

CHAPTER 1

INTRODUCTION

We are now in the middle of a long process of transition in the nature of the image which man has of himself and his environment [...]. There was almost always somewhere beyond the known limits of human habitation [...] a frontier. That is, there was always someplace else to go when things got too difficult [...] The image of the frontier is probably one of the oldest images of mankind, and it is not surprising that we find it hard to get rid of. Gradually, however, man has been accustoming himself to the notion of the spherical earth and a closed sphere of human activity.

K. E. BOULDING, *THE ECONOMICS OF THE
COMING SPACESHIP EARTH* (1966)

Fifty years ago, Kenneth Boulding argued in his predictive essay on the economics of the coming Spaceship Earth that the world would eventually have to move to a more responsible mode of economic interaction with our planet – from a Cowboy economy (reckless, wasteful) to a self-contained ‘Spaceship economy’ (regenerative, contained). Now we are at last catching up with Boulding’s vision, as the prospect of an economy centred on accessing renewable energy resources from the sun and the wind, and tapping regenerated resources from a circular flow, becomes a realistic option. We are living through a profound industrial transformation, a ‘green shift’ that is being driven by global demographic, economic and technological forces.

We do indeed live in a period of profound change, particularly in terms of energy and resources utilized. The upheavals in the patterns of energy production and consumption – with dramatic swings away from established systems of fossil fuel usage and linear resource throughput – are occurring so fast that it is difficult to keep up with them. Innovations like the Tesla electric vehicles now transforming the global automobile industry, new sources of electric

power, new smart grids and new ways of producing food in urban settings (e.g., vertical farms) all appear so dramatic partly because they are, well, dramatic. But they also invite contrast with decades of stasis in the energy, electrical and transport worlds, that have long been held in a 'frozen' state by patterns of corporate power established earlier. Now it is all being shaken up. There is a green ferment in the air.

The difference in this case is that it is a ferment that is touching not just a handful of countries or a small fraction of the world's population, but it is instead mobilizing the great populous countries of China and India in a world-historic transformation. These two countries (more civilizations than nations) are now reclaiming their traditional place as leaders of the world economy in a profound transformation that may be characterized as the Great Convergence. This term itself is carefully chosen to depict a contrast with the Great Divergence that separated Europe, North America and then Japan – the (not strictly geographical) 'West' – from 'the Rest'.

The relevance to the story of 'greening' is immediate and profound. China started on its quest to join the advanced world three decades ago, with its famed 'opening up' that ushered in sustained economic growth fluctuating around ten per cent per year. This process has now brought Chinese firms to quasi-parity with advanced firms, and in the process lifted hundreds of millions of people out of poverty. India is following the same astonishing pathway with perhaps a lag of a decade or so. As with all previous industrial powers before them, China and India have been following the Western route of utilizing fossil fuels – above all, coal – as their primary source of power, as well as extensive supplies of resources as material inputs. But as they do so, they come across the inconvenient truth that this Western fossil-fuelled model will not scale to global dimensions. There is the issue of carbon emissions and global warming, of course. But the real barrier that China and India face is not so much climate change (a problem that they feel, rightly, they inherited from the West) as immediate pollution from the burning of fossil fuels with their particulate emissions, and the geopolitical entanglements that result from global sourcing of such fuels and resources. This globalization of resource extraction impinges on established patterns of trade and production and sparks trade wars, if not civil wars, revolutions and terrorism. These are the real 'limits to growth' faced by China and India.

The resolution of the problem can be found not in terms of manipulating global political and trade-based economic relations, nor in simplistic calls for a shift to 'zero growth' even before China, India and the other industrializing

countries have enjoyed their time in the sun. Rather, the resolution is to be found in a new pattern of economic growth that is coming to be termed 'green growth', where growth is complemented by changes in energy and resource flows that are more sustainable. Countries embark on a revolution in their energy system, displacing the established fossil fuel supplies and centralized electric power systems, and reduce their resource vulnerability by shifting from linear patterns of resource throughput to circular resource flows. The unanticipated aspect of this global green shift is that it is actually being led by China and (to some extent) by India. These are the countries where the problems are felt acutely and where the solutions present themselves most forcefully.

As the green shift involves new energy and resource and food production technologies, and new companies to drive their adoption, we see Chinese and Indian players emerging in newfound positions of leadership. These players are utilizing strategies of convergence (catch-up) that were perfected by East Asian countries like Korea and Taiwan in their catch-up with the West – initially, in a surge of fossil-fuelled industrialization. We also see Western companies striking out in new entrepreneurial ventures that break with the deadening hand of 100 years of stasis in the oil industry (the period of the 'seven sisters'), the coal industry with the prolonged dominance of firms like Peabody and the commodity giants. As they do so they are imposing Schumpeterian 'creative destruction' on the established order – and Chinese and Indian firms are only too willing to pick up the pieces and scale up the new, insurgent technologies to create new global businesses. These new firms are founded on wind power, solar power, and imminently, water regeneration, urban food production and other constituents of the worldwide green shift.

IT'S NOT ALL ABOUT CLIMATE CHANGE

The conventional argument on these matters of renewables and low-carbon energy and resource systems is that they are all about preventing – or mitigating – climate change. I present in this book a fresh alternative approach to the question of renewables. Yes, climate change is a large and important issue – but to focus on this question alone is to exclude other important aspects of renewables, such as their contribution to enhancing energy security and their cleaning up immediate particulate pollution problems. These are the aspects of renewables that are of most relevance to the emerging industrial giants like China and India.

The major trends I wish to focus on are those that *decouple* economies and economic processes from natural constraints. Now a qualification is in order at

the outset of this discussion. The whole rationale of greening is, ultimately, one that locates our industrial systems within their ecological setting rather than pretending that they lie ‘outside’ ecological processes and cycles. This is my main objection to the story as told by mainstream neoclassical economics – it makes no reference to natural cycles, and works only with abstractions like wealth and income without ever grounding them in real flows of energy and resources. By contrast, ‘greening’ initiatives like those involved in introducing green taxes that tie economic activities to their origins and degree of pollution – and penalize polluting behaviour – make sense because they make producers of goods (like manufactured products) and services (like intercontinental transport) take greater cognizance of their impact on the earth. And this impact is frequently negative, as we are now realizing – and getting worse as ‘business as usual’ industrialization proceeds.

So far, so good – this account does not differ from numerous treatments that view the climate changes resulting from our ‘unthinking’ carbon-based industrialization as the primary issue, and decarbonization (clean energy and dematerialization) as the necessary way forward. But in the way this is posed it frequently comes across as the West forcefully imposing its view of how industrial evolution needs to proceed. As Pascal Bruckner (2013a; 2013b) put it in well-argued texts, even as the West’s influence is diminishing, its arrogance in dictating to others on the planet how they should adjust their processes to make them climate-friendly is rising in its insistence.

A quite different argument is presented in these pages. The argument is that China (and to some extent India) are already feeling the pressures of pollution and geopolitical tensions created by their wholesale replication of a Western industrialization strategy, and are now seeking a green alternative with serious intent, on a global industrial scale. The driver is not so much a concern to save the world from climate change. It is rather a very real concern that the industrialization process being mounted by emerging giants like Brazil, India and China will be stalled by increasing local pollution and by geopolitical complications, and that a green alternative represents the only option available that can guarantee energy and resource security. And the key to this security lies in a feature of renewables that is seldom highlighted, namely, the fact that the devices used in power systems based on renewable resources are in all cases products of manufacturing. If manufacturing is what produces the devices needed to generate power and drive a circular flow, then it can be performed – in principle – anywhere. This is why manufacturing is central to resolving the issues of energy and resource security, as discovered by countries like China and India.

Manufacturing the devices needed to produce power is a completely different process from drilling for oil in more and more hostile locations, shipping the oil across the world in giant tankers, and then building a vast infrastructure for the processing, distribution and sale of the oil-based products. Manufacturing wind turbines and solar cells is governed by quite different ‘laws’ and places a country that pursues this alternative green strategy on a quite different footing, free from concerns over ‘energy security’ (meaning access to fossil fuels at a reasonable price) and able to frame energy and resource strategy as a part of its manufacturing and industrial development strategy.¹

Manufacturing is a special process that creates increasing returns, by virtue of declining costs as markets expand and new niches for specialization are created. This is the process of intensive economic growth driven by circular and cumulative causation described so clearly by Allyn Young (1876–1929) in his account of how mass production industries work. We are now grappling with the same issues as industrializing countries like China and India build new green industries based on mass production and falling costs that promise to oust industrial products based on fossil fuels, resource extraction and open-air food production. If we apply this reasoning to the rise of new green industries, where China and now India are the countries taking a leading role, then we have a new and arresting twist to the story of our industrial evolution.

The story told here is one where China and India are able to enhance their energy and resource security – mitigating the domestic pollution created by their earlier coal-based industrialization strategies, and ensuring a reliable source for raw materials through the ‘mining’ of urban resource flows. This is not a shift dictated by any technological demand or geopolitical constraint – as has been the case for fast followers on the path of industrialization like Japan, then Korea and Taiwan in the fossil fuel era. In this story, the real driver is the shift to green growth, undertaken as a strategic and entrepreneurial initiative that turns out to have far-reaching implications. The driver is the strategic goal of enhancing energy and resource security – with decarbonization resulting as a fortunate side-effect. I propose in this book to leave climate change to one side and to focus instead on the strategic issues – the choices that are being made by the converging countries, and their material and energetic implications.

As my collaborator Hao Tan and I have argued in successive articles in *Nature*, there is a profound aspect to this shift and a reason why Chinese and

1. Erik Reinert and I developed this argument in an article published in *Futures* in 2014.

Indian firms are emerging as leaders of the transition.² It is manufacturing that lies at the core of the shift. What is being disrupted is not just a way of producing concentrated power, but a way of producing power via the extraction of fuels in a global system of drilling, mining, processing and transport. This system is now being disrupted by a new emergent global system based on the different principles of manufacturing. New power devices like wind turbines and solar cells can operate anywhere on the planet and produce power and store it any time.

The fact that some Western companies like Tesla are surging to world leadership in the new green era only serves to underline the point that they too are doing so by basing their strategies on manufacturing. They are the exceptions that prove the rule that the new, green era that is opening up is one that will be based on secure foundations of manufacturing. This green shift offers emerging countries an optimal way forward both in terms of industrialization through manufacturing (with all its labour enhancement and employment aspects) as well as clean and green energy that does not tie them up in geopolitical knots.

The fact that the green growth strategy is also one that delivers low-carbon emissions is a convenient side-effect that runs counter to the inertia displayed by Western oil, coal and gas and electric power and transport industries. We need to be clear about what is driving the disruptions in these industries. The driver is lower costs induced by expansion of markets as China and India enter world production and distribution systems for renewable power and circulation of resources.

This is the fascinating world of upheaval that I tackle in this book. Kenneth Boulding would no doubt have been fascinated as well – if a little disappointed that we had taken so long to heed his words.³

2. See ‘Manufacture renewables to build energy security’, *Nature*, 11 September 2014, at: <http://www.nature.com/news/economics-manufacture-renewables-to-build-energy-security-1.15847>; and ‘Circular economy: Lessons from China’, *Nature*, 23 March 2016, at: <http://www.nature.com/news/circular-economy-lessons-from-china-1.19593>.

3. Boulding is one of the core group of Western scholars who made decisive contributions to an understanding of the green shift, well before it had become global and well before it attained its present significance. Others would be Barry Commoner, Herman Daly, Allen Kneese, Robert Costanza and Robert Ayres. Their contributions will be reflected in the arguments presented in this book.

GEOPOLITICAL AND ENVIRONMENTAL LIMITS TO FOSSIL FUELS

Fossil fuels conferred enormous benefits on the Western world as it industrialized over the past 200 years. The transition to a carbon-based economy liberated countries from age-old Malthusian constraints. For a select group of countries representing a small slice of the global population, burning fossil fuels enabled an era of explosive growth, ushering in dramatic improvements in productivity, income, wealth and standards of living.

Now the ‘peripheral’ countries that missed out on this initial industrial revolution are clamouring to have their time in the sun. For much of the past 20 years, China and India have led the charge in claiming the benefits of fossil fuels for the rest of the world, mainly through the use of coal. Recently, however, they have begun to moderate their approach. As their use of fossil fuels brushes up against geopolitical and environmental limits, they have been forced to invest seriously in alternatives. In doing so, they have put themselves at the vanguard of a planetary transition that in a few short decades could eliminate the use of fossil fuels altogether and transform the global industrial system.

In the United States and Europe, the benefits of renewable energy are predominantly seen as environmental. Energy from the wind and sun can indeed offset the need to burn fossil fuels, helping to mitigate climate change. In China and India, however, renewable energy is viewed as serving multiple purposes. The relatively rapid transition away from fossil fuels that is under way in both countries is driven not so much by concerns about climate change as by the economic benefits renewable energy sources are perceived as conveying.

Indeed, while the economic benefits of renewables can be attractive to advanced economies such as Germany or Japan (both of which are starting to move away from fossil fuels), the advantages for emerging industrial giants are overwhelming. For India and China, an economic trajectory based on fossil fuels could spell catastrophe, as efforts to secure enough for their immense populations ratchet up geopolitical tensions. By contrast, an economy based on renewables and the circulation of resources would promote domestic manufacturing and improve local environmental quality by, for example, reducing urban smog, as well as enhancing resource and energy security. The greening economy would offer supplies of energy and resources that would renew themselves, at costs that diminish because of the manufacturing learning curves involved.

The arguments advanced against renewable sources of energy – that they can be expensive, intermittent, or not sufficiently concentrated – are easily rebutted. And while renewables' opponents are legion, they are motivated more by interest in preserving the *status quo* of fossil fuels and nuclear energy than by worries that wind turbines or solar farms will blot the landscape. We will deal with – and demolish – these objections as the argument unfolds.

In any case, those wishing to halt the expansion of renewables are unlikely to triumph over simple economics. The renewable energy revolution is not being driven by a tax on carbon emissions or subsidies for clean energy; it is in fact being driven by reductions in the costs of manufacturing that will soon make it more cost-effective to generate power from water, wind and the sun than from burning coal. Likewise the costs of battery energy storage are falling, as are costs of operating electric vehicles – all part of the current disruption to the power, energy distribution, transport and other industries associated with the green shift. Already in 2013 these trends were so striking that the investment bank UBS was advising its clients to become active in what it called 'the unsubsidised solar revolution' – meaning that the renewables revolution was passing the point where subsidies were needed, and would henceforth be driven by cost reductions making it more competitive than power generated from fossil fuels. The trends have only grown stronger since this report appeared.⁴

Countries like China and India are discovering that they can build their way to energy security by investing in the industrial capacity needed to produce wind turbines, solar cells and other sources of renewable energy – at scale. As China and India throw their economic weight into the renewables industrial revolution, they are triggering a global chain reaction (via a process known as 'circular and cumulative causation') that promises to drive diffusion of the alternatives until they have completely superseded their fossil fuel antecedents. With solar in the lead, we can anticipate a wholesale transformation of energy by 2030 or sooner. Likewise we can anticipate that the dependence on extracting resources from the earth, and the build-up of industrial wastes, will give way to a circular flow of resources in countries that take the necessary measures (as China is demonstrating). These are the directions in which our global industrial system is now evolving.

4. See UBS Investment Research, 'The unsubsidised solar revolution', 15 January 2013. For a full copy of the report, see: <http://www.qualenergia.it/sites/default/files/articolodoc/UBS.pdf>.

The evolutionary dynamics of this shift are driven not by simple product or technology substitution, as conceived by mainstream economics with its focus on costs, taxes and substitution, but by processes of technoeconomic supersession as captured in Schumpeterian analysis. What is really driving the change is the creative destruction wrought by one group of firms at the expense of an established group as industrial infrastructures are transformed and new business models oust the old. The green shift is the latest episode of this process of Schumpeterian industrial evolution.⁵

There is indeed a wave of initiatives emerging that is transforming our industrial system, disrupting the established patterns in one industry after another – in power generation, in resources regeneration, in food production, in transport (e.g., electric vehicles, high speed rail) and in the finance that is driving all these disruptions. Established companies in the fossil fuel industries, the power generation business, the transport business and agribusiness are all reeling from the new challenges that come one on top of another. And what is so striking is that it is manufacturing companies that are leading the disruption – placing manufacturing once again at the centre of industrial expansion and wealth generation, this time as the driver of the green shift.

Unlike mining, drilling or extraction, manufacturing activities benefit from learning curves that make production increasingly efficient – and cheaper. Investments in renewable energy drive down the cost of their production, expanding the market for their adoption and making further investment more attractive. The cost reductions are significant. From 2009 to 2014, these mechanisms drove down the cost of solar photovoltaic energy by 80 per cent and reduced the cost of land-based wind power by 60 per cent, according to Lazard's Power, Energy and Infrastructure Group.⁶

The impact of the rapid uptake in renewable energy and the shift to a Circular Economy can be expected to have consequences as profound as those unleashed by the Industrial Revolution. In the eighteenth century, the economies of Europe and

5. See the classic descriptions of capitalist industrial dynamics provided by Schumpeter starting with his *Theory of Economic Development* (1912) or in its academic exposition (Schumpeter 1928) and proceeding through *Capitalism, Socialism and Democracy* (1947) which introduced the concept of creative destruction, and culminating in his numerous contributions to understanding processes of entrepreneurship. The challenge is to link these classic descriptions of capitalist industrial dynamics to the green shift that is currently under way.

6. See the regular reports from New York bank Lazard on leveled costs of energy, available at: <https://www.lazard.com/perspective/levelized-cost-of-energy-analysis-90/>.

the United States initiated the transition to an energy system based on fossil fuels as well as an extensive resource acquisition system based on colonies without fully understanding what was happening and what the consequences might be. This time, we can see the way things are changing and prepare for the implications.

Despite prognoses of ecological catastrophe, the outlook is not all gloom and doom. On the contrary the current initiatives to green the industrial system are creating the biggest business opportunities of the twenty-first century. Efforts to reduce carbon dioxide emissions may not after all be the prime driver of the renewable energy revolution. It is very possible that without the green shift that is occurring in China and India, efforts to minimize the impact of climate change would never succeed. If the world is to avoid the worst dangers of a warming planet, we may have China and India to thank for it.

CHINA'S ENERGY STRATEGIES

There are many ways of demonstrating how China is leaping ahead in renewables and circular economy initiatives. One of the simplest and most graphic of the visualizations is the comparative build-up of capacity in renewables, emphasizing the role being played by generating sources from water (hydro), wind and sun – or WWS sources. This is shown in Figure 1.1.⁷

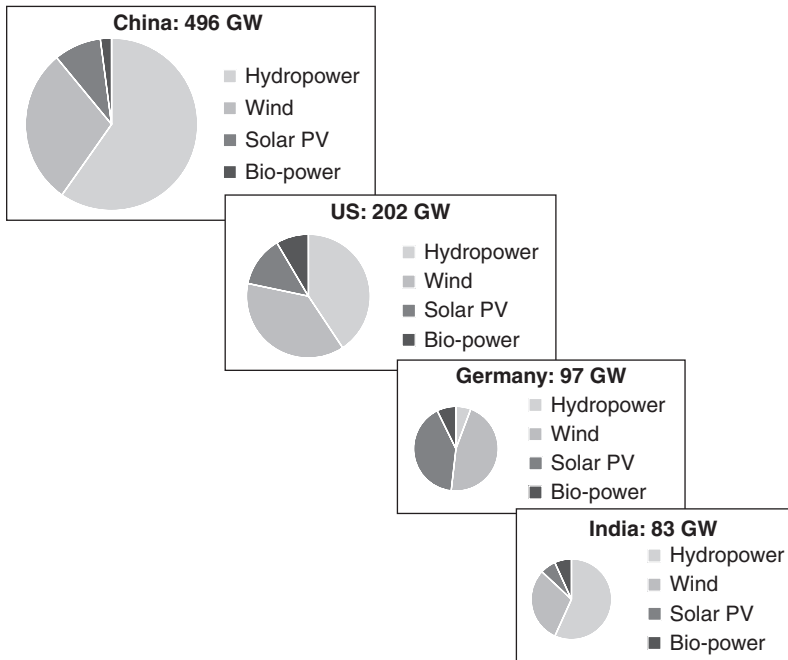
When we focus just on solar photovoltaic power, the impact that China is having is even more striking. Figure 1.2 shows how China has rapidly moved to world leadership in PV cell manufacturing, starting from virtually nothing in the year 2000. This is evidence of a healthy industry and one where Chinese firms now exercise considerable influence on technological trends.⁸

It is striking to consider the direct comparison between China and an advanced set of countries such as the EU, in terms of investment in clean energy systems, where it is clear that China has now caught up with and overtaken the EU. Drawing on data from BNEF and Xinhuanet, the London-based consultancy *E3G* reveals the widening gap in the chart (see Figure 1.3) that shows just how far China has come in consolidating its position in the lead in the shift to a green economy. China invested over \$100 billion in clean energy in 2015, compared with just \$40 billion for the EU – outranking the EU 2.5 times.

7. See my updated analysis of trends in China's renewable energy revolution at: <http://apjjf.org/2016/17/Mathews.html>.

8. See Green (2016) for a discussion of the state of the PV industry and the influence of China, and Zhang and White (2016) for further details of China's rise to become the world leader in solar PV manufacturing.

FIGURE 1.1. China's generation capacity from WWS sources compared with other leading industrial countries, 2015.



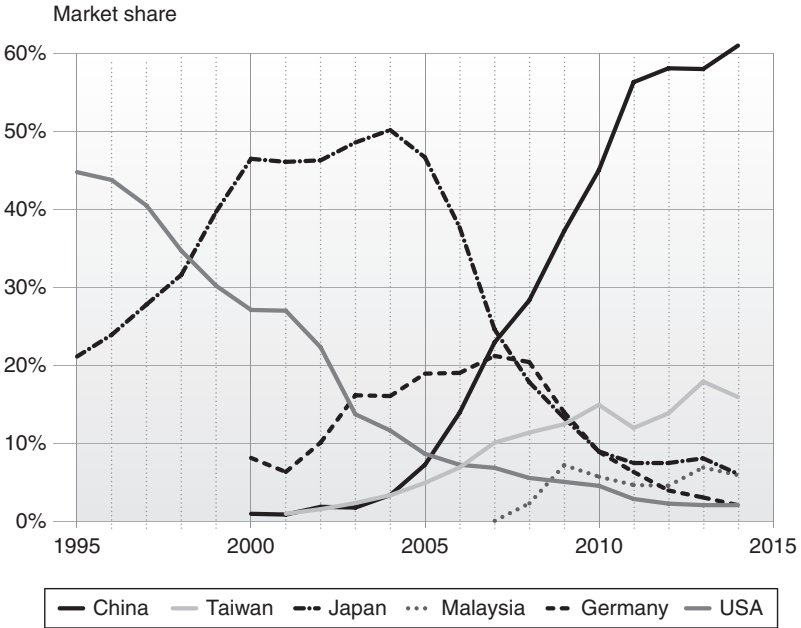
SOURCE: Mathews and Tan 2015.

The tipping point, where China's investment overtook that of the EU, came in 2013, and has strengthened each year since then – while EU investment has actually declined. Per capita investment by China also overtook that of the EU in 2015, while China's investment in clean energy as a proportion of its GDP has already reached 1 per cent, compared with less than 0.3 per cent for the EU.⁹

The *E3G* authors comment that this is a poor way for the EU to approach the biggest business challenge of the twenty-first century, by cutting back on its expenditure and handing China clear leadership. This in turn can be expected to translate into dominance of next generation product development,

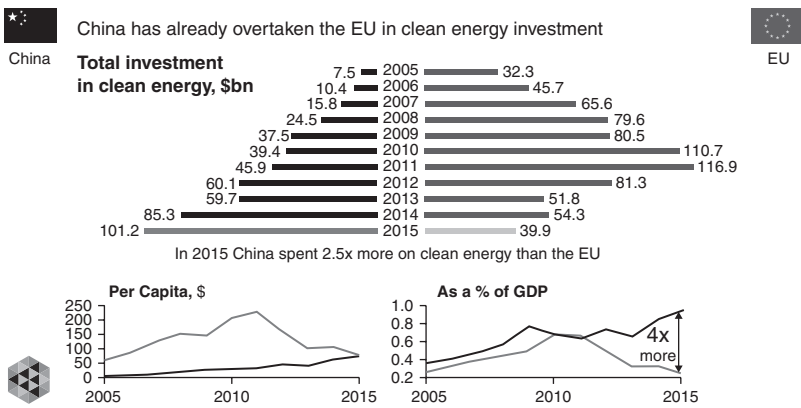
9. See the *E3G* report 'Pulling ahead on clean technology: China's 13th Five Year Plan challenges Europe's low carbon competitiveness', by Shinwei Ng, Nick Mabey and Jonathan Gaventa (March 2016), available at: https://www.e3g.org/docs/E3G_Report_on_Chinas_13th_5_Year_Plan.pdf.

FIGURE 1.2. Transformation of PV cell manufacturing over the past 20 years.

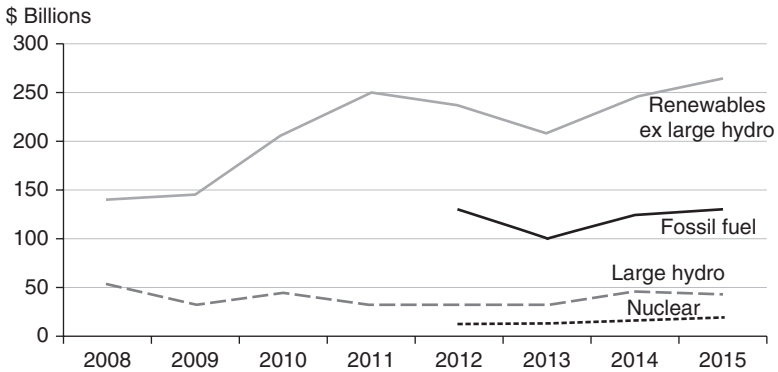


SOURCE: *PV Magazine*, June 2016.

FIGURE 1.3. Clean energy investment, China vs. EU, 2005–2015.



SOURCE: E3G.

FIGURE 1.4. Global investment in power capacity, 2008–2015.

SOURCE: UNEP/Frankfurt School of Finance and Management.

next generation patenting and next generation standards setting, all fruits of expanded R&D spending.

The dominance of wind and solar power in this global green transition is also striking. Figure 1.4 makes the point strongly, revealing how investment in wind and solar is racing ahead of all other investments in electric power capacity, exceeding \$250 billion per year. By contrast, investment in thermal (coal burning) power generation languishes at around \$130 billion per year, large hydro at around \$50 billion, and nuclear is still a long way behind, at around \$10 billion. Investment data tell us where a complex system is headed in the future – and these data could not be clearer about the direction of evolution of the world’s electric power system.

ANTHROPOCENE CHOICES: MORAL VS. ECONOMIC

We live in the era of the *Anthropocene* – the geological era where human activity is viewed as the most significant force shaping the planetary environment. Paul Crutzen, the joint founder of the idea, dates the Anthropocene from the beginnings of the industrial era in the early eighteenth century; others date it from the end of World War II, and specifically from the detonation of the world’s first atomic explosion, at Alamogordo in New Mexico in 1945.¹⁰

10. See Crutzen’s article in *Nature* (2002), ‘The geology of mankind’; for the later dating of the onset of the Anthropocene, see Steffen et al. (2015).

Depending on the date chosen, we are witnessing either an epoch of fossil fuel usage or an acceleration of the use of fossil fuels and human-sourced power such as nuclear power since the 1950s.

This world that we (our species, *Homo sapiens*) have created is a dynamic entity that is subject to constant change and evolutionary pressures. I build on the arguments of Yuval N. Harari that what drives our evolution now is not so much biological processes as technological and economic choices that are occurring much faster – hundreds of times faster.¹¹ And the biggest set of changes under way are those associated with the greening of the technoeconomic system we have created called capitalism.

There are two quite distinct approaches to comprehending the changes under way in the global industrial system that is now encompassing the planet as a whole. There is the approach that takes the achievements for granted and looks to the means available for curbing carbon emissions that are widely understood to be responsible for triggering climate change. This is the approach that is embodied in the UN-sponsored Kyoto process that looks to convince countries that it is in their long-term interests to decarbonize their economies – a process that culminated in the series of ‘intended nationally determined contributions’ (INDCs) for reducing carbon emissions proposed and adopted by countries at the Paris Conference of the Parties meeting in December 2015. In the end this is viewed as a decision point in our industrial civilization that is framed as a *moral choice*. It is not ‘Socialism or barbarism’ this time but ‘Decarbonization or heat death’ that appears to define the choice.

But there is a quite different approach that looks at the real trends away from the Western-centric industrial manufacturing system and the shift towards a Sinocentric system (China as the world’s factory) as the dominant trend, with China’s (followed by India’s) ramping up of energy and resource systems needed to power these immense manufacturing engines being created. As they scale up their systems, China (and India) are discovering limits, not so much in terms of energy (oil, coal) or resource limits but in terms of geopolitical limits. Put bluntly, this is to view the world in terms of their concern over triggering wars, revolutions or terror in response to their striding across the world in search of energy and material resources and securing them through their own companies’ activities.

As they discover the limits to scaling up the traditional Western ‘business as usual’ system, these emerging countries are discovering the advantages of greening – in the sense of switching away from fossil fuels towards renewable

11. See Harari (2014). I discuss his approach to our species’ history further in Chapter 2.

energies, and away from linear resource flows to resource regeneration via circular flows. China in particular has embraced these green growth strategies with determination, in terms of greening its energy system, its resource regeneration system and the financial system that is feeding both – even as it continues with its black systems based on fossil fuels and linear resource throughput. This approach sees greening not so much as a moral imperative but instead as an *economic imperative* – as the only feasible means for China and India to maintain their vast industrialization efforts without triggering wars, revolutions or terror that would undo all their aspirations for modernization.

The really interesting feature of this dichotomy, of two quite different sets of choices, is that as China and India green their industry and financial systems, they effectively decarbonize their systems as well and achieve the goals that have been sought by those pursuing the moral imperative of change. China (and India) discover that in order to make their industrial initiatives manageable from a geopolitical standpoint, they must bring them under control from an environmental and ecological standpoint. They discover through green growth that economy and ecology become compatible.

ECOMODERNIZATION STRATEGIES

Ecomodernization is the generic term for the processes that are under way. The term refers to a way of reducing the impact that our industrializing processes have on our planet, by decoupling economic processes from their ‘natural’ moorings. Ecomodernization refers to a strategy, a shift in direction. It is not a ‘model’ where a given input produces a given output. In the ecomodernization story the production of food, of water, of resources and of energy are all seen to be processes that are placing increasing strain on the earth, but as they become progressively decoupled from their natural settings, they allow us (*Homo sapiens*) to eliminate or reduce the negative impact imposed by our industrial processes.¹²

There is under way a series of technoeconomic transitions that all share the feature that they involve in one way or another the disruption of existing patterns in the production of food, water, energy and resource regeneration in favour of IT-enhanced ‘smart systems’ that are driving down costs and facilitating

12. On ecomodernization see contributions such as Spaargaren and Mol 1992; or Mol 2006. The most recent and comprehensive contribution to this genre is *The Ecomodernist Manifesto*, produced by the Breakthrough Institute (2015). I will be engaging with this text throughout the chapters to come.

widespread diffusion of these eco-modern systems. We are not dealing here with an autonomous process with a technological dynamic of its own so much as a process driven by the expansion of markets and consequent cost reductions that typically characterize the rise of new mass production industries ousting the old. The difference this time is that it is the industrialization of China and India that is driving the cost reductions as they diffuse around the world through capitalist competition.

Ecomodernists such as the authors of the *Ecomodernist Manifesto* are correct in pointing to these processes as being associated with the dominance of cities (urbanization) and their more rapid greening than other parts of the world. But what they fail to point out is that China and India are emerging as the drivers of the process, based on their quest for green modernization. Processes for producing food, water, energy and resources can all be discerned as reducing the human footprint, concentrating activities into smaller areas (or where large land areas are required, in ways that do not interfere with ongoing activities), and generally decoupling human settlements from their natural moorings. It is in China and India that these processes are manifested most clearly.

So – we are on the cusp of the greatest transformation of our global industrial system, a transformation that will enable us to live with natural processes and ecological balance in a way that has not been possible in previous (fossil-fuelled) phases of our industrial evolution. The goal of returning over half of the earth to rewilding processes (as enunciated by Harvard biologist E.O. Wilson in his new book *Half Earth*) is in sight of being achieved; the bigger and more ambitious the goal, the more likelihood of its being achieved.¹³

Are China and India aiming for such lofty goals? We do not know. They are hardly going to reveal explicitly their deep strategic goals. But we do know that in pursuit of their eminently sensible goals of integrating themselves into the capitalist-industrialist world system, they are having to do so through managing their industrial processes – their energy systems, resource regeneration systems, food production systems – in ways that were never an issue for the Western powers as they industrialized. We have moved into a completely new era in our species' industrial evolution – an evolution that involves cultural and economic initiatives rather than the genetic/biological changes that dictated our earlier evolution. And the latest of these strategic shifts is the shift towards

13. On rewilding, see Wilson (2016). Goals of nature conservation and biodiversity protection now loom large; see F. Mathews (2016) for a philosophical investigation.

greener industries, products and manufacturing processes, where China and India are no longer spectators but key players helping to drive the process. What we see emerging is a completely new sociotechnical industrial system that promises to reconcile the economy with its ecological setting.

WHEN CERES MEETS GAIA

In Greek mythology the goddess *Gaia* is the great mother of all: the primal Greek Mother Goddess; creator and giver of birth to the Earth. She has famously been adopted by James Lovelock as the name for his biological Earth stabilizing system, elaborated on by Lovelock and Margulis in numerous books and influential articles.¹⁴ Gaia is both a dynamic entity and one that pre-exists: there was a Gaia before the species *Homo sapiens* rose to prominence, and there is sure to be a Gaia after we have lived our span as a civilization on the earth. As an industrial civilization we are seeking to adapt to Gaia and finding a way to accommodate to her demands. In the first two to three hundred years of our industrial era we have learnt how hard this is going to be. But we take heart from the fact that our early excursions into energy and resource systems have not as yet actually killed off Gaia, and we are finding ways through renewable energy and the recirculation and regeneration of resources to minimize our impact.

In the interests of keeping our eyes focused on the goal, let us agree to call the technoeconomic system that we as a species are constructing as CERES (denoting a Circular Economy and Renewable Energy System), as counterpart to the wildness of Gaia.¹⁵ *Ceres*, who in the Roman pantheon is the goddess of agriculture and fertility, is an appropriate reference point for our goal of creating a self-sustaining technoeconomic system that can leave Gaia to get on with things, without our trying to replace her. Ceres is the Roman counterpart to the Greek goddess Demeter. Ceres is ideal as a name for our emerging

14. See Lovelock's early exposition, *The Ages of Gaia: A Biography of Our Living Planet* (1995) and more recent pessimistic accounts *The Vanishing Face of Gaia: A Final Warning* (2010) and most recently *A Hard Ride to the Future* (2015); for the original scientific statement in the journal *Tellus*, see Lovelock and Margulis (1974).

15. In my 2015 book on *Greening of Capitalism* I coined the acronym CERES for a Circular Economy and Renewable Energy System – and I would like to elaborate on this in the present text, and defend it as a meaningful contribution to the debate over the transition that is under way.

sustainable technoeconomy because of her linkage with notions of fertility, childbearing and nurturance.¹⁶ These female attributes are more appropriate to a sustainable technology than the male attributes of strength, heat, perseverance and hardness, associated with the male god *Hephaestus* (metallurgy, fire, and craftsmen – along with volcanoes), or his Latin equivalent, *Vulcan*.

Vulcan and Hephaestus are the gods that have led the fossil-fuelled world close to the abyss. We now need a more caring, motherly and fertile character to depict our emergent technoeconomy, and Ceres is the appropriate figure (along with her acronym that captures both Circular Economy and Renewable Energy). Of course there is a wild side to these mythologies of fertility; many of the pantheons depict goddesses like Ceres as having a dangerous element, aroused to fury if not treated properly. The Hindu female Matrikas ('seven mothers') certainly capture this wild side of the mythologies of fertility.¹⁷

The British scientist James Lovelock has done the world an enormous service in his formulating the theory of a 'living earth' named Gaia, that is, one where life self-regulates itself and the planet by keeping the atmospheric environment more or less constant, and likewise the oceans. But Lovelock in his most recent writings (he is now in his 90s) comes across as decidedly pessimistic. What I am proposing in this book is a way in which Gaia (a product of the processes of the earth) can be complemented by Ceres (our own creation of a renewable energy and Circular Economy system). Can these two concepts of how the earth works, represented by two powerful deities, be reconciled? Lovelock has become very pessimistic, asserting that Gaia will look after herself, and that if we survive at all it is likely to be as a greatly diminished industrial civilization, numbering no more than 1 billion people. In this book I argue why I believe this prognosis to be mistaken. As industrialization proceeds at a global scale, I maintain that the changes

16. I first came across CERES as the inspired name for an eco-park in inner Melbourne, where it stands for Centre for Education and Research in Environmental Strategies (CERES); its website can be found here: https://en.wikipedia.org/wiki/CERES_Community_Environment_Park. I would hope that the people who now run Ceres in Melbourne would approve of my use of the name for a broader purpose, namely as a technoeconomic system (involving a Circular Economy and Renewable Energies) that is compatible with Gaia.

17. In most early references, the Matrikas are described as having inauspicious qualities and often described as dangerous. They come to play a protective role in later mythology, although some of their inauspicious and wild characteristics still persist in these accounts. Thus, they represent the prodigiously fecund aspect of nature as well as its destructive force aspect.

that ‘we’ are driving, as a species, and now encompassing moves to green the economy in China and to some extent in India, in the form of green growth strategies, represent a viable way forward.¹⁸ They give us a chance of reconciling economy with ecology – or Ceres with Gaia.

OUTLINE OF CHAPTERS

The book is structured as follows. Part I canvasses the issues involved in the global green shift, starting with an overview of the major transitions that have occurred since a group of countries industrialized by discovering how they could extract power from fossil fuels. Chapter 2 traces this story through the original Industrial Revolution, which sparked the Great Divergence between West and East; its Great Acceleration during the post-world war II era; and now the Great Convergence as China, India and other countries look to catch up with the erstwhile leaders. For the reasons canvassed above, they find they cannot do so by emulating the Western model, and are perforce having to invent a new green growth model, and one that promises to be the most fundamental transition of all – the next Great Transformation. Chapter 3 introduces the main theoretical frameworks to be used, focusing on the concept of ecomodernization and how it depends for its success on a decoupling between growth in physical activities and growth in income. Chapter 4 brings the focus back to technoeconomic transitions, of which the current Green Shift may be characterized as a sixth wave fulfilling the most recent IT-driven fifth wave but as applied to energy and resources and food production. The story progresses in Chapter 5 with an outline of how China, India et al. are benefiting from their adoption of green growth strategies, and how they are blazing a trail to be followed by other industrializing countries. Chapter 6 discusses the role of finance – serious finance, created by banks and financial institutions in the form of green bonds targeted at institutional investors, and capable of raising the trillions of dollars that are going to be needed for the Green Shift to be successful. Chapter 7 then returns to the issue of developing countries and whether they can energize their development by becoming early protagonists of the green shift, emulating the China model.

18. In his most recent musings, on a future with robotics, Lovelock is more relaxed about climate change; see his interview with *The Guardian*, at: <https://www.theguardian.com/environment/2016/sep/30/james-lovelock-interview-by-end-of-century-robots-will-have-taken-over>. I am dealing with his arguments as they have been articulated over the past two decades.

This theme is extended in Chapter 8, which introduces the important concept of local content requirements as being key to building of new green industries, and how this brings the world climate system into potential conflict with the world trade system – and offers a means of reconciliation. The final chapter in Part I rounds out the set of issues by bringing in the decline of fossil fuels. Much of the book is devoted to the rise of new energy and resources industries – but the counterpart is the decline of the old fossil fuel based industries. They are now facing a prolonged phase-out – and one that needs to be executed in a socially responsible manner.

Part II canvasses the processes of the green shift in greater detail, starting in Chapter 10 with the fundamental driver of population, which is widely expected to peak at around 9 billion people before mid-century, as foreseen by the all-important theory of the demographic transition. This peaking is argued to be the key to success of all the other greening strategies. In successive chapters we then discuss the major determinants of the green shift, namely energy, resources, water and food and the character of the sixth wave innovations that are emerging in each of these sectors. Chapter 11 canvasses the most important features of the green shift involved in the energy transition, with a focus on the likely choice of renewables over fossil fuels and nuclear power. The discussion moves to a detailed examination of the role of renewables in enhancing energy security, which as argued in Chapter 12 should be viewed as their major feature (rather than their contingent contribution to reducing carbon levels), while Chapter 13 provides a detailed rebuttal of many of the myths raised to discredit renewables, particularly the myth of vast areas of land needed by wind and solar power (the myth of ‘Renewistan’).

Chapter 14 then takes the story forward to resources, where a parallel argument is developed that sees countries like China and India enhancing their resource security by building circular flows of materials based on closing industrial loops, in the pattern of the Circular Economy. Chapter 15 extends these arguments to encompass water and food production, where ecomodernizing trends are viewed as making major breakthroughs in regeneration and production of water and food in urban settings – encompassing vegetables as well as artificial meat and dairy products that are cultured. This discussion is capped in Chapter 16 with the concept of hydrosolar gardening, which draws together food, water and energy production in a positive triple nexus of synergistic interactions. Chapter 17 brings all these sixth wave initiatives together to discuss their integration in the creation of new eco-cities, where again we find China in the lead with Sino–Singapore joint ventures creating

new eco-cities in Suzhou, in Tianjin and in Guangzhou. Others are likely to follow – sparking emulation around the world. The final chapter returns to the themes of ecomodernization and asks whether we as a civilization can create a circular economy and renewables-focused industrial system, named after the Latin goddess Ceres, to provide a fitting complement to the mother goddess who rules our living planet, Gaia. The book closes by asking: is there a way to reconcile ecology with economics, or Gaia with Ceres?