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Ecologies of Steel
An Introduction

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We are constantly told that economies are dematerialising and that experience is becoming evermore virtualised. In this context, to embark upon a project which seeks to understand a material, and a commonplace one at that, in all its cultural, technical and historical complexity, might seem like a very unfashionable thing to do. Yet it is this very disappearance from public discourse of that which remains stubbornly, materially present that compels us to insist upon the necessity of a project which forces attention on the increasingly overlooked material substrate of our everyday lives. Our project also contests the material/immaterial dichotomy. In the last few decades, material production has certainly lost its leading edge status, being symbolically dethroned by the rise of the immaterial economy in which image and information are driving the creation of economic value. But while the power of logo/brand name increases, that to which it is attached has not disappeared, but simply slipped out of view as material production has become increasingly decentred and mobile, migrating from 'industrialised' to 'newly industrialising' regions. While marketers and image-makers in New York or Tokyo work to carefully craft branded identities for sports shoes or personalities for plush toys, the actual stuff that comes to bear the

created meanings gets manufactured in China, Mexico or wherever cheap labour can be found. The shift then has not been from material to immaterial production, but rather, that the immaterial, as information, meaning or sign, has come, directly or indirectly, to drive material production. This is in fact not a new development. As we will see, it is just that it has become more obvious in recent times.[1] Understanding the nature of the material/immaterial relation in the current moment is vital for thinking the future of steel or of any other material; grasping the inadequacies of how this relation and how this historical moment is dominantly characterised is also vital.

The methodology of this project is based upon a 'relational' approach, which has informed other work we have done on materials and the designed environment.[2] This was developed to account for the impacts of materials in the complexity of their contexts and in response to the rise of more narrow, quantification-based approaches to industrial environmental impact assessment, such as embodied energy analysis.[3] Taking a relational approach to the exploration of a material means not viewing it as discrete or singular. Steel, for example, cannot be considered independently from iron or from carbon-based fuel (charcoal, coal or coke). Nor can it even be assumed that steel is a clearly definable form of matter (while there are well over 20,000 formulations of steel in the marketplace, this figure itself means little because of the capacity for customisation). A relational approach is consistent with, but also significantly extends, the way in which environmental impacts are currently understood by the advanced sectors of the steel industry, which is via 'life-cycle-analysis', a method which *conceptually*, (but rarely in practice) provides the possibility of making connections between environmental impacts across time, geographical space, multiple processes and materials.

Like plastic, the word steel is a common one and most people when they hear or read it conjure an image of a material in their mind. But like plastic, 'steel' generically names a wide range of materials as well as having acquired a metaphysical status. Steel is thus taken to be a strong material and a metaphor of strength. This further suggest why a strictly empirical approach to understanding its impacts is not adequate, as does the problem of defining iron and steel historically and cross-culturally.

Steel has been differentially defined over time and there are difficulties in translating words from different languages that refer to different kinds of iron. Metallurgical knowledge is often employed trans-historically and trans-culturally to decide whether or not a particular material is steel – this, on the basis of its carbon content, or the differences in carbon content between the material's surface and core; or sometimes it is appearance and performative qualities that are used as criteria to judge. We will not attempt to retrospectively apply these contemporary metallurgical

definitions of steel. Instead, we acknowledge that since ancient times, distinctions have been drawn on the basis of qualities such as malleability, hardness, softness, ductility, tensile strength and colour, generating complex classificatory systems within which the highest grade of metal that combined the most desired qualities often got designated as 'steel'.

What Are Ecologies of Steel?

One way we will signal relationality in this text is by talking about particular 'ecologies of steel'. But there is more than one kind of ecology. Every environment (a place) is accompanied an ecology (a system). Environments are connected and transformed by ecologies (systems relationally connect). Relationality is in fact a very useful way think about and beyond systems, their internal functions and interactions.

It is no longer appropriate to view ecologies just as natural systems, if it ever was. This is because of the depth and extent of transformations of 'the natural' by 'the artificial,' that have occurred over many thousands of years, but which have gathered pace over the last century to the extent of seeming to erase the line between the two. Genetic engineering is a current, overt instance of the breakdown of the natural/artificial binary. However, ecologically speaking, iron predated this binary breakdown by many eons.

Iron is usually deemed inanimate and artificial. Yet iron is the core of our planet, it makes up some four percent of its crust, and is also part of the very life blood of all red-blooded animals. Iron is a bridge between the inert and the organic; it is an active element that links natural and unnatural ecologies. It is vital for the health of the human body, enabling the manufacture of haemoglobin, which is essential for transporting oxygen to the lungs, brain and all other parts of the body. Iron, via the food chain, is extracted from the land as a mineral trace element absorbed by plants and thereafter, animals. We ingest iron from meat, vegetables and nuts. Iron then is part of a vast and complex web of ecological relations still only partly comprehended by the natural sciences. Yet this complexity is still only part of the picture, for our ecology of dependence is constituted as much from what we have made as from all those ongoing processes whose origins pre-dated, and have been altered by, human presence. Iron and steel have played, and still play, a major part in ecological formation and transformation.

Iron and steel will be shown to have significantly changed the 'nature' of the planet by: the appropriation of material resources; the impact of manufacturing processes; the use of iron and steel in other environmentally transformative activities from agriculture to arms and transport; the kinds of environments iron and steel have enabled to be constructed from skyscrapers to underground railways; and by their use in the manufacture of myriad products to be found in almost every space of human existence. The

making of the modern world is inseparable from the expansionary production of environments of iron, steel and reinforced concrete, the production of all those objects in iron and steel that became implicated in countless economic and social functions of everyday life and of the body that is materially and immaterially formed in this world. Then of course, there are ecologies of meaning, and here we encounter iron and steel as language, image, symbol, metaphor.

Politics of the Project

The stories of 'ecologies of steel' can tell something of the impact and future of a particular material of human artifice and something of all materials of our world-making. More than this, in telling the stories of steel we can come to realise that which we now call unsustainability has been a *telos*, a direction put in place and forcefully driven from the very moment that anthropoidal being started to shape a world to the needs of dwelling beyond animality. In making environments, in using tools, human beings made both themselves and their fate as technological world transformers. The bringing of fire to metal not only created a quantum leap in the potential for technological advancement, it also accelerated the passage toward the unsustainable. This is not to condemn distant, past generations, on the assumption that they could foresee where their actions would lead. However, once it is realised that the forms of human world-making have been increasingly towards world negation (unsustainability), a moment of ethical confrontation arrives.[4] We humans of this epoch are of this moment. We are the generation that have to change the direction away from unsustainable 'growth and development' in order to secure the 'being-of-being' (the relational web of being in which we are implicated). The task, in these circumstances, is not 'saving the planet' but rather, taking responsibility for what we do individually and collectively. As soon as we see this as an engagement with what we build, how we make, what we learn and how we dwell, we are back in a world of material fabric of which steel is a big part.

What all this means in direct terms is gaining a much better understanding of the impacts of iron and steel-making in the past and present, as well as how to significantly reduce its impacts in the future. This involves examining what is made with steel, why, and how it could be used more sustainably. But caution is needed here, as 'sustainable' has become a very loose term, attached willy nilly to all kinds of activities which in fact sustain the unsustainable by seeking, or maybe only appearing, to slightly modify the impacts of something which is, in essence, damaging.

Giving substance to these claims is the very basis of this project. We shall be re-reading the history of iron and steel-making in Europe and Asia as a material and cultural archaeology that transformed landscapes, climates, ecologies, industries,

infrastructures and ways of life. We will look at the language and culture of iron and steel-making as it played a part in the rise of scientific knowledge – specifically we will revisit thinkers from antiquity, East and West to examine the *continuity* of metallurgy across what most historians usually miscast as a progression from magic to alchemy to science.

Improving the performance of metal has been an unceasing preoccupation of metallurgy. The history of iron-making is inscribed in the material's present and future. Advances in the development and refinement of iron and steel always trade on knowledge and technologies from the past, but much more is carried from 'the past' than the dominant narratives of iron and steel generally acknowledge.

The Material Research of Ecologies of Steel

This project is not just about a specific material, or even about 'the material' *per se*, rather it is a neo-materialist exploration of the determinate relations of steel from the perspective of the relationality of ecologies (as opposed to the essentialism of 'the ecological').

This is not the same as 'material determination'. Simplistic notions of material causality become redundant, as soon as we admit the numerous determinate relations of steel (what determines it and what it determines). This panoply of relations is manifested as exchange between knowledge, materials, technologies, cultures, economies. This is one way of characterising 'the ecologies of steel' and clearly, it opens up a complexity beyond a single system or structure, but which we will strive to grasp and make available to view, at least in part.

Language and Perspective

Besides the technical languages of steel and metallurgy, this account draws on histories of technology, science, inter-cultural studies, environmental studies, as well as design history and theory. This brings advantages and problems. Viewing the object of study from multiple perspectives enables a rich and complex picture to be assembled. But for readers, this means encountering terms that shift between familiar or unfamiliar. The text needs to be read at variable speeds: the new will need to be taken slowly, while the familiar can be moved across quickly. However, caution is needed because the way in which standard accounts will be treated will not always be standard. The treatment of the history of iron-making in Europe and Asia is a case in point: a revised assessment of the how knowledge travels and a different perspective on 'development' will create significant differences of historical interpretation.

History is given prominence in our account because we believe that one of the major reasons the condition of unsustainability

goes largely unrecognised today is a preoccupation with the present, a looking to 'the future' and a forgetting of the past. There are no quick fixes – things cannot become sustainable instantly. Sustainability cannot be created unless the condition of unsustainability is thoroughly understood, and this cannot be done without historical knowledge. So history, as revised, has a very important future.

There is a vast literature on the history of European iron and the steel-making. Many of these histories treat the development of iron and steel-making as a series of technological progressions that begin with early methods of smelting ore in bloomeries, then move to the arrival of the blast furnace and the foundry industry, then the development of steel-making processes, the introduction of the Bessemer converter and open hearth steel-making, followed by an account of the modern integrated steel works, basic oxygen steel-making and ending with the mini-mill and the electric arc furnace. We engage this history, but our intention is to extend and recast it. For readers wishing to explore standard accounts there are a number referenced in our bibliography.

While such histories of iron and steel give the impression of a single narrative of progress, there really is not just one story or one position of speech. The more those differences between languages, cultures and values have come to be recognised, the more difficult and inappropriate it has become to secure a single account of any historical phenomenon. This does not assume that all perspectives are equal (pluralism) but rather that an ethical choice has to be made in the face of the differences of the plural. In the case of the 'history' of iron and steel, a globally integrated account that 'pulls together' all available histories into one history would not only fly in the face of this thinking, but be an impossible task – nobody, no thing and no event ever arrives cut from context and totalised within a single frame of reference. Because histories are contestable and there is no neutral space from which to tell, all one can do is to make one's viewpoint, one's bias, explicit. Without question, we write with a bias toward sustainment.

These comments connect with how we will be viewing environmental impacts.

Clearly human lives, all life forms, have environmental impacts. We cannot eliminate impacts – that is not the aim. Rather what can be done is to develop a better understanding of consequences and of the difference between positive and negatives impacts (briefly, those that sustain ecologies versus those that destroy ecologies be they biophysical, social or symbolic). This knowledge can then be used to exercise responsibility and make decisions.

Again, environments have to be seen relationally. Our (western) understanding of what constitutes an environment is part of

the problem. We assume that a building site, city, park, forest or garden is discrete, something bounded, whereas ecological relations mostly operate within and across such boundaries in ways quite at odds with our image of them. Our mode of seeing is an historic construct and our knowledge of 'the world' is culturally specific. This point has been made many times before, especially in relation to values, behaviours and the domain of the social. Bringing this perspective to the notion of environmental impacts has another implication, which is that we are constantly in a situation of acting, and thus enacting transformations, but in a condition of very limited knowledge. It is not as if the evidence is simply there but hidden, rather it is that we mostly lack the sensibility or disposition to see available signs, think what is not normally thought or speak what is normally silent. Without question, one of the major aims of this book is to help create this sensibility. For this to happen not only do the way we think environments have to change, but also the way we think many other things such as: science, alchemy and magic; cultures as Eastern or Western; the premodern, modern and postmodern.

Problems and Solutions

There has been a longstanding, and as yet, historically unregistered tension between the creation of the unsustainable and the desire and need for sustainability. Current forms and forces of unsustainability are lodged in longstanding practices, values and thinking. The archaeology of unsustainability is to be found first in the coming to dominance of cultures that viewed the resources of planet Earth as an infinite 'standing reserve' to simply use at will. The second historically longstanding factor is the 'sustainment of the immediate.' In other words, for many cultures, short term action to sustain the status quo has failed to take into account the need for structural sustainability of all that is essential to sustain (which is itself historically and geographically variable as environments and ecologies change). It has only been in recent times that the problem of unsustainability and the need for the sustainable has arrived. Even so, the nature of both unsustainability and sustainability are still barely understood. Our anthropocentrism (human-centredness) foregrounds sustainability as the sustainment of the humanoid species, and the human in a web on non-human ecologies. In other words, the making of the crisis of unsustainability is a projection of human needs and values upon material circumstances – it is objective only from our point of (subjective) view. We may eliminate ourselves and many other life forms, but it is extremely unlikely that that we have the ability to obliterate all life. In this context 'sustainability' is a value that is attempted to be realised as a material condition to mobilise against the long reach of a propensity

towards the unsustainable, which so far, in our limited way, we have only objectified as discernible environmental impacts.

While what has just been outlined is very abstract, one of the main imperatives of this project is to historically concretise these claims by using steel as a case study for considering how the unsustainable might be turned toward the sustainable. The choice of steel is, of course, not arbitrary. In its inseparable relation to iron, it travels back in time and across all continents; as the primary material of industrial production, it has been at the core of the making of the industrialised world – its tools, economies, wars, working lives, made structures, ways of life and ecologies. Steel, that is the material, the industry and its products, has not only been, but still is 'world shaping.' After concrete, it is the most plentiful manufactured material on the face of the planet. Thus, via steel, it becomes possible to shift general imperatives into the particular and the 'to hand', as objects of thought and action. All of this is quite different from that pragmatism that says 'let's just get on with the job' of sustainability, for without a far clearer sense and understanding of the unsustainable it is not possible to distinguish between: symptom and cause; informed action and hollow gesture; or therapeutic versus transformative action.

Another reason why a purely technical account of iron and steel could not adequately convey the actual power of these materials is that iron and steel have enormous symbolic force. Any attempt to think through strategies for reducing the environmental impacts needs to take this symbolic power, this 'ecology of meanings', into consideration.

Symbolically, in the Western tradition, steel is the result of Prometheus bringing fire, 'the divine spark' of energy and illumination, to Earth, whereupon it was adopted by Hephaestus (Vulcan), the god of fire and the forge. And thus, a force of the gods was transferred to the hands of 'man.'

Iron and steel have been objects of thought, metaphors for power and strength; they have stood for the entirety of the human relation to matter. Consider the view expressed in the 'Natural History' of perhaps the greatest Roman thinker, Pliny:-

> It remaineth now, in the next place, to discourse on the mines of iron, a metal which we may well say is both the best and worst implement now used in the world; for with the help of iron we break up and tear into the ground; we plant and plot our groves; we set our vineyards and range our fruitful trees in rows, we prune our vines, and by cutting off the superfluous branches and dead wood, we make them every year look fresh and young again. By means of iron and steel, we build houses, hew quarries, and cut stone; yea, and in one word, we use it to all other necessary uses of this life.

Or consider the view Philosopher John Locke writing in 1690, some 1600 years after Pliny:

> For it is rational to conclude that, since our faculties are not fitted to penetrate into the internal fabric and real essence of bodies, but plainly discover to us the being of a GOD and the knowledge of ourselves enough to lead us into a full and clear discovery of our duty and concernment, it will become clear to us, as rational creatures, to employ those faculties we have about what they are most adapted to, and to follow the direction of nature where it seems to point us out the way…. Of what consequence the discovery of one's natural body and its properties may be to human life, the whole continent of *America* is a convincing instance: whose ignorance in useful arts and want of the greatest part of the conveniences of life, in a country that abounded with all sorts of natural plenty, I think may be attributed to their ignorance of what was to be found in a very ordinary and despicable stone, I mean the mineral *iron*. And whatever we think of our parts or improvements in this part of the world, where knowledge and plenty seem to vie with each other, yet to anyone that will seriously reflect on it, I suppose it will appear past doubt that, were the use of *iron* lost among us, we should in a few ages be unavoidably reduced to the wants and ignorance of the ancient savages *Americans*, whose natural endowments and provisions come no way short of those of the most flourishing and polite of nations.

More simply, but of the same ilk, here is Harry Scrivenor, a historian of the iron trade, writing in 1854:

> It is a doubtful point, whether the domination of man over the animal creation, or his acquiring the useful metals, has contributed most to extend his power.

And it is the fact that this extension of power has been inseparably bound up with the forces of unsustainability that will drive our telling of the stories of the ecologies of steel – a telling absolutely necessary to gain the kind of understandings that can generate conditions of sustainment for futures to be possible.

In the final analysis, we hope that what we present will challenge the thinking of those readers with an existing knowledge of the steel industry by making it possible to view steel from a broader perspective. For those readers who know little about steel, we hope that what follows will not only introduce new knowledge, but also a whole new way of understanding materials, their relation to culture, their place in processes of change and the force they have upon the form of the future.

Structure of the Book

Part 1 introduces the founding moments of iron and steel-making, re-presenting them in ways that can inform the present and future.

Chapter 1 presents a trans-cultural prehistory of iron-making that aims to confound the idea of a linear history and to show how the making of iron was implicated in the development of an 'ecology of mind'. The spread of knowledge of methods of iron-making from the Middle East to Asia, Africa and Europe evidences the emergence of a traffic in ideas and also demonstrates the 'world shaping' force of ideas. The chapter examines the advanced iron-making industry of ancient China. Then it looks at the emergence of iron and steel-making in Greek and Roman culture, demonstrating that their methods were far more sophisticated than iron-making at the end of the Dark Ages, which is where most histories of European iron-making start.

Chapter 2 historically reviews the dependence of iron and steel-making on carbon-based fuels (wood, charcoal, coal and coke), explaining the thermo-chemical processes and their environmental impacts. From its inception, iron-making generated environmental problems and there were 'environmental crises' from the late Middle Ages. This history is then connected to present day concerns about greenhouse gas induced climate change by considering how the steel industry's emissions could be reduced by, for example, newly reinvented charcoal-based methods or by the use of materials like plastic waste as fuel.

Chapter 3 examines how the making of metals and the quest to understand them grew out of a complex collusion between magic, alchemy and metallurgy. The telling of this story of inter-weaving, seemingly incommensurate areas of knowledge runs counter to the more familiar notion of progressive displacement of the one by the other. Magic, alchemy and science continue to co-exist in the present as the nature of contemporary advanced materials show. A case study of a particular alchemist, George Starky, and his connections to Isaac Newton, is examined, as is the emergence of process and physical metallurgy.

Part 2 examines iron and then steel-making as crucial agents of the creation of industrial society. The consequences of the widespread industrial application of iron and steel in war, on the sea and on land, especially in terms of rail and building construction, are major concerns.

Chapter 4, besides looking at the emergent technology of steel-making in the 18th and 19th centuries and its relation to industrialisation, addresses the machine tool industry, specialised tool steel, workplace management and the rise of leadership in engineering from America. The drive to make ever more accurate, precision-performance machine tools and the

development of the kinds of steel to make such tools is shown to be pivotal to the rise of industrial mass production and much more. The impact of these developments on the directions the steel industry took is also discussed.

Chapter 5 shows how steel established its presence as the dominant material of the modern epoch by considering some of the major world-forming and transforming applications of steel – specifically modern warfare; railway systems, shipbuilding and the construction industry. Also included is a case study of Austin, a ground-breaking American systems building company, which established a particular type form and mode of delivery of steel-framed industrial building that has had massive, but mostly unacknowledged impacts.

Chapter 6 reviews the 'state of the art' of current steel-making technologies in the context of 'the state of the world.' The fate and environmental implications of integrated steel works, electric arc furnaces and iron substitute materials are considered.

Part 3 is framed by the imperative of Sustainment. It confronts the essence of the present and future challenge for the steel industry which is: given the extent and nature of its environmental impacts, a very significant net reduction of the overall impact of the entire industry is the only way forward. What this means is that improving the environmental performance of the industry while increasing output is just not a viable option. Creating and maintaining a viable steel industry able to advance the ability to sustain, and in so doing create a significant income stream, is thus the pressing challenge.

Chapter 7 argues that the reductive empiricism of environmental science and the rigid legalism of regulation do not have a sufficiently relational picture of impacts and therefore are not capable of dealing with the difficult issue of *structurally inscribed unsustainability*. To counter this, the chapter gives an account of certain environments and ecologies of iron and steel-making that have existed at different times and places, attempting to weave together a discussion of biophysical impacts with other impacts less amenable to incorporation by environmental science. The contention is that seeking to understand the *fundamental nature* of the processes of iron and steel-making, and the kinds of environments that they create, is a prerequisite for posing appropriate solutions. The chapter is structured around specific ecologies, or sets of exchange relations within particular environments; it shows how particular materials exchanges such as the extraction, transport and processing of ore and fuel, create distinctive environments which then impact upon other ecologies and environments.

Chapter 8 gives an account of the ways in which the steel industry (and industrial environments more generally) have been sought to be regulated over the last one hundred years. It reveals the limitations and contradictions of government control

of environmental matters, as well as something more troubling – which is the fundamental limits of current economic and political structures for the advancement of sustainment.

Chapter 9 looks to the future, but not as a vacant space waiting to be filled by projected visions, as utopians and naive futurists would have it. Nor is the future viewed with a faith in the ability of science and technology to resolve the mounting planetary problems of unsustainability, as technological determinists believe. The chapter opposes such 'future visions' by: re-examining the very nature of materials; considering the potential for transformation and redirection by design, design innovation and new standards; addressing the problems of public perception of industry change; and stressing the importance of bringing questions of the immaterial to any new thinking about materials and the economy.

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Notes

1. The shift was perceived by a number of cultural theorists throughout the twentieth century, from Adorno and Horkheimer who wrote about the rise of the Hollywood culture *industry* in the 1930s to Roland Barthes' explorations of the semiotics of mass culture in the 1950s in which he noted that it was no longer possible for anything *not* to signify, even functionality becoming 'the pure sign of functionality', to Jean Baudrillard who in the 1960s announced the arrival of the 'political economy of the sign' in which commodities came to be produced immediately as signs and signs as commodities.
2. See, for example, Anne-Marie Willis and Cameron Tonkin *Timber in Context: A Guide to Sustainable Use* Sydney: CIS Publications, 1999.
3. Embodied energy is the total of all energy required to make a particular material or product (calculated on a per unit basis), including extraction of raw materials, processing, manufacturing, transport. For further discussion see Bill Lawson *Building Materials, Energy and the Environment* Canberra: Royal Australian Institute of Architects, 1996.
4. The most significant material manifestation of an increased velocity towards unsustainability was delivered over the course of modernity. See Tony Fry *A New Design Philosophy: An Introduction to Defuturing* Sydney: UNSW Press 1999.