). Eco-innovation is taken to encompass changes in technologies and in technological systems impinging on energy and resource efficiency, the closing of material loops and a shift in supply chains to low-carbon alternatives. Eco-innovation or 'sustainable innovation journeys' (Schot and Geels 2008) usually start from the assumption that global environmental problems are creating a new agenda for energy and resources policy – and proposals for regulatory agencies in Europe or the United States are then discussed.

In this paper a different perspective is taken. The view from China is that a vast new country and population is seeking to become part of the industrialized world. But the process of industrialization and its diffusion is throwing up enormous problems. How might these be tackled in such a way that China's industrialization (and that of India, and of Brazil) might be able to continue? The argument developed is unusual in that it starts not with concerns over climate change and global warming, but rather with the industrialization of China, which is bringing hundreds of millions of new people within the ambit of industry – and where the Chinese come up against the inconvenient truth that the western model of industrialization which they desire to emulate will not scale. And so, the paper argues, for reasons to do with resource and energy security, the Chinese are being forced to develop a new model of industrialization based not just on fossil fuels and resource extraction but on a parallel and complementary development of renewable energy systems and a Circular Economy, together with a green system of finance to drive the needed investment. This green model of development, it is argued, will serve China well, and has the fortunate side-effect that it offers a solution to the otherwise intractable problem of global warming. The paper argues that the Chinese have stumbled upon a remarkable truth, namely that energy and resource security are best protected by the rapid development of manufacturing industries capable of producing vast numbers of power devices (solar cells, wind turbines) which can be expanded at a pace limited only by the growth of the market. The model being developed in China, it is argued, will through capitalist emulation become the model eventually adopted by India and Brazil, and after them by other developing countries, and – eventually – by the developed world as well. The new systems will diffuse through the processes of logistic industrial dynamics, keeping up and then overtaking the fossil fuel expansion, and driven by the cost reductions

implied by learning curves. China, it is argued, will be the first country to take industrialization to its limits, creating energy and resource security through the expansion of manufacturing industry rather than through expansion of mining and extraction with its fossil fuel and resource dependence. This liberation will prove to be a powerful stimulus for the further development and industrialization of China. But will it happen fast enough to prevent China's 'black' industrialization from ruining its own and everyone else's environment?

The paper thus develops a broad macro-perspective on the dominant global trends that are shaping industrial dynamics today, informed by the literature on sociotechnical regime transition as well as the political economy of China's rise. The argument is developed through twelve propositions.[1]

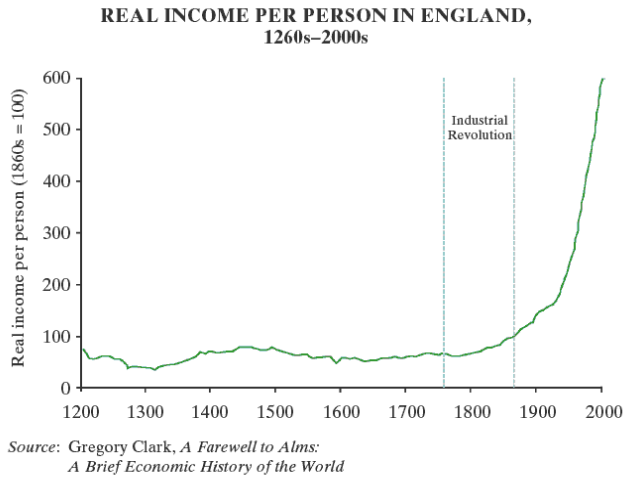
1. Fossil-fuelled industrialization has lifted billions out of poverty

Fossil fuelled industrialization has been a world-transformative experience, lifting a billion people (in the advanced world) out of poverty, and now offering a similar prospect to billions more in China, India, Brazil and elsewhere. The scale and intensity of this transition is enormous.

What is called the 'industrial revolution' was in effect a transformation of the economy, overcoming age-old Malthusian barriers with the power of fossil fuels to drive unheard of increases in productivity. Britain first converted in the 18th century to a coal-fired energy system that, together with important socioeconomic innovations such as the patent system and joint stock companies, allowed private firms to drive innovation and profit from the productivity improvements. This drove income growth in a way never before experienced.

Fig. 1. Growth of per capita income, England, 1200s – 2000s

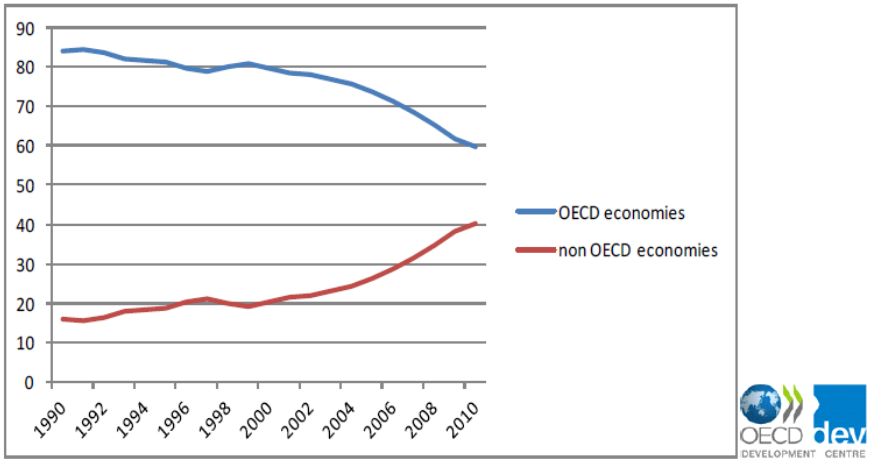
[1] This paper is a summary exposition of the arguments advanced in the forthcoming book, *Greening of Capitalism: How Asia is Driving the Next Great Transformation* (Stanford University Press, 2014).



Traditionally, agricultural improvements had led to rising rural incomes and rising population, which was then curbed through famine, disease or war. But in Britain in the 18th and 19th centuries, access to coal and its use in newly discovered sources of power (the steam engine) these Malthusian barriers were overcome, creating the world's first industrial system. It rapidly diffused across Europe in the period after the Napoleonic wars and then across to the eastern seaboard of the US, driven by new industries' access to coal. Oil then followed in the early 20th century, with the US as lead player, followed by gas. Together these fossil fuels transformed the world, providing the engine of a new kind of economy – the industrial economy, based on manufacturing. It has lifted close to a billion people out of ageless poverty – in Britain, Europe and the US, plus Japan – and has since spread across the world, and is now promising to lift billions more in China, India, Brazil and other industrializing giants. There is under way a dramatic convergence in manufacturing output and income that testifies to this global diffusion of industrialization: Fig. 2 shows how manufacturing is relentlessly moving east, while Fig. 3 shows how some East Asian countries have largely caught up with their western predecessors in terms of per capita GDP, and now China is on track to do so.

Fig. 2. Manufacturing moving east

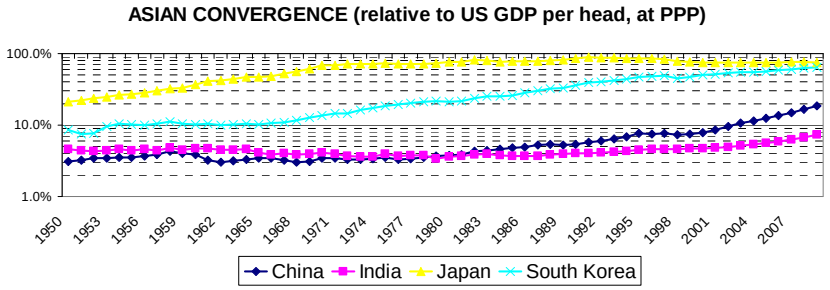
Share of manufacturing industry value added in total world manufacturing value added, 1990-2010



SOURCE: OECD Development Centre based on IHS Global Insight, special tabulations (2011) of World Industry Service database.
Note: OECD: no data for Austria, Estonia, Greece, Hungary, Iceland, Luxembourg, Portugal, Slovak Republic, Slovenia.

Figure 3 shows that China already is already close to 20% of US GDP per head (on PPP terms) while India is approaching 10%, and both are rising fast.[2]

Fig. 3. Asian convergence in GDP per head



Source: Martin Wolf, 'In the grip of a great convergence', *Financial Times*, Jan 4 2011, at:

http://www.ft.com/intl/cms/s/0/072c87e6-1841-11e0-88c9-00144feab49a.html

If this next 'Great Transformation' (to use the phrase of Polanyi) is to be achieved, then the scale of the energy system will have to expand at least sixfold (to drive growth for six billion rather than one billion) and as the pace of change accelerates, so the intensity is magnified – meaning that the current transition involving diffusion of industrialization could be subjecting the planet to 100 times the intensity of the original industrial revolution. The issue is: can such a transformation scale to encompass all the peoples clamoring for industrialization and its wealth-generating promise?

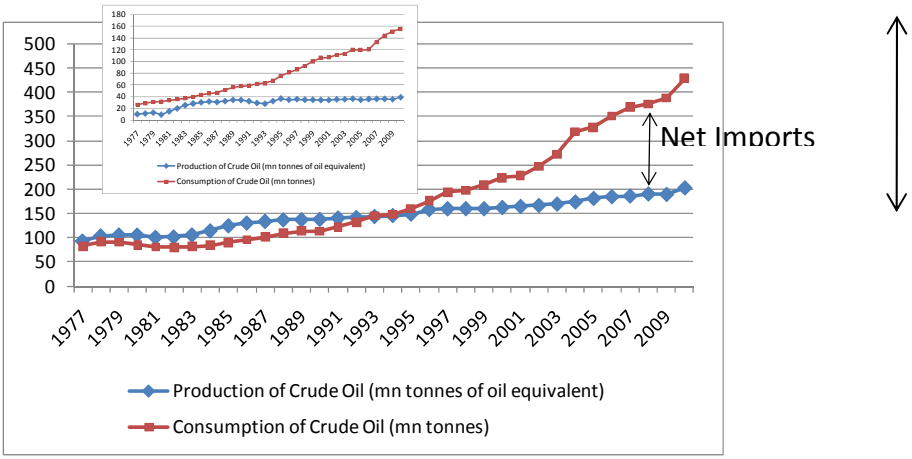
[2] According to World Bank data, in 2011 the US had GDP per capita (PPP) of $50,000, while China recorded $9,233 and India $3,876.

2. … but in its 'business as usual' form it cannot scale

The answer is clear: the fossil fuelled and resource-intense model of industrialization cannot scale, having now filled the planet and threatening a series of related environmental and ecological catastrophes, headlined by global warming. An alternative model of industrialization is needed, and has to be found.

The first problem with a continued 'business as usual' trajectory is the energy insecurity it will create. China is already becoming critically dependent on oil imports, and India is in an even worse situation. If the present fossil-fuelled pattern of industrialization continues, it will drive these countries into conflict-prone zones of the world in search of ever-less accessible oil supplies.[3]

Fig. 4. China's/India's looming oil gap

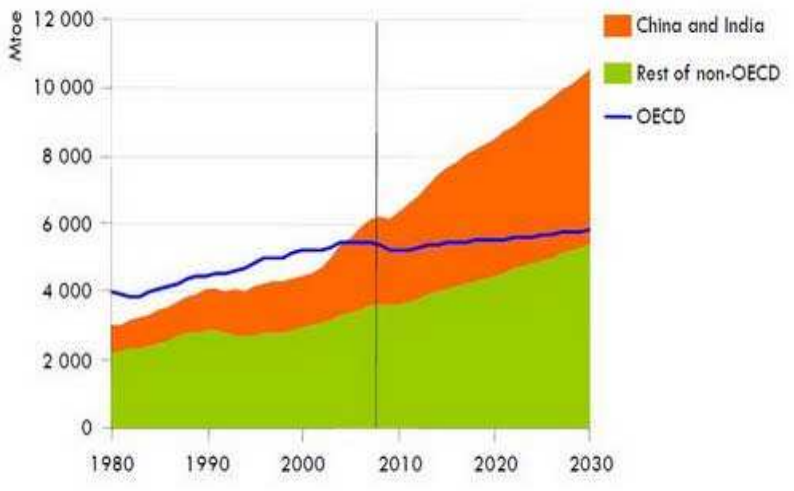


Source: Compiled from CIA *World Factbook*

Almost all future projected increases in oil supplies are going to come from the presently industrializing countries, placing further strains on supply lines.

Fig. 5. Oil consumption shifting to China and India

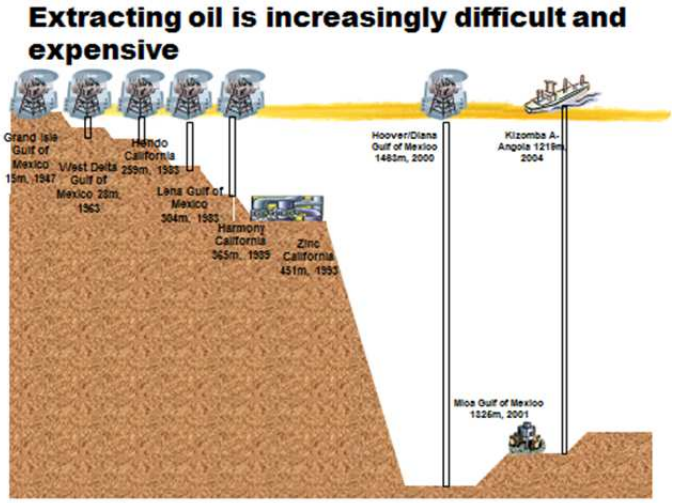
[3] On the accelerating pace of resource competition, see Klare (2012).



Source: IEA 2011 *World Energy Report*

The oil supplies being contested are going to become more difficult to access, and hence more expensive and more dangerous (Fig. 6). Continued reliance on fossil fuels therefore spells growing energy insecurity and hence economic insecurity. On top of this, there is the problem that continued 'business as usual' (to use the phrase of the IPCC reports) if expanded by the intensity projected by global industrialization, will create unbearable pressures on the life-sustaining processes of the planet.

Fig. 6. Extracting oil is becoming increasingly difficult and expensive



Source: BP

There is no way around the issue: an alternative model of industrialization has to be found. Simply calling for reduced global consumption, or the newly fashionable call for 'zero growth' condemns China, India et al to perpetual poverty. A way has to be found to satisfy their aspirations which does not cost the earth.

3. Kyoto, carbon taxes or CSR will not work …

The main candidates for a change offered by the West are threefold: voluntary national reductions in carbon emissions (the Kyoto model); a carbon tax to reverse market imperfections (the economics candidate); and social and corporate responsibility (the management candidate). None of these has any prospect of making a real difference to the 'business as usual' trajectory.

The Kyoto process has involved UN-coordinated negotiations at successive Conferences of the Parties that have failed to stem carbon emissions. Voluntary national commitments to reduce carbon emissions have been made, but in reality carbon emissions have continued to rise, reaching 9.3 billion tonnes in 2011 and rising at 2.5-3% per year. If the growth of emissions in Annex 1 countries has moderated, this is only because they have outsourced much of their manufacturing to China and the developing world. While 'carbon lock-in' prevails, there is no prospect of this process taking the world off its BAU trajectory.

Economists strongly endorse carbon taxes, either as fixed but growing levies on the scale of carbon emissions, or in the form of cap and trade schemes which set emissions levels and allocate tradeable pollution permits to companies.[4] But there is little evidence that carbon taxes can provide a sufficiently strong tool to change companies' behavior when they are applied (as in partial form in the Scandinavian countries) – and much evidence to indicate that they are in fact politically impossible to implement in the face of resistance from fossil fuel vested interests.

Corporations themselves have introduced various forms of initiatives under the general rubric of 'corporate and social responsibility' (CSR). But where these are not outright cases of 'greenwashing' they too can be expected to do too little too late, because of well-known collective action problems.[5]

4. But China's green development model could provide a solution

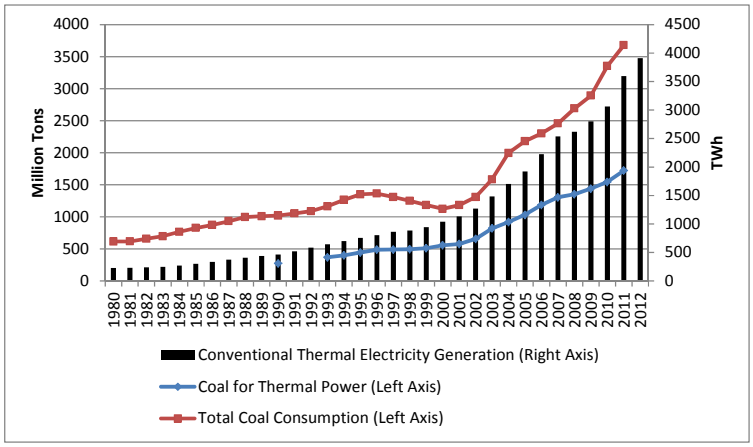
[4] See Garnaut (2008) or Stern (2007) for influential statements of the economics of climate change, and Nordhaus (2008) for a discussion of the rationale behind carbon taxes.

[5] See Devinney (2009) for a balanced discussion of CSR. Of course innovations in social and corporate accounting such as carbon pricing are welcome (see e.g. Lodhia 2011); it is just that they cannot possibly bear the weight of a system-wide transition.

The outlines of a green alternative are however becoming discernible. China is the leading player -- followed by Indian and Brazilian emulators. Green development is emerging as the 'inevitable choice' for China – because China has both motive (the sickening pollution) and means (a strong state that is prepared to act).[6] The same logic is likely to drive developments in India and Brazil. China's green investments are already matching its 'black' investments in fossil-fuelled energy systems, and can be expected to overtake them through logistic industrial dynamics.

Over the course of the past decade and more, since China joined the WTO, the scale of its manufacturing activities has grown exponentially, necessitating an equally devastating expansion in its dependence on coal for its power generation and major industries. China is still building a billion watt (1 GW) power station every week, fuelled by coal. This is the 'black' face of China's industrialization. Indeed China is now burning nearly as much coal as the rest of the world combined – nudging 4 billion tons per year.[7] Its rapid ramping-up of coal consumption and fossil fuel electric power generation follows a well-known course (Fig. 7).

Fig. 7. China's black face: build-up of thermal power



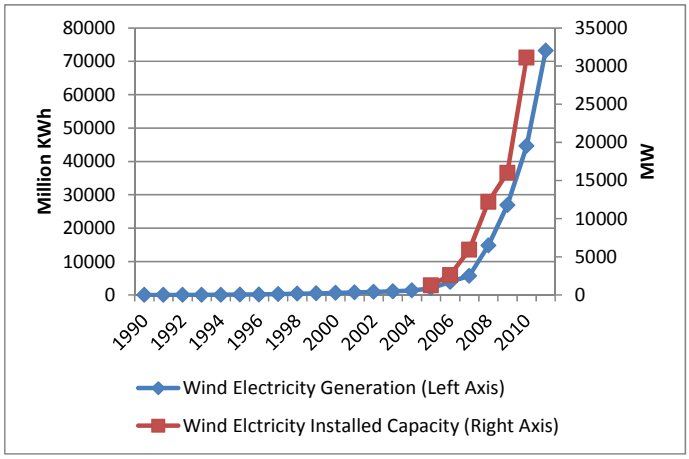
Source: Mathews and Tan (2013)

The Chinese leadership appear to recognize that this strategy will not scale because it will call for coal production and oil imports that will force China to go out into the world in search of resources, and impinge too openly and aggressively on other countries' claims.

[6] See Hu Angang (2006; 2011) for the relevant arguments concerning China's options.
[7] See the statement from the US Energy Information Administration, 'China consumes nearly as much coal as the rest of the world combined', EIA, January 29, 2012, at: http://www.eia.gov/todayinenergy/detail.cfm?id=9751

China has a clear interest in avoiding resource-based confrontations (at least away from its immediate neighborhood) because it has a strong commitment to achieving its development peacefully. If resource confrontations are to be avoided, Beijing realizes that renewable energy industries will need to be built as fast as is physically and technologically possible. Current efforts seem directed precisely towards this goal. Consider just one example. In wind power, China has risen from a marginal position in 2005, doubling its wind power capacity each year, to the point of being world leader by the end of 2010 (Fig. 8). This is what might be recognized as its 'green' development model.

Fig. 8. China's 'green' face: Build-up of wind power



Source: Mathews and Tan

By 2012, China was adding more power generating capacity in hydro, nuclear and 'new' renewables than in conventional thermal power stations – an extremely important milestone, both for China and the world. Its 12th Five Year Plan has notable goals of raising these levels.[8] In terms of electric power, China's leadership (in the form of the planning body, the National Development and Reform Commission) anticipates that by 2015 no less than 30 percent of electric power capacity will be generated from non-fossil sources (including a small amount of nuclear) – up from less than 5 percent in 2001. By 2012 wind power capacity already exceeded that of nuclear power. This can only be described as an energy

[8] See for example Mathews (2011b; 2013a; 2013b) and Mathews & Tan (2013).

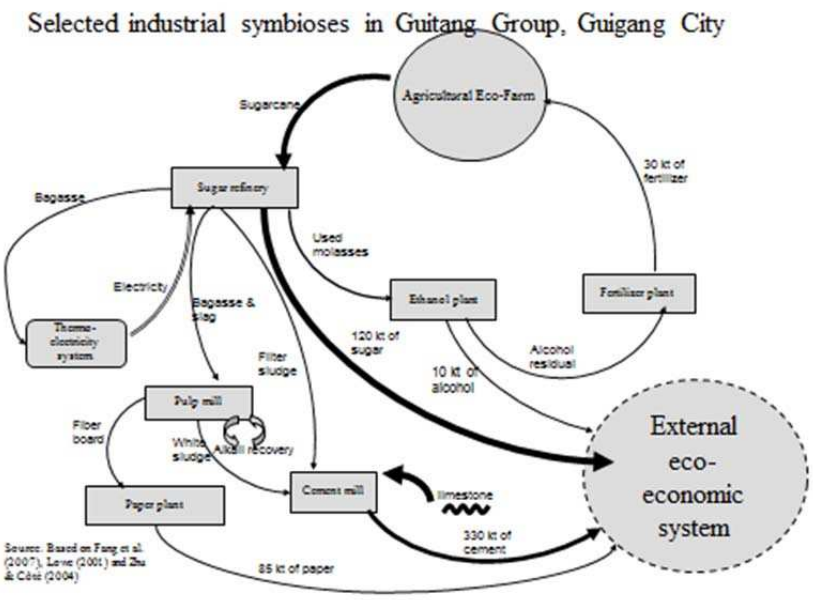
industrial revolution.[9] As China drives down the costs of renewable energy systems, so it accelerates their diffusion across the developing world.

China is active across all green sectors, and in particular it is taking powerful initiatives in reducing resource throughput by linking outputs of one industrial process to inputs into another. Called the 'Circular Economy' in China, this is an instance of industrial ecology, and adopted as central government policy. China may be characterized as a most pragmatic exponent of circular and eco-responsible thinking – even as it grapples with the worst forms of industrial pollution. This is the 'green and black' paradox of China, again. China's 12th FYP consolidates previous efforts to promote resource recirculation, after the pattern of the 3Rs – reduce, reuse, recycle. China has adopted these goals not just as an 'environmental' policy, but as a mainstream development goal. China's national leadership appears to have understood that continued development in the traditional linear manner, starting with resources taken from nature at one end and proceeding via production processes to the creation of wastes disposed in nature at the other end, is simply no longer feasible.

A real version of the Circular Economy is found, for example, in the inter-related material and energy flows associated with the Guigang sugar complex in China, as shown in Figure 9.

Fig. 9. Industrial symbioses in Guitang group, China

[9] While the 12th Five year Plan set this target of 30% by non-fossil sources as being reached by 2020, it was brought forward to 2015, under the 2012 Energy White Paper. See Mathews and Tan (2013).



Source: Mathews and Tan (2011)

In the case of Guigang, a group founded as a state-owned sugar producer in 1954, the evolutionary steps towards closed loops have been documented. It began as a conventional sugar mill, but in time it developed new loops to make use of wastes or by-products, creating new value chains that are now propagating through the local economy. There is the sugar process itself, linked to an ethanol production facility, which has now closed the loop through wastes from the ethanol plant (vinasse) being converted into fertilizer and recycled back to the cane farms. The other main chain is concerned with paper, which starts with the crushed cane (bagasse) as raw material, converting this to a pulp that is then turned into paper and sold to the wider economy. Since 1998, the Group has started the operation in using the filter mud (after being dried) generated from the sugar refinery process as a raw material for cement production, thus creating a new value chain. Furthermore there is recycling of bagasse as fuel for the production of heat and power that is used in all the other industrial processes found in the Guigang group. This eco-complex received recognition in China by being designated as the country's first eco-industrial park, in 2001.

Since the same pressures are going to be experienced by India and Brazil, they too can be expected to pursue a similar 'green and black' energy industrial revolution – driven by rising fears for energy insecurity. In India power blackouts and brownouts are now recognized as a major factor in holding back India's growth rates.

Many developing countries are now starting to use the language of energy and resource security in building their renewable energy systems. Take the case of Malaysia, and in particular its Sarawak Corridor of Renewable Energy (SCORE) project, which involves construction of 20GW of hydroelectric power along a 320-km riverine corridor, and calling for investment of US$105 billion by 2030. SCORE is viewed by Malaysia's planners as a developmental project of the highest priority, an important component of both the 9th and 10th Malaysia Plan (respectively covering the years 2006-2010 and 2011-2015).[10] One of the key drivers of the SCORE development is energy security, namely to get Sarawak off its current near 100% dependence on fossil fuels (gas and oil) and move instead to a portfolio of energy sources, with hydropower anticipated to rise from a 10% share in 2006 to 71% share by 2030.

The same arguments apply with equal force to the case of water security, which is emerging as a major problem not just in China but throughout the developing world and developed world as well, calling for novel solutions in just the same way as resource and energy security call for novel solutions (Hering et al 2013; Sedlak 2014).

5. Competitive emulation will drive diffusion

Leading advanced industrial countries such as Germany and to some extent Japan are also shifting to regard clean technology investment as a significant business proposition rather than as a cost – for their own reasons and through competitive dynamics. The United States is not yet providing leadership in this transition due to the strength of its established fossil fuel industries and the induced weakness of its manufacturing sector.

Economists hold the floor in discussion of policies to mitigate climate change, emphasizing the costs and of such policies (e.g. in terms of % of GDP) and the timing.[11] By contrast, the more pragmatic business sectors in advanced countries like Germany and Japan have already recognized that green energy and clean technology in particular represents the biggest business opportunity of the 21st century, and are moving rapidly to establish strong positions in these sectors.

Germany announced in June 2011 a radical about-turn in dropping its previous reliance on nuclear (which had been retarding the renewables option for decades, as deplored

[10] A specific development agency has been created for SCORE: the Regional Corridor Development Authority (RECODA), which is vested with responsibility for attracting and coordinating the investment. For discussion, see Sovacool and Bulan (2013). For the latest developments, see the project's website at: http://www.recoda.com.my/

[11] See e.g. Garnaut (2008); Stern (2007).

by scholar-activists like Scheer) – triggered by the Japanese Fukushima disaster. This was then followed up with successive announcements on its planned build-up in renewables industries – in what the Germans call the *Energiewende* ("energy transition" or transformation. Germany has moved on from its heavy promotion of renewables markets, via its feed-in tariff system embodied in the Renewable Energy Sources Law of 2000 and earlier incarnations, to the far more significant promotion of renewable energy industries themselves – exactly as is being done by China.[12] Although for various reasons more problematic, Japan also has the makings to pursue a similar course. Japan has a track record of building a circular economy and providing strong backing for renewables earlier in the 1970s and 1980s until lower oil prices discouraged such initiatives. So before too long Germany and China and perhaps Japan and Korea are likely to emerge as serious proponents of green industries, both for domestic consumption and export. Between them, these industrial powers would represent an unstoppable force turning the global industrial machine from its present addiction to fossil fuels into something quite different.

Such a story cannot be told for the United States, where the country is counting the costs of a lost decade after the events of 9/11. It may be argued that US foreign policy has been shaped by oil ever since its domestic supplies peaked in 1970, while more and more ambitious plans for securing and protecting oil supply lines were being formulated in the 1990s, then put into effect under the Bush Administrations of 2000-2008. While the Obama Administrations have sought to build support for clean energy systems, nevertheless it has been difficult to move forward in the face of entrenched fossil fuel interests and a hostile Congress. Most recently the US debate has shifted to the pursuit of what oil companies call 'energy independence' through securing access to shale oil, tar sands oil and through resort to hydraulic fracturing to produce coal seam gas. This too has encouraged investments in semi-secure 'alternative' fossil fuels supplies, slowing the uptake of renewable energies. In the manufacture of renewable devices such as wind turbines and solar PV cells, the US has fallen behind industry leaders including China, Germany and Japan – for reasons discussed under the rubric of 'financialization' of US corporations and the offshoring of many activities, resulting in virtual de-industrialization.[13]

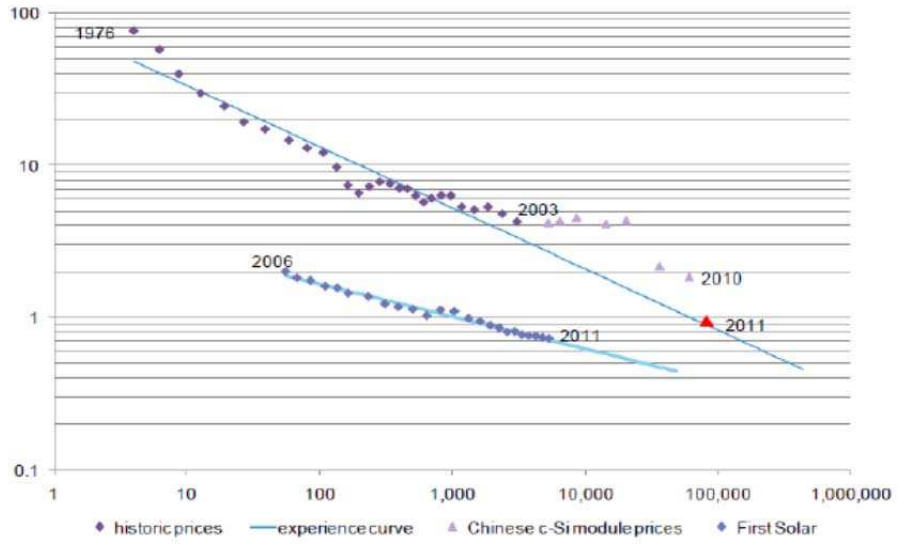
[12] See Davidson (2012) for a striking account of the German *Energiewende*; it promises to provide a lead for the rest of the world in how to build renewable energy industries, comparable to that already instigated by China.
[13] On financialization and its impact on the real economy, see Dore (2008) and Lazonick (2011).

6. Transition dynamics driven by cost reductions will be compatible with growth

The global transition from a fossil fuelled industrial system to one based on renewable energies and resource efficiency (circular economy) may be viewed as the dominant technoeconomic trend of our time, promising to become even more significant in the coming decades.[14] Uptake of renewables is driven by relentless cost reductions through the learning curve – reflecting the manufacturing dynamics of production of renewable devices. The green transition can be compatible with continued economic growth – understood as intensive growth, not as extensive growth based on expanding resources throughput. The growth model is Kaldorian, based on circular and cumulative causation.[15]

It is the falling costs associated with the manufacture of renewable power systems that accounts for their rapid take-up around the world. Costs for solar PV cell production are falling at 45% per year – making imminent the advent of grid parity (when power can be produced from renewable sources at costs to match those of the cheapest and dirtiest coal). Fig. 10 shows the experience curve for solar PV, demonstrating the rapid cost reduction.

Figure 10. PV module experience curve, 1976-2011



Source: Bazilian et al (2013), Fig. 1

[14] On the current transition to a new technoeconomic paradigm, driven by renewables and China, see Mathews (2013a).
[15] On circular and cumulative causation and its centrality to capitalist dynamics, see Kaldor (1970).

In this chart, based on and updating the chart on experience curves contained in the recent IPCC report on Renewable Energies (IPCC 2012), the overall experience curve is shown in the upper blue line, indicating that costs had reduced to the **long anticipated point of $1 per watt** by the end of 2011 and bringing solar photovoltaic (PV) power within the range of almost all emerging and developing countries. The years immediately preceding this show that costs hovered for several years (2004 to 2008) at around four times this level ($4/W) – a phenomenon now understood to be due to suppliers being able to command feed-in tariff rates locked at these levels, while restricted silicon supplies meant that there was little price competition. It was this that led many to believe that costs of renewable energies would always exceed those of conventionally fuelled power. But as silicon supplies became more flexible, so manufacturers reduced their prices, which in turn reduced input costs for solar cell producers, and their prices fell as well. The second blue line represents the cost curve for thin-film solar cell producers, dominated by the US firm First Solar. Because thin film PV cells utilize much lower quantities of silicon their costs have always been lower – but are not yet enjoying the economies of scale of amorphous silicon cells. The message is clear: the costs of solar PV cells are falling at around 45% per year.

China and the countries putting their efforts into renewables like wind power and solar PV are all making a good bet. Renewable energies contribute directly to promotion of energy security (or rather reduction of insecurity) even when evaluated in terms devised to discuss security in terms of fossil fuel supplies. Accordingly, renewables may be considered fundamentally as a source of energy security – in that they are associated with manufacturing activities that generate increasing returns and declining costs. As recognized over centuries, manufacturing activities are superior in terms of wealth generation to agricultural and extractive activities because they embody increasing returns, as opposed to diminishing returns for activities that are dependent on land as a resource.[16]

By contrast with the fossil fuel focus of energy security, and its emphasis on diversity of fossil fuel supplies and their economic feasibility, the emphasis in energy security through manufacturing is on ensuring the viability of manufacturing value chains and the prosperity of manufacturing firms, where competition will ensure that prices are reasonably predictable. This is a perspective that focuses on the real advantages of renewables, as manufactured products. The processes of creating manufacturing value chains will build on each other,

[16] Erik Reinert has made this point forcefully in many writings; see his book Reinert (2007) for a summary exposition.

creating multiple interconnections and increasing returns as they do so. This may be described as a chain reaction of value creation that can benefit all countries that have some level of renewable energy resources. The contrast with the prospect of diminishing returns from extractive activities is striking.

This perspective on energy security through the manufacture of renewable energy devices (rather than succumbing to the insecurity associated with extractive activities) indicates why a green economy can have economic growth while not increasing its 'carbon footprint'. If growth in its conventional sense is viewed as increase in resource throughput (measured as in GDP) then planetary boundaries clearly place a limit on growth. But if growth is considered in the Kaldorian sense of growth in incomes through successive rounds of specialization, each one expanding the market, and the whole growing through circular and cumulative causation, then growth can be seen to occur against a constant resource baseline. As more and more resources are circulated (recycled) and industrial ecological connections are made, as in China's pursuit of a 'circular economy' (outputs of one process feeding into another process as inputs) so the tempo of economic activities can increase but in a way that is decoupled from increases in resources throughput.

A major institutional reform to drive the uptake of renewable energies and clean technology around the world would be a global cleantech trade agreement. Behind the huge surge in IT investments of the past 15 years stands a similar agreement providing for free trade in IT goods.[17] What gives this IT trade agreement teeth is that it was adopted by the WTO, and now drives targeted free trade momentum amongst the world's leading economies, stimulating their adoption of IT products and helping to expand markets for IT producers. It drove the elimination of tariffs on hundreds of products, making them accessible by developing economies around the world. The ITA proves that free trade really does work – when it is targeted and really is free.

So a trade agreement focused on clean technology goods (and perhaps eventually services) could work in the same way. It would bring together a core group of signatories who would agree to phase out tariffs and trade barriers on goods that are central to the promotion of green growth, say over a five- to ten-year period. This agreement would be

[17] This was the 1996 Ministerial Declaration on Trade in IT products (better known as the Information Technology Agreement (ITA)), concluded by 29 participants at the Singapore Ministerial Conference in September 1996. It has now expanded to 70 participants, who have signed up for an agreement that envisages totally free trade in all IT goods. (See the WTO website on the ITA: http://www.wto.org/english/tratop_e/inftec_e/inftec_e.htm

adopted by the WTO, and become operable as other countries joined in. It could be phased to cover core products and tariffs at first, perhaps becoming broader in scope subsequently.[18]

7. But a transformation will require smart government intervention …

The transition is going to require smart government intervention, both to break the power of 'carbon lock-in' of existing fossil fuel interests, and to establish clear rules that can be credibly enforced to govern the new investment trajectories. Strong states will have advantages over weak states. Ideologies that minimize government role in the economy are ill-suited for making such a transition.

The problem is to get from a BAU trajectory to something quite different involving renewables, resource efficiency and eco-finance, where unfettered markets may be expected to work well. The transition is most unlikely to be brought about by market forces alone (such as through consumer demand perhaps buttressed by carbon taxes) because the carbon lock-in is simply too strong. Indeed, the 'free-market environmentalism' school of thought would have it that if the foundations of capitalism can be extended and built upon more completely then all the problems will disappear. As Jeffreys puts it: 'Free market environmentalism can save the planet'. Faith in market fundamentalism however has not been well rewarded, as the blowback from deregulated financial markets attests.[19]

The industrial dynamics and innovation literature now offers a sophisticated analysis of sociotechnical regime transitions, where the focus is not just on changes in technology but on changes in whole sociotechnical regimes (e.g. power regime, mobility regime) and ultimately in technoeconomic paradigms or sociotechnical landscapes.[20] These broader concepts provide the setting within which changes in technology might be viewed as being accelerated or as blocked. Debate has focused on the extent to which such regime transitions might be driven

[18] There is already an excellent precedent in the Asia-Pacific countries agreeing to such a clean tech deal at their APEC Ministerial last September in Vladivostok. The statement from the APEC member countries committed them to reduce tariffs on 'environmental goods' to a level below 5% by 2015. There followed a long list of clean tech goods (encompassing for example renewable energy systems and components, energy efficiency technologies and environmental monitoring systems) as an attachment. (http://apec.org/Meeting-Papers/Leaders-Declarations/2012/2012_aelm.aspx The APEC agreement was an excellent start. The next step could be for the G20 to adopt such an agreement at their next Summit – as prelude to being adopted at the WTO.

[19] For a robust advocacy of free-market environmentalism, see Anderson and Leal (2001), who are associated with the Property and Environment Research Center (PERC); a succinct account is provided by Jeffreys (1994).

[20] For an overview, see Schot and Geels (2008) as well as Kemp and Oltra (2011); for an analysis of historic case studies and in particular the destabilization of existing regimes, see Turnheim and Geels (2013) for an insightful analysis of the British coal industry and its destabilization.

by niche-initiated changes welling up from below, or by top-down changes driven by state action. This latter perspective obviously makes sense for the case of China.

A realistic view is that there is a necessity for the state to take action to help drive the system onto a new trajectory with new rules and standards that make the system more 'sentient', more attuned to the scale and scope of interaction between economic and ecological processes. Specifically, there will need to be new rules for the transition to a new kind of green growth capitalism – and these new rules will need to engage with the details of energy, resource throughput, and finance, replacing the existing trajectories with new state-mandated renewable pathways.

8. … and private sector finance attracting institutional investors

While historical analysis reveals government guidance to be essential, the finance required to invest in the new green economy is beyond the capacities of tax-based public finance; the bulk of the funds are going to have to come from the private sector. The OECD estimates that the scale of investment required in renewables in the decade 2010 to 2020 to be around $6.3 trillion (i.e. well beyond anything envisaged through public funds), while the size of the potential investment pool is estimated at $71.1 trillion in 2010, and growing rapidly, drawing from investment funds, insurance companies and pension funds (Fig. 11). Another recent estimate of the needed investments (from the HSBC in 2013) is of the order of $1 trillion each year for the next two decades. The $70 trillion or more managed by institutional investors will prove to be critical, and can be tapped by institutional innovations such as green banks, climate bonds, targeted loan programs as well as sufficiently patient venture capital.

Bonds are the core of the international capitalist system. It takes countries decades, if not centuries, to build effective bond markets. They enable governments and leading corporates to raise funds, on the strength of their credibility and reputation. They are 'investment-grade' securities, meaning that they are only offered for large amounts – and so their value for green finance is that they can aggregate across a large number of small projects. Diseconomies of scale associated with small projects are decisively overcome by a green bond.[21]

[21] See Mathews and Kidney (2012) for a discussion of the rationale informing climate bonds.

Financing of cleantech projects via green bonds make for cheap capital, since the interest charges will always be lower than for conventional bank finance. This means that renewables and energy efficiency projects that might have been put out of the running because of high cost of capital suddenly become viable. The diffusion of green energy and resource projects is therefore accelerated. An example is the $500 million Kexim bond, issued on international markets in March 2013 by the Korean Exim Bank, and oversubscribed by institutional investors. The proceeds raised are to be channelled towards green investment projects, verified as such by a responsible third party. This can be described as the first real national climate bond – setting an important precedent, and revealing Korea's green growth strategies in a positive light.

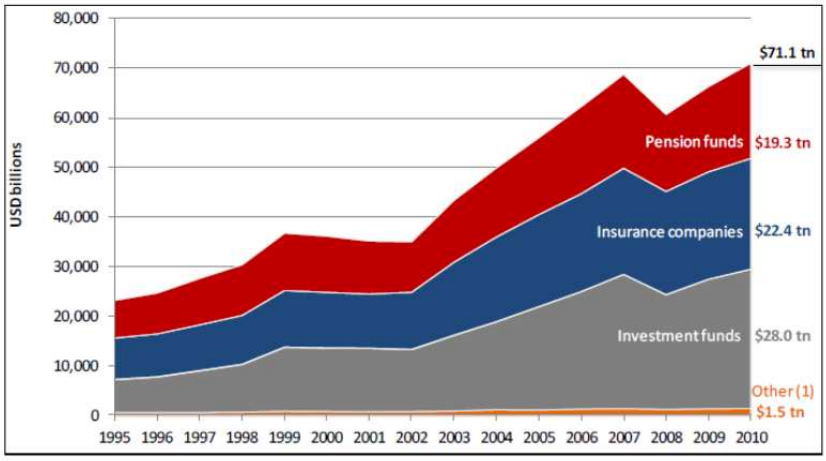
Bonds are serious financial instruments that are not to be played with. If a country's bonds lose their value, then the country faces ruin. (Technically, it would be unable to meet its payments, and would have to default – a desperate step.) Hence a green bond issued with a national government's imprimatur (as is the case with this 2013 bond issued by the Korean Export-Import Bank) means that the bond will hold its value only if the projects really are an investment in a green future, and really do have the backing of the government. The bond markets will see through any shenanigans, and punish the issuer severely.

So here is a novel situation where the bond markets could emerge as vital players in the transition to a green economy. The enormous investment potential of the bond markets is there to be tapped to finance green investments – but has been done so only in a minimal way until now. The ideological insistence of the UN and the parties to the Kyoto process that all green investments should emanate from tax-based public sources (which could manifestly not finance the transition in any realistic manner) has now been overcome.

The 'big guns' of capitalism are therefore about to be employed. And the big investors – institutional, pension and insurance funds, which have between them over $70 trillion in investable funds according to the OECD (Fig. 11) – are now becoming actively involved, thanks to bond issues like that of the Kexim Bank.[22] Sustained attention is now being given by the OECD to the barriers standing in the way of the deployment of such funds at scale in accelerating the uptake of renewable energies around the world.

Figure 11. Investment pool made up of institutional investors, 1995-2010

[22] See the report from the OECD Finance, Insurance and Private Pensions Department in August 2012 by Kaminker and Stewart (2012).



Source: Kaminker and Stewart (2012), Fig. 2

Most of the projects that professional fund managers find themselves being presented with involve fossil fuel energy systems and unacceptable levels of carbon emissions, and for this reason such projects present unacceptable risks of default. For the most part, the kinds of low-carbon projects that they would like to invest in are unsuitable, in that they small, or under-insured and guaranteed, or are found in emerging markets where risk spreads are high. So there is scope here for some innovative financial institutions to step forward with investment vehicles (bonds) that overcome these obstacles.

Development banks such as the China Development Bank (CDB) and Brazilian Development Bank (BNDES) can be expected to play critical roles, as they adapt their lending policies to the needs of green sector investments. The BNDES has already developed preferential loan schemes utilizing sociotechnical criteria to identify eco-favorable projects, while the CDB has pioneered the role of bonds as financing vehicles in China, setting the stage for the next step of issuing climate bonds to eco-worthy projects.[23]

The contrast with carbon trading has to be underlined. The idea that pollution allowances could be traded and that the 'carbon markets' so created might drive investment in the desired direction, has now been shown to have little potential – given the dismal performance of the ETS in Europe and collapsing carbon prices elsewhere. But to tap into the bond markets is a real form of green finance, and one where Seoul and the Korean Exim Bank may just have seized the initiative away from Wall Street, Frankfurt and London.

By contrast, global equity markets, while offering invaluable support, are unlikely to do the heavy lifting (even through the role of venture capital). For one thing, globally the bond

[23] On the China Development Bank and its lending initiatives, see Sanderson and Forsythe (2013).

markets are around three times the size of the equity markets (consisting of traded shares in listed corporations).[24] But the main reason is that bonds have arguably the greater power to aggregate investment projects across multiple lines, to reach 'investment grade' that would be attractive to institutional investors – lowering the cost of capital and reducing risks and uncertainty. Equity (share capital) by contrast is tied closely to the performance and prospects of individual companies and their managements, and can be side-tracked by concerns over individual earnings by senior management – as is evident in the past decade in the US with the strong trend towards share buybacks undertaken to drive up share prices and enhance the value of executives' stock options (Lazonick 2011).

9. Government policy settings will be critical to building confidence

Government policy settings favoring market mandates, feed-in tariffs, green and cleantech standards (e.g. for green buildings), government procurement and a change in the balance of taxation (swinging taxation towards wasteful materials and energy rather than intellectual activity and labor) will play a role in reducing uncertainty and thereby encouraging green investment strategies and directly stimulating the new trends.

In August 2013 the China State Council issued guidelines for investment where they support the issuing of green investment and credit instruments, and foresee a rate of growth for the green sector in China as being consistently at a level of 15% per annum in the next decade – as opposed to half this level for the economy generally. This sends a very clear signal to the investment community that green energy and clean technology are to be favored, and can expect to earn superior returns.

By contrast, the typical solution of 'carbon markets' (such as the European Emissions Trading Scheme (ETS)) may be viewed as a 'faux solution' that could create a financial bubble. Financial market operators are likely to see scope for speculative investments that have less and less to do with real clean technology investments. Likewise my reason for offering scant support for carbon taxes is that they are – even in the opinion of their advocates – a weak instrument for changing business activities.[25]

[24] McKinsey's report on *Mapping Global Capital Markets* in 2011 estimated the size of the global capital funds market as being $212 trillion – of which bonds (debt) markets accounted for $157 trillion, and stocks (equities) for $54 trillion (McKinsey 2011).

[25] For a strong defence of the role of 'carbon pricing', see the latest OECD environment report, *Climate and Carbon* (OECD 2013).

After all, it is a matter of record that the world shifted to railroads without a tax on canals, or to personal computers without a tax on typewriters. Likewise the argument is that if the world accomplishes the transition to clean energy and resource efficiency (circular economy) it will not be solely through taxes on fossil fuels but because the green alternatives will deliver superior services at lower costs. The agency through which this will be accomplished will be strong state intervention; its actions will be of a direct kind (such as setting market mandates or government procurement) rather than through the setting of indirect price-guided signals. China has already developed a series of high-tech zones which incubate globally competitive firms (Zhou 2008); this process can now be expected to diffuse through green innovation.

In the longer term investments in clean technology and energy are bound to be 'safer' than those made in fossil fuel systems, in the sense that they are much less susceptible to fluctuations in price caused by materials and resources shortages – but they need to be supported by strong government endorsement and guidelines.

10. Fast-follower latecomer strategies will prosper…

While much of the literature on green growth focuses on the role of innovation, in reality it will be technology diffusion and the formulation of fast follower strategies that will prove to be of greater salience for countries like China. Latecomer strategies will prove to be extremely important in making the transition, as countries like China gain access to the store of advanced technologies and utilize them, without the inertia induced by carbon lock-in, to place their economies on a new cleantech footing. Fast follower strategies perfected in East Asia can now be applied to drive the diffusion of green innovations, with latecomer countries enjoying cost advantages in the application of renewable energies as their costs continue to decline.

It is developing countries that will make the critical resource and energy decisions over the next two decades, as they make their bids to join the industrialization process as it diffuses around the world. The real driver of the capacity of emerging industrial giants such as China, India and Brazil to take up and implement green technologies and systems is their capacity to build and manage *national systems for technology diffusion*. This means having institutions that scour the world to seek out new and promising technologies; institutional means to secure these technologies and transfer them to the home base; and capacity to

diffuse the technology as fast as possible amongst domestic firms. What we see in China today, as well as in the other East Asian countries like Taiwan and Korea, is an application to the renewables sector of policies of *fast followership* that have been tried and tested in earlier experiences with electronics, semiconductors and IT.[26]

For example, fast followers look for industries where there is growth potential and a dominant technology, where mass production can be implemented. Taiwan and Chinese solar PV firms have clearly focused on the dominant technology of crystalline silicon, which is mature, has reached mass production level, and is largely free of intellectual property constraints. Even in second generation PV there is a new dominant technology led by thin-film semiconductor mixtures, of which a new semiconductor layer made up of copper, indium, gallium and selenide (CIGS) may emerge as dominant. And in the case of Concentrated Solar Power, molten salt technology again looks likely to be dominant – and hence to be the target of sustained efforts at new industry construction in countries such as China and India. Similar considerations apply to wind power, where Chinese and Indian firms are introducing their own innovations -- Goldwind in China introducing its own turbines equipped with Permanent Magnet Direct Drive (PMDD) technology, which eliminates the need for gearing, and Suzlon in India introducing the marketing innovation of providing full customer support along the entire value chain, including financing. These cases reveal how technology and market dynamics continue to drive the transition to a new cleantech economy.

11. … while the outcome is anything but determined

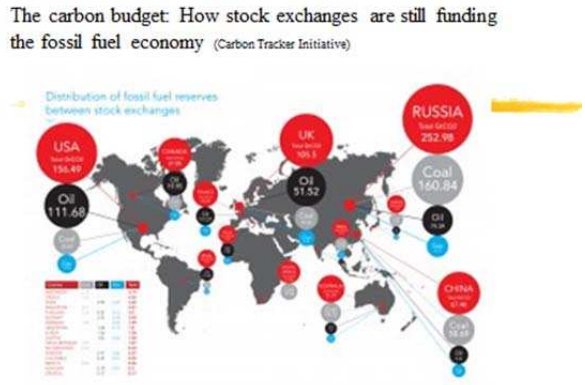
The outcome of the current transition is however anything but certain. Carbon lock-in and the inertia induced by vested interests may prevail, and the shift to clean technologies may prove to be too little and too late to avoid the worst excesses of climate change. The adaptability of capitalism as a world system is about to be given a most stringent test; the alternatives in the form of a global environmental dictatorship or free market wreckage are unthinkable.

The reality is that the world's capital markets are still allocating investments mostly to fossil fuel projects, while the fossil fuel companies themselves are amassing 'stranded assets' in the form of reserves of fuel that underpin their share price – but which can never be burnt. The Carbon Tracker Project in London has done the world a service in identifying how

[26] See Mathews et al (2011) for an analysis of Taiwan's fast follower strategy in rapidly entering the solar PV industry.

deeply these finance institutions are still tied to the fossil fuelled economy (Fig. 12). The changes needed to drive the world to a new kind of economy will have to run deep and involve major institutional resettings.

Fig. 12. Stock exchanges are still financing Business as Usual



Source: Carbon Tracker Initiative: http://www.carbontracker.org/

12. Global leadership rests with China and the US

Global leadership in the transition will inevitably rest with the United States and China, as the two largest industrial economies with the two greatest carbon foot prints. Early initiatives to create a binding climate treaty were doomed to fail, but may be revived once either China or the US build sufficient institutional and business momentum. Asia is demonstrably taking the lead in developing a new model of growth (e.g. Spence 2011) for the 21st century – just as the US was the lead country in developing an oil-driven model of growth in the 20th century.

It is the diffusion of a new model of green growth around the world that is the most critical issue. In the end our industrial civilization will need to operate within global limits and laws, but the path towards such a sustainable and ecologically balanced economy will prove to be fraught.

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