Preface: Why and How

The story of humanity – evolution of our species; prehistoric shift from foraging to permanent agriculture; rise and fall of antique, medieval, and early modern civilizations; economic advances of the past two centuries; mechanization of agriculture; diversification and automation of industrial protection; enormous increases in energy consumption; diffusion of new communication and information networks; and impressive gains in quality of life – would not have been possible without an expanding and increasingly intricate and complex use of materials. Human ingenuity has turned these materials first into simple clothes, tools, weapons, and shelters, later into more elaborate dwellings, religious and funerary structures, pure and alloyed metals, and in recent generations into extensive industrial and transportation infrastructures, megacities, synthetic and composite compounds, and into substrates and enablers of a new electronic world.

This material progress has not been a linear advance but has consisted of two unequal periods. First was the very slow rise that extended from pre-history to the beginnings of rapid economic modernization, that is, until the eighteenth century in most of Europe, until the nineteenth century in the USA, Canada, and Japan, and until the latter half of the twentieth century in Latin America, the Middle East, and China. An overwhelming majority of people lived in those pre-modern societies with only limited quantities of simple possessions that they made themselves or that were produced by artisanal labor as unique pieces or in small batches – while the products made in larger quantities, be they metal objects, fired bricks and tiles, or drinking glasses, were too expensive to be widely owned.

The principal reason for this limited mastery of materials was the energy constraint: for millennia our abilities to extract, process, and transport biomaterials and minerals were limited by the capacities of animate prime movers (human and animal muscles) aided by simple mechanical devices and by only slowly improving capabilities of the three ancient mechanical prime movers: sails, water wheels, and wind mills. Only the conversion of the chemical energy in fossil fuels to the inexpensive and universally deployable kinetic energy of mechanical prime movers (first by external combustion of coal to power steam engines, later by internal combustion of liquids and gases to energize gasoline and Diesel engines and, later still, gas turbines) brought a fundamental change and ushered in the second, rapidly ascending, phase of material consumption, an era further accelerated by generation of electricity and by the rise of commercial chemical syntheses producing an enormous variety of compounds ranging from fertilizers to plastics and drugs.

And so the world has become divided between the affluent minority that commands massive material flows and embodies them in long-lasting structures as well as in durable and ephemeral consumer products – and the low-income majority whose material possessions amount to a small fraction of material stocks and flows in the rich world. Now the list of products that most Americans claim they cannot live without includes cars, microwave ovens, home computers, dishwashers, clothes dryers, and home air conditioning (Taylor *et al.*, 2006) – and they have forgotten how recent many of these possessions are because just 50 years ago many of them were rare or nonexistent. In 1960 fewer than 20% of all US households had a dishwasher, a clothes dryer, or air conditioning, the first color TVs had only just appeared, and there were no microwave ovens, VCRs, computers, cellphones, or SUVs.

In contrast, those have-nots in low-income countries who are lucky enough to have their own home live in a poorly-built small earthen brick or wooden structure with as little inside as a bed, a few cooking pots, and some worn clothes. Those readers who have no concrete image of this great material divide should look at Peter Menzel's *Material World: A Global Family Portrait* in which families from 30 nations are photographed in front of their dwellings amidst all of their household possessions (Menzel, 1995). And this private material contrast has its public counterpart in the gap between the extensive and expensive infrastructures of the rich world (transportation networks, functioning cities, agricultures producing large food surpluses, largely automated manufacturing) and their inadequate and failing counterparts in poor countries.

These contrasts make it obvious that a huge material mobilization and transformation will be needed just to narrow the gap between these two worlds. At the same time, material consumption has been a major cause of environmental pollution and degradation and further multiplication of current demand may pose a worrisome threat to the integrity of the biosphere. These impacts also raise questions of analytical boundaries: their reasoned choice is inevitable because including every conceivable material flow would be impractical and because there is no universally accepted definition of what should be included in any fairly comprehensive appraisal of modern material use. This lack of standardization is further complicated by the fact that some analyses have taken the maximalist (total resource flow) approach and have included every conceivable input and waste stream, including "hidden" flows associated with the extraction of minerals and with crop production as well as oxygen required for combustion and the resulting gaseous emissions and wastes released into waters or materials dissipated on land.

In contrast, others studies have restricted their accounts to much more reliably quantifiable direct uses of organic and inorganic material inputs required by national economies. I will follow the latter approach, focusing in some detail on key (because of their magnitude or their irreplaceable quality) materials consumed by modern economies. Their huge material claims lead us to ask a number of fundamental questions. How much further should the affluent world push its material consumption? Are any further increases associated with genuine improvements in quality of life? To what extent is it possible to divorce economic growth and improvements in the average standard of living from increased material consumption? In other words, does relative dematerialization (reduced material use per unit of product or performance) lead to absolute decline in demand for materials?

In order to answer these questions in a convincing manner I must review the evolution of human material uses; describe all the principal materials, their extraction, production, and their dominant applications; and take a closer look at the evolving productivities of material extraction, processing, synthesis, finishing, and distribution and at the energy costs and environmental impact of rising material consumption. And, as always in my books, I will not offer any time-specific forecasts regarding future global and national use of materials. Instead, I will look at possible actions that could reduce our dependence on materials while maintaining a good quality of life and narrowing the gap between affluent and low-income economies.

We must realize that in the long run even the most efficient production processes, the least wasteful ways of design and manufacturing, and (for those materials that can be recycled) the highest practical rates of recycling may not be enough to result in dematerialization rates great enough to negate the rising demand for materials generated by continuing population growth, rising standards of living, and the universal human preference for amassing possessions. This makes it highly likely that in order to reconcile our wants with the preservation of the biosphere's integrity we will have to make deliberate choices that will help us to reduce absolute levels of material consumption, and thereby redefine the very notion of modern societies whose very existence is predicated on incessant and massive material flows.