CHAPTER 9 Futuring: sustainment by design

Our previous chapters reviewed the variety of ways in which iron and steel-making have been implicated in ecologies of mind, matter and the social. We have endeavoured to show how the industry's production processes, materials and products have significantly contributed to changing 'natural' and made environments.

Iron and steel have become a part of the very fabric of our taken-for-granted world to the extent of obstructing our ability to critically reflect upon what exactly these materials have created or destroyed. The environmental history of steel-making confirms the truism that nothing is created without something being destroyed. The industry's and our future increasingly rest upon improving our ability to see what our actions make and unmake, and thereafter make informed choices. It is in this context that practical questions and ethical decisions have to be made about the environmental costs and benefits of steel-making and steel products. In the last instance, unless steel has sustaining ability, it has no ability to justify its future production.

1. Steel futures

This final chapter will look to the future, but obviously not with a crystal ball.

The future cannot be viewed as a vacant space simply waiting to be filled by projected visions as utopians and naive futurists would have it. Nor is it appropriate to view it as replete with problems of unsustainability that in time science and technology will be able to resolve. Certainly, the future cannot be deemed as a coming age of renewed spiritual enlightenment. Rather, we need to think of the future as being in large part filled by the ongoing agency of things created in the past. The world-scape is littered with the evidence of human attainments, but equally with the enormous accumulated detritus of human errors. Unavoidably, human interventions in the 'natural world' means that each generation inherits things to manage, wastelands to remediate and the ever growing challenge of striving to overcome the unsustainable.

Specifically, this chapter will address some of the factors that over-determine the agenda of advancing 'sustainment' within the steel industry. It will then take a philosophical turn, directed towards informing the practical. To start with, two of the most pressing and linked cultural and material problems of the present are considered — climate change and unsustainable development.

2. Climate change

To a limited degree, greenhouse gas (GHG) induced climate change is being addressed by science, technology and political policy. It has taken over a decade for the moderate Kyoto Protocol on climate change to become operational, and, as discussed in the previous chapter, the Protocol's greenhouse gas reduction target for industrialised nations of 5.2 percent is extremely modest. That this target was meant to be just a first move towards a reduction of 60% on current emission levels — the reduction that many of the world's leading climate scientists deem as needed — is almost totally ignored. Likewise, actions to assist newly industrialising nations to develop large-scale renewable energy technology infrastructure is just not happening.

Clearly, this is an issue of major concern to the steel industry. It would be disingenuous not to acknowledge energy efficiency gains, process improvements to reduce pollutants, work on embodied energy assessment and lifecycle analysis — all of which have been advanced by the informed sections of the industry. Yet these modest reforms are doing little in the face of major problems — not least because the industry is still dominated by the goal of increasing overall output. There seems to be almost no recognition of global warming and associated accelerated climate change as a fact.

Climate change demands two courses of action: mitigation (to reduce the levels and impacts of greenhouse gas emissions) and adaptation (to deal with living in a still rapidly changing climate). While the former is being explored (be it with great difficulty), the latter has hardly begun to be contemplated. Certainly, there is also a general failure to acknowledge that global warming and associated climate change are directly linked to the actions of producers and consumers: this, through the volume of natural resources appropriated, how these are treated, what is made from them and the kinds of lifestyles that are inextricably bound up with specific patterns of resource and energy usage.

Globally, the focal point of discussion on climate change has been based on the reports of the Intergovernmental Panel on Climate Change (IPCC).[1] The research and analysis on climate change is laden with a number of highly charged problems — the science of climate projection is very imprecise, not least because the rate and nature of the change is not altogether clear given that it is so dependent on human industrial, agricultural and domestic actions. Additionally, climate change has also significantly reduced the predictive value of historical data (rainfall, temperatures, etc for particular regions). Determining the appropriate extent of mitigation measures such as tree planting (to absorb carbon dioxide) is difficult because of the imprecision of the science of carbon sequestration. It is extremely hard to quantitatively correlate the relation between variations in ground vegetation, trees, soils and wetlands in the natural environment — what is clear is that different plant materials sequester carbon at different rates and over varied duration.[2] Demarcating between 'natural' and 'human induced' processes is also still problematic. In short, there is just not enough known about the behaviour of carbon and the 'carbon budget' of widely different ecologies. However, the effects of rapid industrialisation are far more evident, with China set to displace the USA as the world's largest emitter of greenhouse gases in the near future.

The problem is accumulative. Because of the length of life of gases in the atmosphere (which can be more than 200 years), today's climate is a product of emissions from the 19th and 20th centuries. So, even if the situation was to be stabilised soon via large and stringently applied emission reductions (which is extremely unlikely), climate change will still remain a factor for several hundred years. As the Third Report of the Intergovernmental Panel on Climate Change makes clear, this is not least because it takes a very long time (several centuries) for mean ocean temperatures to adjust (ocean temperatures are the critical control factor in climate behaviour).

Against this backdrop, one has to act on trends rather than exact science, acknowledging the enormous risk from the ever-upward accumulation of greenhouse gasses in the atmosphere. This suggests that there are enormous dangers in waiting for clear proof before taking decisive action.

Now to the other, and still totally neglected action in response to climate change — the need for adaptation.[3]

Subject to global location, the human population is faced with very significant geo-climatic changes, which have already commenced. On the negative side — drought, more frequent extreme weather events (especially floods and landslides), higher UV levels, a gradual expansion of tropical climate regions (accompanied by a spread of tropical, vector-borne diseases), increased desertification, higher wind speeds (resulting not only in more wind damage but the loss of a great deal of top soil), rising temperatures (with corresponding increases in heat-related deaths, forest and grass fires) and changes in the lifecycles of animals, insects and plants. Agricultural production and settlement will become impossible in some places. Because of these circumstances, it has been claimed that there are now 26 million environmental refugees, in contrast to 22 million from political conflict.

On the positive side — the climate in some parts of the world will improve — summers and winters will be warmer and agriculture will flourish.

There will be major problems to confront, mostly in countries least able to deal with them. The choice here will be between financial and humanitarian aid or abandonment of whole populations (a trend, if one looks to Africa, already started). Second, and far more dangerous to global security, will be the proliferation of climate change refugees. Having large numbers of people on the move from inhospitable conditions and divested of their cultural grounding (climate is as much a cultural as a biophysical determinate) will pose threats to political stability arising from contestation over resources and the limited ability of many existing population centres to absorb large numbers of people. Again, this trend has already been recognised and the drift has started. Moreover, military strategists have designated it as a likely source of future wars — a language and a global mapping of potential environmental conflicts already exist (with water as the most politically 'volatile' resource).[4]

Where does the steel industry fit into this picture? Certainly, it faces major technical challenges to achieve significant emissions reductions (which we have addressed already in other chapters). Adaptation poses an even more enormous challenge, and goes directly to the relation between built forms, the environment and climate change.

According to global geography, buildings of all types, both old and new, as well as infrastructure, will have to deal with either more heat, rain, wind, snow, hail or dust. They will need: more shade and external shelter; better management of their thermal mass; more insulation; greater ability to detain large volumes of storm water and discharge it at rates that do not exacerbate flash flooding; more durable landscaping; greater capability of withstanding wind speed and impact damage from hail and flying debris. Buildings that respond to this scenario will survive, but many won't. This situation will have profound structural design, construction and retrofitting implications. For example, standards will have to alter (again a fact just starting to be recognised by the International Standards Organisation). Construction methods, facade and roof engineering will have to change, as will external plumbing. Various forms of storm water retention will add cost to building design and construction. In some areas, glazing will need more shade and wind protection devices.

As the 21st century progresses, climate adaptation and emissions reduction will become inter-linked drivers of building design. One can expect to see very different domestic, commercial, industrial and institutional architecture starting to appear in the coming decades. Clearly, this will have important implications for steel products in the built environment — some will be rendered obsolete, but many new ones will be needed.

3. Unsustainable development

We should consider briefly the overall model of 'development,' within which the varied patterns of usage of steel were established. A contemporary picture is already clear.

Levels of material 'consumption' are growing as the global population increases and becomes ever more urbanised. The desire for 'sophisticated' consumer goods and ecologically unsupportable lifestyles is accelerating, not least among 'newly industrialising' nations. The flawed past of unsustainable late-modern/postmodern industrial nations still remains the model of the future for the 'newly industrialising.' What is lacking are alternative ideas, images and methods that enable poorer nations to leap from a pre-modern industrial (or dysfunctional) economy to a fully industrial one without replicating the error of the 'advanced', quantity-based postmodern economies. As yet, the idea of sustainment is still not contributing to the creation of economies that can improve the quality of life and environment, and make a path to the future. As time will tell, the notion of growth-based development, undergirding 'sustainable development', is incapable of solving the problems of uneven development and poverty.

These briefly outlined examples touch on a complexity that itself is a fraction of the complex problem of unsustainability.

Over two centuries of industrialisation, plant and animal species have been depleted and biodiversity reduced. Industrially produced toxic chemicals introduced into the environment by accident or intent, have transformed the biosphere over the last several hundred years.

With this situation, and all other examples of the unsustainable, we find a history of human-centred self-interests obscuring the ability to recognise that it is human values that are at the core of the problem of unsustainability. This condition cannot be overcome by an act of will of 'the enlightened'. Anthropocentrism is not something that is in addition to being human, but rather its essence. In this situation of non-transcendence, the idea of liberation is pointless. What is appropriate instead is accepting responsibility for what we are, and cultivating awareness of that for which responsibility has to be taken. Certainly the acceptance of this proposition should be regarded as an essential quality of leadership in almost every field of human endeavour.

Reactive measures such as quantifying pollutant discharges and monitoring bio-physical impacts can tell us plenty about the symptoms of the unsustainable, but little of fundamental causes. As discussed in the previous chapter, this kind of environmental reporting is the dominant approach of progressive organisations, including the more 'enlightened' steel companies.

From the positioned outlined, we need to ask a range of questions of steel, critically engage 'answers' and confront inscribed practices concerning: the *way* steel is made; *why* steel is used; *what* prefigures its use; *what* fixes the volume and form of products (including the technologies and social relations of production). The forcefully active and consciously back-grounded symbolic dimensions that determine how we perceive and act on the material require special attention. We have noted that in the past and present steel's iconic status (as product and industry) has been mobilised by individuals, organisations and nations. This is evident, commercially, in the images, design concepts, ideologies and technologies that underscore the market(ing) framing of its perception, use, valorisation and disposal. Things are never exactly as they seem.

As matter or as an object of perception, steel cannot simply be reduced to the output of processes of production. What 'it', and an ecology of steel, is, equally rests on a 'community of meaning' — with its ability to link products, images, cultures, knowledge, environments and experience. Without such 'commonweals' of shared sense and meaning, *our* world would simply fold into confusion and chaos.

The steel industry, in common with other industries, has more than an ecology and economy — it also has a social fabric. However, this fabric, and the community integral to it, is slipping away. To a large extent, technology has weakened the mutual dependence and trust formed by the dangers and hardship of labour; the skill and knowledge constituted and transferred in the workforce; the solidarity of the culture and the class created (and manifested) in times of industrial conflict or suffering. This, together with the continuity of traditions; sharing of pleasures; or a belief in a God, destiny or nation — frequently enabled attainments of mind and body to be reached, love to be unselfishly given and life to be sustained, this all completely against the odds. While there is much of this past that was appropriate to displace, there is also a great deal to conserve that goes by unrecognised. Such conservation should not merely be for historical interest but for contemporary — and futural — needs.

The community formed in adversity, in opposition to exploitation in the early part of the second industrial revolution was very different from the one sought to be created later by paternalistic employers attempting to artificially engineer community by the provision of housing and social structures to which all had to comply. Control of a workforce by authoritarian welfarism was epitomised by the rules and dependencies created by company housing estates — for instance, in the 19th century in England, by the Cadbury company (remembering that cocoa was a beverage deployed in alcohol abstinence campaigns) and in the 20th century, in the USA, by the railway rolling stock manufacturer, Pullman Palace Car Company of Chicago. One of the highest profile and most aggressive examples was Henry Ford's social project at Highland Park, Detroit. Here, in 1914, he set-up a 'sociology department' to administer a regime of surveillance and control of the moral behaviour of workers after his introduction of the $5 day (which was then double the industry rate).

4. Learning and defuturing

While a comprehensive confrontation with the reality of anthropocentrism, the complexity of unsustainability and the elaboration of a new sovereignty is well beyond the scope of this chapter and the project of this book, it is crucial to understanding the directive force of steel's past, present and future and all that can be captured by the idea of 'ecologies of steel'. In other words, 'the future of steel' has to be engaged within a planetary rather than in an industry context.

To a very significant extent, what we have been setting out to promote is a sensibility that is better equipped to think sustainment and act toward its advancement in very real ways. Learning what is unsustainable, that is — learning what takes futures away (what 'defutures') — is a prerequisite for advancing sustainment. Without this knowledge, there is no possibility of discovering what already sustains and what means of sustainment need to be created. This learning requires looking back to look forward, looking for future inscriptive forces in the afterlife of the past carrying forward into the future. Least these views are taken to be on the absolute margins consider a voice of the mainstream. These are comments made at the opening of a steel industry conference in Madrid by

Ian Christmas on his appointment as Secretary General of the International Iron and Steel Institute in late 1998. The context was his thoughts on 'major changes in steel.' Here is a little of what he said:

> I feel it would be fundamentally wrong to assume that the growing importance of environmental issues for the future of our industry will change. Indeed, I believe that the need to demonstrate the long-term sustain-ability of steel is fundamental to its survival. There is a trend in the world to believe that the consumption of intangibles such as services is good, while the use of tangibles using materials is bad. In future, the ability and willingness of our customers to continue to use steel to solve their problems will only be given provided we can demonstrate that steel has a sustainable future. It will be a fundamental requirement to operate and a criterion for the selection of materials.[5]

And then a few moments later:

> I feel sure that the most successful steel companies will be those that are able to demonstrate how their strategies for the development of their business are consistent with sustain-ability.

The actual implications of making the steel industry 'sustainable' are profound for industry in general. It requires making a very clear distinction between 'creating the ability to sustain' and 'sustaining the unsustainable'. For the steel industry to become a means towards sustainment, and thus for its wealth, viability and advancement to flow from serving this end, implies major reform and redirection.

The scale of the challenge and the trans-generational implications of sustainment need to be grasped. The agenda of sustainment requires a broadening of focus well beyond the remit of one's existing knowledge, practice or industry. Equally, it requires a facility to move from understanding 'the big picture' — the significance of anthropocentrism — and the detail of a specific context. In all our differences, we are only still at the very earliest moments of this massive, pressing and mostly unrecognised re-directional project, the fate of which still hangs in the balance.

It took human beings many thousands of years to create civilisation, explore and map the planet and establish the foundations of human knowledge; it took several hundred years to make a partly modern world on this planet; and it has taken several decades for a minority to realise the error of our auto-destructive mode of occupation (manifest not just in the ways we make, build and dwell, but also in the way all these activities are prefigured by the way we think and design).

The challenge of sustainment, as 'extended responsibility', is set against this backdrop. It centres not on our exercising a stewardship of 'the world' but rather a stewardship of our embodied (life roles) and disembodied (institutionalised) selves that recognises what needs to be made, conserved or unmade. The essential project of sustainment fundamentally confronts the anthropocentric essence of 'us' — the locus of the unsustainable. This anthropocentric quality of human being while not able to be transcended, can be instructed (taught and/or ordered) on the basis that 'self interest' has now become indivisible from responding to 'the interest of human and non-human others.' What we have now then is an 'extended responsibility of the self' which can act to open a future rather than defuture.

Having created conditions in which the future is no longer an assured 'event', our responsibility now extends to the making of time, which means acting to identify and destroy the things that take the future away (defuture).[6] This process of identification is one that begs to be learnt — in large part, it is an intellectual skill, which forms part of the 'discipline' of 'extended responsibility.' The entire project of this text has been informed by such thinking. The archaeology of the past that has been undertaken was not done as an historical, academic exercise, but as a practical one connected to 'the design of the future'.

It is in this setting of the significance of the (anthropocentric) self to the 'world' and of the past to the future, that *futures* of the steel industry are considered.

5. New technologies, materials and reactive development

The search for, and realisation of, technological advancement, has existed from the very birth of iron and steel-making. Improvements in the manufactured material, production technology, applications, the lowering of manufacturing costs and more recently, the reduction of negative environmental impacts, have all been drivers of change. We have seen how technological advancements can become liabilities. For instance, once coke was a celebrated breakthrough, then coke-making became a problem and now perhaps its days are numbered.

All sorts of technological possibilities are proffered as the future of the steel industry. Some of the more immediate and developed ones were commented upon in chapter six. There are others on the more distant horizon such as using plasma energy to smelt iron at the mine site so that iron rather than ore is shipped out. Laser furnaces and nuclear fusion are other contemplated technologies.

Certainly, one of the most basic lessons of the past is that no major technology should ever be introduced without a substantial accumulative impacts study, extremely comprehensive environmental management plan and a proper sign-off by an appropriately selected 'precautionary principle' biased community of judgement. Again, the cost in time and money of such an exercise would be high, but the economic and ecological costs of not doing could be immeasurably higher.

More immediately, as we shall soon see with a few examples, the logic of production technology, materials recovery, reuse and recycling all beg exploration beyond the bounds of current practice. In this context, we can also talk about new materials. Let's start here.

The creation of new steels, super-steels, ultra-high performance steels and the like is not only part of the research and development project of the industry, but, as we saw when looking at alchemy, represents a kind of thinking that is part of its culture and tradition. However, whole new areas of materials research are opened up by the imperative to advance sustainment by material 'sustainments'. At a basic level, materials interfacing begs much greater exploration — not least the need to easily separate, clean and design-out the contamination of EAF steel by tramp materials (the quality of steel produced directly links to the quality of scrap). Changing the status and perceived values of materials is also part of the agenda of extended responsibility — a program of cultural reclassification could for instance have an enormously positive materials conservation outcome. In this respect 'scrap' is an outdated and inappropriate naming which authors material neglect and misuse. Another ('jargon free') language is needed to communicate effectively to society at large the growing importance of material recovery and resource management — a term like 'secondary resources' goes some way towards this.

We live in a contradictory age in which the immaterial forces of information and high speed exchange of capital are overwhelming the significance of material forces in the popular imagination of most industrial/post-industrial nations. It is not that materials no longer count but, within the wider culture, they are becoming obscured from view and downgraded. Such an issue begs more recognition within steel industry. Cultural strategies need to be explored and developed to go well beyond the more familiar concerns of 'workplace cultural change' or 'marketing steel with a positive cultural image.'

6. Materials of invention and generic materials

Steel has been, and still is, a material of invention. Any one of its forms at any given moment can be taken as a material from which to invent (the example of tool steel examined in chapter four is a good illustration). As the market and environmental circumstances increasingly call for steel to be more 'sustainably' produced, and have more 'sustainable' qualities, and as the agenda of sustainment becomes more sophisticated, the pressure 'to invent' and innovate will increase. Additionally, steel will have to find ways to respond to increasing competition from other materials, especially high performance, but un-recyclable composites and exotic metals like magnesium (which, to date, is still produced in very small quantities — the estimate for 2004 is 5 million metric tons)[7]. Such materials are making inroads into steel's market share in the auto industry on the basis of reducing vehicle weight so as to reduce fuel consumption and thus greenhouse gas emissions.[8]

Alongside the unfolding contest of materials within particular industries, other changes are afoot. The very way we think about materials is starting to unravel. Rather than having fixed qualities, materials are now starting to be conceived of as infinitely variable, having the capacity to be made into whatever they are desired to be. Examples, some still experimental, include: programming of genetic data to create a genetically engineered biodegradable material with a precisely designed lifespan; the mass production of change-in-process custom-designed polymers; the manufacture of high impact, ultra-high temperature super-hard ceramics; and the creation of new kinds of composites that uniquely combine the qualities of quite different types materials.

These developments in the production of materials and the imperative of sustainment put on notice the notion of 'core business,' based on standard materials and the subordination of corporate direction exclusively to shareholder interests. Alongside 'business as usual' is the possibility of an alternative future for steel emerging out of the industry's ability to survive, reinvent itself and flourish on the back of contributing to advancing the conditions of sustainment. One possibility here may well be the rise of the 'inter-related products (IPs).'

7. A new model

The IPs concept (which is not being claimed as unique) is neither based on the privileging of a single material nor is it simply centred on product diversification, rather its takes the production of multiple products, or co-products, as an organisational principle.

A steel company thus becomes a maker and marketer of a range of inter-related products that cluster around steel-making, well beyond the status of 'by-product.' A product mix might be, for example: the existing range of standard steel products; new advanced alloy steels and products; reusable 'standard structural steel components'; the sale of energy; BF slag cement and slag cement products (like bricks and pavers); liquid and solid waste management and engineered soils. Clearly, such a concept runs against the current wisdom of sticking to 'core business' and is thus vulnerable to criticism from within the current economic paradigm. Certainly, the concept throws up many organisational issues and invites a great deal of investigation and creative innovation — driven by the many potential economic and environmental benefits.

Notwithstanding the challenge of numerous problems, and the need for a great deal of research, there is a possibility of reducing net steel production (the simplest method of reducing impacts), introducing supplementary products and making 'extended (producer) responsibility' the basis of: new income generation; a new industry identity (from steel-maker to a materials maker, manager and 'trading community'). Such as scenario would also change public perception of what the industry does economically, socially and materially.

In this model, steel could be manufactured by an automated continuous process with very low man hours per ton ratio, while at the same time retaining, or even extending, a workforce via the 'IPs sustainment value added products'. This links to extending the structural position of the steel industry in supporting the development of the social ecology of the immediate and extended community, while also establishing a whole new set of inter-industry, local government and NGO relations. Likewise, such an approach could contribute to solving immediate environmental problems of waste management and greenhouse gas reductions — not just by making less steel, but by increasing the utilisation of zero rated materials (that is those waste or by-products of steel making, like slag, that have their emissions credited to steel) and by maximising energy co-generation utilisation.

Modest trends towards this kind of organisation of production already exist. In Kalundburg, Denmark, for example, an oil refinery, a biotechnology company, a plasterboard manufacturer, a power-generator and a local authority have collectively created a micro-economy in which they trade energy and materials. For the steel industry, such co-operative structures could be mapped onto consolidations between corporations involved in competitor materials. The existing collaboration between steel corporations to create a 'light-weighted' steel car body to compete with the increase of plastics, aluminium and magnesium in the auto-industry is an example of this).[9] The type of structural change signposted needs not to be simply subordinated to economic imperatives, but, as indicated, be powered by the imperative of advancing sustainment, materially.

Of course, it is easy to find objections to such ideas. However, they beg to be tested against pragmatism based on: identifying opportunities; precisely defining problems; making critical choices; ability to deliver solutions; projecting likely consequences — all of this guided by located understandings of the biophysical, economic and cultural needs of sustainment. This adds up to a substantial change of direction that needs to be distinguished from the rhetoric of sustainability mobilised by those elements within the business community whose commitment to action does not go beyond 'sustaining the unsustainable.'

8. Design, redirective practice and time

The inclination towards 'sustaining the unsustainable' is the dominant direction of existing product, engineering, architectural and information design practices. As they are now, they lack transformative ability. It follows that the nature of these practices demands to be transformed so as to acquire the agency of sustain-*ability*. The kinds of things they need to know include:

〈 what of those designed things in their field of operation actually defuture and what products, services, knowledge, skills and practices have sustaining ability

〈 how that which is designed and made acts to defuture;

〈 how to read the inscriptive power of objects, processes and services to sustain or defuture;

〈 how to recognise that products, services and systems are always relationally connected and (and thus are process rather than a product);

〈 how to recover lost knowledge;

〈 how meaning is constituted, communicated and perceived; and how it can be reconfigured to totally transform material values and thus impacts.

This last point needs particular qualification. It is frequently assumed that sustainability automatically means material transformation, however, in many instances to change what something means transforms how it is viewed, valued and consequently how it is used. Impacts can increase or diminish according to shifts of meaning — that which was once waste becomes a resource, that which was neglected becomes cared for, that which was deemed to have a short life becomes long-lived. Changing meaning is thus a key means of sustainment.

Foregrounding the importance of changing meanings and creating 'redirective practices' reconnects with the proposition that the unsustainable is anthropocentrically located in 'us' — thus the need to engage values, desires and self-centred actions. However, this requires one additional and substantial qualification. The making of new meanings and the creation of redirective practices takes time — it takes time to make time, remembering that making the sustainable is a making of time. In the last instance, the bottom line is not economics but sustainment — the precondition for every modality of (biological and economic) exchange.

9. Design innovation and new ultra-standards

The UltraLight Steel Auto Body – Advanced Vehicle Concept (ULSAB-AVC), a project undertaken by over thirty world steel makers is an example of a design strategy that illustrates change in process, design-led innovation and a certain pragmatic engagement with sustainment.[10] Although such developments are directionally and incrementally positive, they are still very much within the remit of 'sustaining the unsustainable' and thus vulnerable to substantial criticism. While light-weighted car bodies can reduce fuel consumption, they do little to engage the major problem of the sheer number of cars on the planet — which is just about to dramatically increase — for example, China, one of member of the consortium, is moving into the global auto-industry in a big way. Additionally, there is the escalation of gridlock in most of the world's major (and many minor) cities — which itself generates many economic, social and environmental problems. Thus, the rapid growth of car ownership erases any gains in emission reduction from light-weighting even if it were to become the norms. So while the action partly mitigates the problem it does nothing to solve it.

A less problematic example of light-weighting is the way high performance steels (HPS) have allowed the design and construction of bridges requiring less material, less maintenance, having a longer life and lower cost.[11] Over fourteen such bridges have been built in the USA, which itself has generated a demand for more. There are still problems to confront with these structures, especially the relation between stressing, weight and wind. Equally, the function of a bridge within an entire transport infrastructure and the nature of that infrastructure itself, all invite interrogation.

Affirmatively, however, the use of high performance materials to reduce materials output is a positive example of how economic viability can be retained or extended, while production, and its associated environmental impacts, can be reduced. In many respects such thinking is not new, at the same time approaching it with knowledge of ecological interconnectedness adds the possibility of a whole new design and development process. There are also innovations — recalling earlier remarks on 'materials interface' and 'inter-related product and materials' — which suggest quite new uses and relations between materials. Current research into the use of high-performance fibre-reinforced polymer decks for steel bridges would be one example of this.

Another design strategy that has made a mark in both product design and architecture, especially in terms of steelwork fabrication, is 'design-for-disassembly' (DFD). The idea is to enable 'direct 'or 'adaptive' reuse by deploying either traditional fixing methods like bolting or new kinds of fasteners, so as to facilitate rapid disassembly with ease. DFD aims to deliver by design, a multi-life and/or multi-function building or a building with reusable system components that extend the life of material in use (which is a superior/lower impact outcome than materials recycling). The economic shift implied by DFD is from income based on the sale of materials to income from smart design services.

Such approaches change evaluative norms — both performatively and aesthetically. They change how capital investment is able to be viewed (capital cost, payback period and rate of return over time etc.) and in so doing increase the scope and importance of design tasks.

Other developments are possible. Neo-standardisation and ultra-standards that reflect a changing climate are design strategies with the potential sustainment.

Neo-standardisation is a possible trans-industry design project in which a comprehensive designed regime is developed, based on 'standardised reusable structural components' like: beams, girders, compression members (struts, columns), tension members (bars, tube, angle), connection plates, structural framing (purlins, girts). These would all be system-designed so as to lift prefabrication and design-for-disassembly (DFD) to another level of design. It could combine information management (e.g., information on 'building-life management' and component identification) with a highly systematised regime of standardised components and a DFD ethic to create the possibility of very flexible multi-life structures. This revisits and reinvents one of the founding principles of the second industrial age (an age which paradigmatically established the economic 'logic' of volume output by mass production) which was the design and manufacture of interchangeable of parts. The contemporary challenge is to enable the 'the designing of difference' with standard components. This requires highly tuned design skills, innovative design software and the rigorous development of a comprehensive range of components with industry agreements on new global standards for size and tolerance. The 'imperative of sustainment' needs to be the common value that makes the negotiation and collaboration possible.

Neo-standardisation opens the way to ultra-standards — standards for the design and manufacture of products accredited for multiple life applications. Clearly, there are technical research implications in setting metallurgical standards for the production of steel, components and structures able to deliver a required performance over extensive periods in changing conditions.

A much greater use of design concepts, services and management together with new services such as the recovery of reusable components (rather than just 'scrap'), their testing, certification, storage and resale — all of this can be viewed as potentially viable activity of a more sustainable steel industry in which 'extended responsibility' is a fundamental marketing base. Recycling is of course not rejected — the reverse: it has to be improved.

These kinds of product/service mixes would, of course, be linked to different pricing structures. A cost differential between production for reuse and for custom manufacture would need to be established and generally applied — products being rated on their sustainment value, on the basis of a multi-lifecycle assessment cycling, rather than just on a scrap recovery value.

10. Public perceptions and trust

As has been pointed out, a great deal of the rhetoric of sustainability folds into sustaining the unsustainable. While many actions undertaken in the name of sustainability are vulnerable to this criticism, there is a need to distinguish between actions taken in good faith, backed by a desire to reduce damage to the environment, and those that are mere 'green washing' — the cynical use of environmental gestures and rhetoric predicated on placating or deflecting criticism on poor environmental performance. Green washing is little more than a play of representational appearances. Like many industries, the steel industry has had its share of green washers. At the same time, the industry has often been confronted, especially in 'developed' economies, with having to deal with the large environmental signature of steel works — steel has consequently been fingered as one of industrial society's biggest polluters. Such characterisations have not emerged in the abstract, but usually against the backdrop of steel company whose environmental, social and economic presence looms large over a town or city.

For the more responsible companies, green washing based 'public relations' has given way to relations with the public that recognises environmental action for the common good. Public consultation, more adequate reporting and community partnerships have become essential measures to maintain the goodwill of both the public and the market. Investments have been made to lay foundations of trust upon which to build. Such action, which is still significantly undeveloped, is not only a reflection of change but essential for it.

While the public can perceive the steel industry as a problem, it is also seen by the populations of steel towns and cities as part of the fabric of their culture, community and local economy (with in many instances economic dependence being a significant factor). Without doubt, affirmative perceptions and community attachments are elemental to those social ecologies that need to be sustained. There is a major point to be made here, one that any good manager would know full well — winning the trust and support of the local community is an increasingly important corporate asset.

Industry leadership towards sustainment comes at a large cost; change is hard (especially in an epoch when the rhetoric of change has become exhausted, when change seems to be constant, and its direction is unclear, abstract or far distant). So said, change towards sustainment is essential — it is the primary 'essentialism of living now.' This means stopping what is known to be unambiguously harmful, it means knowing what should be done and finding out how to do it, it means making a fundamental effort to create new options, it means vision, hard thinking and courage, it means educating shareholders, management, workers and clients — all via a managed process of transition.

The norm of modernity has been for technology to lead change. However, as our whole project evidences in a variety of ways, sustainment, while able to be technically assisted, cannot arrive simply by technological means. It requires cultural transformations to establish, extend and inscribe those meanings, values, actions and attitudes so as to make sustainment culturally elemental, and thus something that permeates our education, occupation and recreation. All of these remarks are made to just set up one observation: to change the steel industry needs help, and potentially the most powerful and important source of that help is from its own communities. Leadership in this context is about asking not imposing. It's about honestly *saying what has to change and how change can come by constituting and supporting a community of change*.

In 'developed economies' the move to sustainment does mean a fall in the standard of living (judged according to current norms); it does mean the establishment of redistributive justice as a basis for world trade and it does mean significant alterations to lifestyle. This is the 'high cost.' The trade off, the gain to be created, the argument to be waged, is that the shift from a quantity economy to a quality (and far more sustainable) economy is able to bring about healthier populations, as well as happier and more meaningful ways of working and living.

11. Material and immaterial

One of the political and economic features of globalisation impinging on the steel industry is the growing division between the rising star of *clean immaterial economic activity* and dirty *material industries*. The former are becoming a major characteristic of advanced economies, while there is a geographic drift of the latter to the newly industrialising economies. But this contrast is over-stated. What needs to be considered is what exists between and articulates the two poles of the material and immaterial.

Immaterialisation (information, e-commerce, knowledge industries, software, financial services and so on) is not just a disengaged 'other' of the material, but a supplement to it. Furthermore, the immaterial is a means of prefiguring the transformation of the material. For instance, material reuse as a systematic and general practice, while depending on embodied material factors, cannot occur unless it is immaterially prefigured (i.e., designed). Here, the designing idea (as concept, value, knowledge, change strategy, communication or logistics) is what drives the change that can reduce the overall volume of material produced and/or extend the life of material in use. This affirms the point made much earlier in the text, that an 'ecology of mind' is relationally bonded to a material ecology. It follows that it is not possible to properly comprehend the 'nature' of a material unless it is viewed from the perspective of the environment from which (its) meaning and use comes and goes. More than this, a material is not simply a collection of atoms, it is also a moment of embodied time, be it of variable duration. All matter is temporal and finite, even when its 'life' is beyond our measure.

These comments point to the imperative to 'extend the life of materials in use by immaterial means.'

As implied, the meaning of a material can never be captured just by an exposition of its qualities and applications. Steel is no exception. A technocratic archaeology of its production cannot grasp its meaning adequately. No matter how much information is given, say on a material's forms, production, fixing methods, finishes or the products made from it, we learn very little. Would it be possible to comprehend a fine piece of architecture or an elegant object of engineering by just reciting the catalogue of materials and industrial process of its production? A recitation of the material composition of an object does not create a picture able to generate interest or concern. For this, we have to look elsewhere.

Immaterialisation then can be recast as the prefiguration (by knowledge and design) of forms of the material rather than its disappearance. The entire software industry is predicated on this proposition — software drives hardware, the hardware exists simply to support it and what it thereafter does. The material is in effect 'immaterialised' in order to be seen — we only see it via a screen of knowledge. One cannot 'see' iron or steel as such without the knowledge to recognise it. Analogously, the idea of 'sustainment' introduces a new knowledge that can transform how materials are seen and thought. It equally shifts how responsibilities for the material can be comprehended.

From a steel-maker's point of view, *information* can be used to determine material reuse. This could be extended to new models of material ownership. An immaterialisation strategy could, for example, be of considerable importance in architecture and civil engineering. A move could be made to sell *material use* rather than end product. This would mean a steel-maker would retain material ownership, *but* lease the material's use, as well as provide design and technical support for efficient use and maintenance of the material in its functional use — all this to ensure recovery for reuse. Such 'leasing-for-life-cycle' could fuse with and further extend the concept of 'extended producer responsibility' (often understood as product 'take back'); this could be implemented by legislation or by industry agreement within a broader notion of 'extended *responsibility'*.

In summary, the arguments and ideas in this chapter all strive to indicate that with thought and effort it would be possible to shift the centre of gravity of steel companies away from an existing mind set of 'core business,' conventional industry economics. Rather than lowering sights, what we have begun to conceptualise is an economy of much higher returns for investors, society and the industry itself; an economy that can substantially contribute to the sustainment of environments, communities and markets by remade organisational structures, production methods and immaterial strategies.

12. A China postscript

We have suggested that a "…a much greater use of design concepts, services and management together with new services such as the recovery of reusable components (rather than just 'scrap'), their testing, certification, storage and resale — all of this can be viewed as potentially viable activity of a more sustainable steel industry…"

To carry this suggestion forward it is worth looking back to discover what has already been learnt — to do this we once more look to China.

Mass production, a factory system and work forces of thousands were all elemental to Chinese economic activity well over two and a half thousand years ago.[12] And, as we registered in our first chapter, Donald Wagner's view was that 'China was the world's largest and most efficient iron industry until about 1700.' We also pointed out that China was making steel over 2000 years before 1700, and that the culture had acquired a great deal of metallurgical knowledge.

Methods of production were often documented in design manuals, many of which were not rediscovered until the mid 20th century.[13] These documents provide a great deal of information on a key principle of interest to us — the principle of modularity. It is in fact at the very core of Chinese culture and was the basis of its written script. Building, pottery, armies, artworks, printing, bronze casting, and much more, were organised on this principle.

One of the manuals with particular relevance to the contemporary imperative for sustainable construction was the *Yingzao Fashi.*

This famous and influential manual was written in 1091, with a second edition in 1103 (no evidence of the first edition still exists). It was a design and technical manual of standards for the Master of Works, which was a section in the Ministry of Works, the government department responsible for the construction of palaces, temples, barracks, government buildings, moats, gardens, bridges and boats.[14] It was produced to deal with the massive expansion of building development in the first 100 years of the Sun Dynasty.

The second edition the *Yingzao Fashi* addressed the ordering of materials, building design, construction details for all building types including the detailing of stonework, carpentry and joinery, wood carving, roofing, plastering and finishes. One of the key features of the manual was it use of a modular standard of measurement (a *fen*) that in many ways prefigured systems building.[15] What is remarkable is the way the modular design methods allowed for a new building to employ components taken from the disassembly of an old building of a different scale and use.[16] In modern terms, what it provided were instructions for adaptive reuse. While having enormous status as a document in Chinese architectural history, the significance of the *Yingzao Fashi* to contemporary design practice, in and beyond architecture, has not yet been comprehended.

Read from the perspective of today's imperatives, it provided instruction on: design for the conservation of materials; waste elimination; design for disassembly and movable buildings; interchangeable components; and, above all, the value of a design-based tradition of construction standards.

One can contrast this ancient thinking with today's, such as the contemporary contradiction of attempting to load 'environmental performance' onto individually expressive and aesthetically overcooked buildings that often have a restricted design-life. Rather than demonstrating 'creativity' this design disposition displays a limited imagination which reduces 'the designed' to technology and mere appearance. The search for 'another imagination' is hardly yet a glimmer on the distant horizon.

During the second half of the 20th century, China moved from being a very minor steel-maker to the world's largest producer.[17] The opening of the 21st Century heralded China's second coming as a globally dominant industrial force. This is not just based on sheer quantity of industrial output, but also on rapid improvement of quality. The big issue in this situation is not so much, whether the position of dominance will come to pass but rather, the model of leadership that gets established.

The volume of China's steel production is being driven by domestic demand from its construction industry trying to meet the needs of rapid urbanisation and from its manufacturing sector (these two markets represent over three quarters of China's total domestic steel consumption). However, China is still importing steel because it is unable meet the highest quality requirement for certain sectors of the economy (in particular, the fast growing auto industry and to a lesser extent, the electrical appliance industry).[18] To rectify this, a major investment and technology upgrade program has been introduced. On this count, China's development disposition is unquestionably extremely problematic. All the signs are that the development vision of 'catch-up' is still driving the national economy — a vision based on the unsustainable economic and cultural history of modernity. This backward looking vision, resting on an outmoded image of 'progress', is linked also to political and cultural devaluation, as well as erasure of, traditions of the recent and distant past.

As we have argued, leadership in the unfolding epoch cannot be predicated upon extending the current paradigm which inscribes the error of the unsustainable. It has to move to the next one — the paradigm of 'sustainment', that is nevertheless fully aware of the problems of paternalism, neo-colonialism, double standards, but is committed to the practical necessity of redistributive justice. On this count, there is more to learn from China's past than its present.

13. A last word on sustainment

Throughout this book, three aims have dominated: first, turning the eyes and minds of the steel industry outwards towards the historical, futural and relational complexity of what we have called the ecologies of steel; second, redirecting designers', engineers' and architects' understanding of the steel industry and its sustaining potential; and finally, showing all interested constituencies that steel is always situated in relation to other materials and forces that articulate the worlds we inherit, occupy and constitute.

Our enterprise has travelled with a type of thinking and a formative 'ecology of mind' directed towards a sustainable future that is based on reading and learning from circumstances of the present and selectively drawing upon an historically interrogated past — be it of innovators, technologies or the values and practices of other cultures. It is worth considering, for instance, that past innovators were not specialists but 'relationists' with a highly developed sense of past and present contexts. To take two whose significance has already been established: Sir Henry Bessemer and René-Antoine Ferchault de Réaumur.

Bessemer, a professional inventor, was born in rural England in 1813, the son of French refugees. While he was a man of demonstrably great creative, technical and inventive powers, he was not averse to appropriating the ideas of others.[19] Besides his acclaimed attainment in metallurgy — the Bessemer converter — he 'invented' many other things: movable stamps for dating deeds and other government documents; an improved typesetting machine; 'gold' powder made from brass for use in paints; sugarcane-crushing machinery; a solar furnace; an astronomical telescope and machines for polishing diamonds. His encounter with steel-making in 1854 was the consequence of trying to find an appropriate metal for a rifled barrel for a gun he had invented for the Crimean War.[20]

Réaumur, in contrast, was an eminent French scientist and foremost entomologist of the early 18th century who conducted research in varied fields. He devised the thermometric scale bearing his name, published multiple volumes of what were to become seminal works of entomological history and researched human biology, with particular focus on digestion.[21] Here is the backdrop against which we can view his improved techniques for making iron and steel — including his development of a cupola furnace. This knowledge, registered in his seminal work on metallurgy, *L'Arte de convertir le fer forge en acier* was published in 1722.

We should remind ourselves of the ancient Chinese attainments in the steel-making technology that both of these men rediscovered and advanced.[22] Besides this common denominator, we also note with considerable interest that Réaumur was a scholar of Chinese science and technology, in particular the chemical composition of Chinese porcelain — an area not exactly distant from the concerns of other pyrotechnic arts, structures and refractory materials!

Our focus on the ecologies of steel has been via the imperative of *sustainment*, this term having been adopted to create differentitation from the limited (industry) view of 'sustainability', which by-and-large centres on the environmental impacts of production and the lifecycle impact materials. To reiterate, sustainment is learning to think and act otherwise. Some of its fundamental aspects, summarising from what was said at the beginning of this chapter, are:

〈 that nothing can be sustained without an identification of the unsustainable;

〈 that all that is unsustainable stems, in the first instance, from 'our' values, desires and actions (human anthropocentrism);

〈 that how, what and why we unsustainably produce our material world needs to be much better understood, specifically, 'the way and the why' steel is used and what prefigures its use (including the symbolic dimension);

〈 that the sustainment of individuation rests on the commonality of community.

The question will no doubt remain in the minds of sceptics (self-projecting their own image as such, or as pragmatists, or 'realists') that what has been argued is all well and good but — 'how can a such a lumbering monolithic industrial force like the steel industry be made to shift direction from its (unsustainable) inscribed productivist logic and practice in the economic reality that rules?' There are many answers to this question. Three of a very different character, have been selected.

The first answer is metaphorical, and comes from steel-making itself. To transform iron, with all its limits, to steel, with all its capability, takes a good deal of energy and a very small percentage of carbon to create the alloy — the point being, notwithstanding the need for energy, that a small ingredient can totally transform everything.

Answer two is the power of the iconic figure, and this comes from the history of steel-making. It is Andrew Carnegie, Scottish-American industrialist who more than any other person drove the expansion of the American steel industry in the late 19th century. He was born in 1835 into a radical Chartist (proto-communist) family in Dunfermline, Scotland, who immigrated to America in 1848, where they joined a Scottish colony of relatives and friends in Pittsburgh. By the time he was 40, Andrew, via work, wit, self-education, luck and later a talent for shrewd investment, had built the first steel works in the USA, importing the Bessemer process from Britain. He later installed Siemens-Martin open-hearth technology. His approach was to employ any means possible, large or small, to keep the man-hours per ton of steel as low as possible. This included breaking the power of organised labour.

The Carnegie Steel Company was a dominant force in the American steel industry; it led the change against, and overcame, Britain's dominance of the industry. All of this made for a very wealthy company and Carnegie himself became an incredibly rich man. In 1901, he sold the company for a vast sum to United States Steel Corporation, which had just been formed and was headed by J.P. Morgan.

Here is the turn, the moral of the story. In spite of his mixed history of labour relations, his aggressive mode of capitalism and his sometime questionable values, through his sense of guilt, Carnegie used his wealth for change. He actually donated $350,000,000 to various causes — an absolutely enormous amount for his day (now equivalent many billions). He gave to many universities, built 2,800 libraries, theatres, child-welfare centres, research institutes, training centres and more. The overwhelming volume of funds went to education in one form or another. Much could be said about Carnegie, positive and negative, however one thing stands out as a common thread across his life above all else — his understanding of the power of learning. From his own experience, he learnt the power of education — that education grounded in everyday life was a primary means of self, organisational and social change.[23]

The third answer is that change is already underway — for all the limits of the uptake of sustainment, not least from a reformism that ends up sustaining the unsustainable — it is now the case that there is movement. The energy needed to move a moving, rather than a static, object is dramatically different.

In summary and conclusion: when one has the right ingredients, a community of committed people, resources from which to learn, and when the object sought to be shifted is already on the move, then change is possible without a vast army. This condition is within reach.

[1] For instance, in January 2001, after its Shanghai meeting, the Intergovernmental Panel on Climate Change (IPCC) released its *Third Assessment Report*. This long, dense and complex document attracted a good deal of media attention and criticism. This was mostly because of the large variation in projected increases in average global surface temperature — from 1.4 to 5.8C^{o} over the period 1990 to 2100. Another variation the report acknowledged is the degree to which regional differences vary from the norm — for instance, the warming of North America, northern and central Asia is expected to be 40% higher than the average. The science is inexact, the shortcomings of climate modelling are very apparent, and the figures produced, mostly fuzzy. However, the trends are clear and invite serious concern. Less ambiguous than projection, is the Report's analysis of historical climate data. For example: global snow cover has decreased by 10% in the last fifty years; Arctic sea-ice thickness has reduced by about 40%; and the heat content of the world's oceans has increased between 0.1 - 0.2C^{o} in the 20th century. Likewise, the historical variations in atmospheric concentration of CO_2 are dramatic: between 1750 and 2000 it increased by 31%; during the last 20 years over 75% of these CO_2 emissions have come from fossil fuel burning. This concentration is said not to have been exceeded during the past 420,000 years and 'likely not during the past 20 million'. In contrast, and in the same period, concentration of methane, which is another significant greenhouse gas, increased by 151% (over half of which is said to come from anthropogenic causes like agriculture, fossil fuel burning and landfills).

[2] See for example John Whitfield 'Sink hope sink' *Nature* 24 May 2001 and Tom Clarke 'Rainforests breathes out' *Nature* 11 April 2002.

[3] One can cite, for example, the IPCC Draft Report on Australia, which paints a sobering picture of higher temperatures, more bushfires, longer droughts, more floods and falling agricultural production. Two contributors to the shifting ground of the climate change debate are the property and insurance industries, both of which are directly exposed to threats posed by the coming climate. In November 2000, Andrew Dlugolecki, then chair of a UNEP insurance industry initiative and Director of general insurance development at CGNU, one of the largest insurance groups in the world, claimed that in the context of increasing extreme weather events 'a 10 percent increase in wind speeds results in a 150 percentage increase in damage'. Against this backdrop, Dlugolecki called for a 60% reduction in GHG emissions (reported in *Financial Times* [London] November 24, 2000). This has to be contrasted with the feeble ambitions of governments and the appalling record of the Australian and US governments in particular. See also *Climate Change and the Financial Services Industry* a two part study commissioned and published by United Nations Environment Program Financial Industry Climate Change Working Group, 2002 at www.unepfi.net .

[4] Insufficient fresh water is a growing global environmental problem. There are many reasons for this besides greenhouse gas related climate change. There is rising demand from: population growth; increasing urbanisation linked to water-profligate lifestyles; pollution of fresh water from poorly managed and unregulated industrial activities; insufficiently developed sewerage infrastructure often resulting in fresh water contamination; poor agricultural irrigation practice extracting too much upstream water; and in some instances the expansion of hydro-electric power generation which dramatically reduces river flow. Equally, deforestation can cause the water table to rise, bringing salts to the surface, which then get flushed into fresh water courses and salinate them. It is against this backdrop that the steel industry has to be recognised as a very significant water user.

We should note that 97.4% of the world's water is salinated. While 2.6% is freshwater, 1.98% of this is locked up in icecaps and 0.59% in groundwater. Of the total amount of freshwater only about 0.014% is available to the human population. However only 0.007% of this is contained in rivers and lakes, while 0.005% is sequestered in the soil and the remaining 0.002 is in atmospheric water vapour with a fraction (0.0001) in biota. Additionally, 60% of the world's population live in regions that only get 25% of the world's rainfall. This does not imply that people get the water in these proportions. Water costs. The cheapest fresh clean water in the world is from Canada where the consumer pays 31 cents per cubic metre, whereas drinking water costs 100 times more than this in Haiti, 83 times more in Pakistan and 60 times more in Jakarta. There are people worse off than this. The World Bank World Commission on Water estimates that 1.2 billion have no access to any potable water. Claims made of five to seven million people dying annually from water related diseases are conservative. This situation can expected to worsen, not least because the world's population will reach 8.5 billion by 2050 and 12 billion by 2099. Also significant is that freshwater use increases proportionally at a greater rate as population grows — over the last century while population more than doubled fresh water use increased threefold. Industrialisation speeds this trend because industrial processes use a vast about of water. Modern lifestyles are great wasters and polluters of water - washing, garden watering, showers, and worst of all, toilet flushing (defecating into fresh water really does need to viewed as pollution). Agriculture not only uses an absolutely enormous amount of water (e.g. approx 2400 litres of water for 1 kg of white rice) but as population grows, what becomes the most critical factor is not just available fertile land or crop productivity (problematically, via genetic modification) but water availability. Marios Sophocleous 'Global and regional water availability and demand: prospects for the future' *Natural Resources Research* Vol 12, no 2, June 2004; Peter H. Gleick 'Making every drop count' *Scientific American* Feb 2001; *Nature* 422: 243, 251, 20 March, 2003 [www.nature.com]; Proceedings of the 3rd World Water Forum, Kyoto, Shiga & Osaka, 16-23 March 2003.

[5] Ian Christmas 'The steel industry at the dawn of the next century' *Iron-making and Steel-making* Vol. 26 No.1, 1999, pp. 20-21.

[6] See Tony Fry *A New Design Philosophy: An Introduction to Defuturing* Sydney: UNSW Press, 1999, which seeks to show, via historical and contemporary examples, how much of the industrially manufactured designed world has taken futures away (defutured), as well as providing the means to read this process — which it called defuturing.

[7] Magnesium has a higher strength to weight ratio than either steel or aluminium; however, it requires even more energy to manufacture than aluminium. Ian Howard 'Race is on for the metal of the future' *The Australian Financial Review*, 14 January, 2000, p. 42.

[8] The introduction of these materials has prompted the steel industry towards innovation, and within the auto industry, light-weighting projects. Perhaps the best known example is the ULSAB-AVC (UltraLight Steel I Auto Body - Advanced Vehicle Concept) project from 1994 to 1998, in which over thirty steel-makers in Asia, Europe, South Africa North and South America, participated. It aimed to create a new 'advanced steel automotive body architecture' for vehicles that would be safe, strong, affordable and significantly lighter. Light-weighting of materials enables improved 'power to weight ratio' to deliver a light car with a small engine equal in performance to a heavier car with a much larger engine (resulting in much lower fuel consumption and thus reduced emissions). The engineering of the project was led by Porsche Engineering Services based in the USA and the outcome was to achieve a body that weighed 36 percent less than the mid-size sedans benchmarked. This kind of design activity falls very much into the 'reactive' frame — not least to the inroads being made by the aluminium industry into what seemed for a long time to be uncontested steel territory. One of the project's key points was stated thus: "The new paradigm is that steel has evolved as a lightweight material. We are challenging the auto industry to think of steel when they think lightweight, and throw out the paradigms of steel past." American Iron & Steel Institute website www.autosteel.org/ulsab_avc/index.htm

[9] See Bryan Berry 'The next millennium' *Iron Age New Steel* December 1999 (Web edition p.1 of 3) and on magnesium, Ian Howard 'Race is on for the metal of the future' *op cit*.

[10] See endnote 8.

[11] See Brian Fortner 'Forging Ahead' *Civil Engineering* April 1999, pp. 60-61.

[12] Joseph Needham *The Development of Iron and Steel Technology in China: Second Biennial Dickinson Memorial* Lecture London: Newcomen Society, 1956. Needham, cites the famed Ironmaster *Cho Shi,* who founded an ironworks in Szechuan in the -3rd century, which had a highly organised system of production and employed nearly two thousand men.

[13] For example, the *Thien Kung Khai Wu* (*The Exploitation of the Works of Nature*) of 1637, which addressed agriculture and industry and is described as 'China's greatest technological classic'. This material is itself linked to a series of important primary texts, like the *Khao Kung Chi* (Artificers Record), which, in turn, contained a chapter of the *Chou Li* (Record of the Institutions of the Chou Dynasty) — the original of this document was lost at the beginning of the Han Dynasty and a substitute document was collected by Prince *Hsien of Ho-Chien* in the second quarter of the -2nd century. See, Joseph Needham *Science and Civilisation in China* Vol 4, Physics and Physical Technology Part 2, Mechanical Engineering, Section 27 p. 18. Note all dates specified are based upon a Western Judeo-Christian calendar – which itself makes a point on the non-availability of a neutral point of reference.

[14] These departments, while subject to occasional changes of name, endured over many hundreds of years.

[15] For an account of this measurement see Lothar Ledderose *Ten Thousand Things: module and mass production in Chinese art* Princeton (NJ): Princeton University Press, 2000 *p*. 134.

[16] Liang Sicheng *Ying Zao ta Shi Zhu Shi* (Vol 1 — 13 of a total of 34 sections) Beijing: Zhong guo Jianzhu, Gongye Chubabshe, 1983. This facsimile edition, based on the first modern translation of 1925, was the product of many decades of research and heralded the beginning of modern Chinese architectural history. The latest edited, with a new introduction, was produced in 1963; however, it was kept hidden during the course of the Cultural Revolution and not published until the early 1980s.

[17] In 1949, China produced 148,000 tons (imperial) of crude steel; by 1996, it produced 100 million. Its output by 2020 is projected to be between 124 to 130 million tons — William T. Hogan, S.J. 'The changing shape of the Chinese steel industry' *Iron Age New Steel* October 1999 (Web edition pp. 1-2 of 10).

[18] *Ibid* p.2 of 10.

[19] See L.T.C Rolt *Victorian Engineering* Harmondsworth: Penguin Books, 1970, p. 182-83. Rolt gives an account of Bessemer's failure to acknowledge and reward Robert Mushet, who had the metallurgical knowledge he lacked for solving the problem of excess oxygen in the steel made in his early converter, this being vital knowledge to make marketable product.

[20] *Ibid* p. 182.

[21] See entries in *Britannica* CD, Version 99 © 1994-1999. Encyclopædia Britannica, Inc.

[22] As indicated in chapter 1, Needham described the Chinese 'hundred refinings' method of steel-making as 'theoretically ancestral to Bessemer conversion' and observed 'direct migration of Chinese workman skilled in this work immediately preceded the group of inventions

associated with the name Bessemer.' Joseph Needham *The Development of Iron and Steel Technology in China: Second Biennial Dickinson Memorial Lecture* London: Newcomen Society, 1956, p. 47.

[23] See Andrew Ritt et al 'A Retrospective of Twentieth-Century' *Iron Age New Steel* November 1999, (web edition 7-8 of 18) and see entry under Andrew Carnegie in *Britannica* CD, Version 99 © 1994-1999. Encyclopaedia Britannica, Inc.