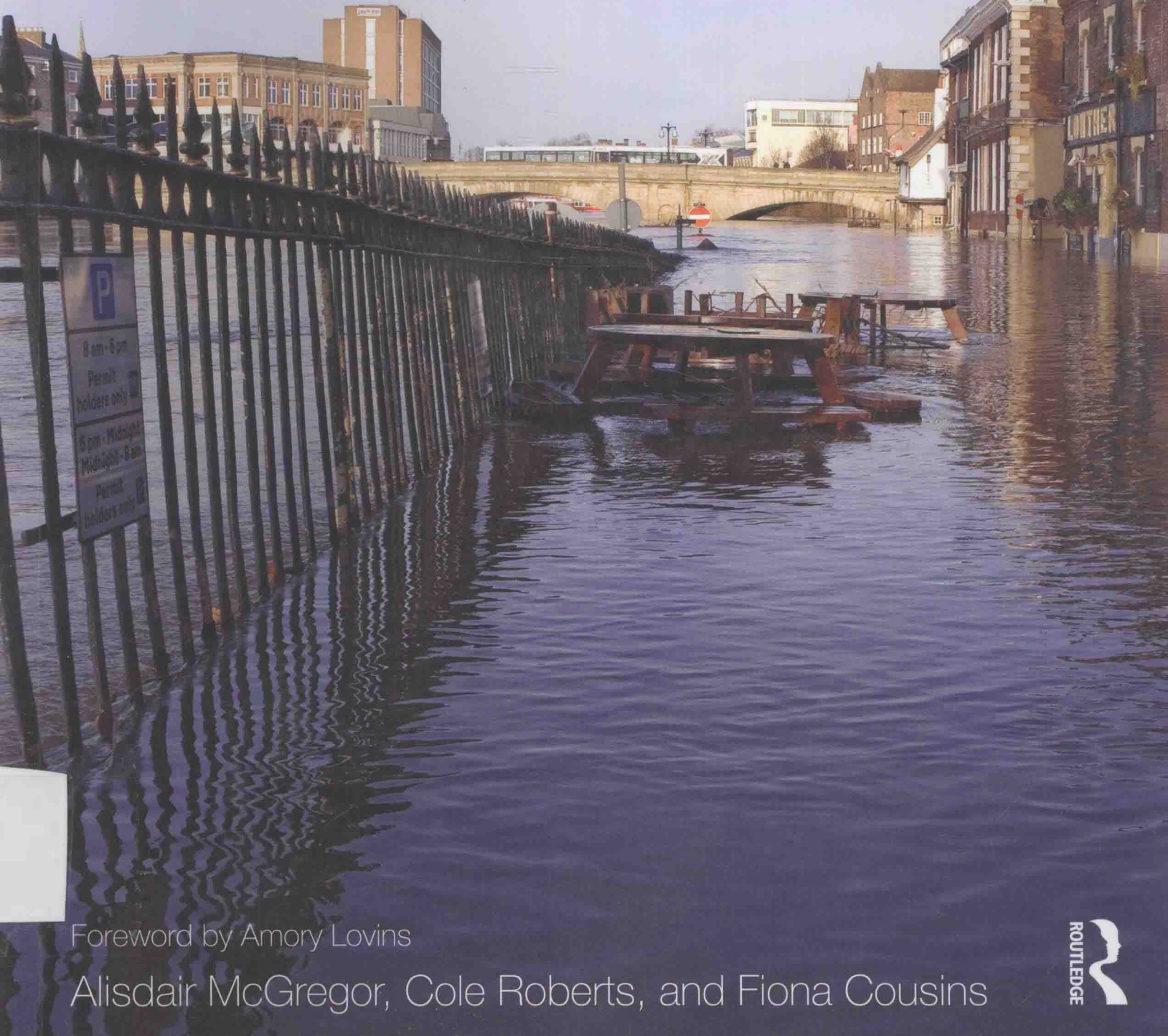


# Two Degrees

The Built Environment and  
Our Changing Climate



Foreword by Amory Lovins

Alisdair McGregor, Cole Roberts, and Fiona Cousins

ROUTLEDGE

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The Built Environment  
and Our Changing Climate

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# Foreword by Amory B. Lovins

I wrote my first professional papers on climate change in 1968 and on nuclear proliferation in 1973. It was clear then to any thoughtful observer that these were energy's two existential threats to civilization, and that we must take the utmost care to avoid both—and certainly not to trade off one for the other. Remarkably misguided policies have now given us both. Yet now as in the 1960s we can still greatly mitigate both threats by choosing the best buys first, rather than the worst. To be sure, many designers of efficient buildings and communities now seek climate-adaptive designs too, either as a hedge against slow adoption of known solutions for mitigating climate change or because some climate change is now unavoidable. But often similar design approaches, as this book describes, can achieve both mitigation and adaptation goals together, at or below normal construction cost.

The best of the best buys is radical energy efficiency, most of all in buildings and communities. Globally, 40 percent of fossil carbon emissions are due to buildings and 24 percent due to transport between buildings; the rest are from industry. Most of this energy is wasted, and technologies for using it more productively keep improving faster than they're installed, so the unbought "efficiency resource" keeps getting bigger and cheaper. U.S. buildings, for example, could save \$1.4 trillion in net present value by wringing three to four times more work from their energy. The savings would be worth four times their cost, earning an average 33 percent internal rate of return (not counting nonenergy benefits that are often much larger). Industry, too, could double its energy productivity, with a 21 percent internal rate of return.

These empirically grounded, peer-reviewed findings rely most of all—especially in our built environment—on a quiet revolution called "integrated design" that this valuable book helps to explicate (in Chapter 10 and throughout). Optimizing whole systems for multiple benefits, rather than isolated components for single benefits, can often make very large energy savings cost less than small or no savings, turning diminishing returns into expanding returns. This is true not only of energy but of all resources, and not just in buildings but across whole urban systems and their resource sheds—transportation, water, waste, materials, and carbon.

For example, consider water, which is intimately linked to energy in many ways and in both directions. Stanford University's Y2E2 building

saves six times as much water indirectly through its energy efficiency as it saves directly through fixtures: synergy beats efficiency. (The building's direct energy savings, increased by higher occupancy and longer hours because everyone wanted to be there, paid back in just two years, a 35 percent annual return on investment.) Similarly, in Pittsburgh's Nine Mile Run, a costly combined sewer–overflow problem (one of more than a trillion dollars' worth across the United States) could be resolved at roughly zero or negative cost through smart landscape architecture and real estate models.

In South Central Los Angeles in 1998, TreePeople experimentally retrofitted a 1920s bungalow so effectively that a thousand-year cloudburst—71 centimeters (28 inches) of rain in 20 minutes, all from fire hoses—stayed entirely on-site. Replicated citywide, this approach could cut water imports 50 to 60 percent, help control flooding, reduce toxic runoff into the sea, improve air and water quality, save energy, cut by 30 percent the flow of yard wastes to landfills (creating instead water-retaining, soil-building mulches and composts), beautify neighborhoods, and create perhaps 50,000 jobs for urban watershed managers. The city's two biggest water agencies, one annually spending a billion dollars bringing water in and the other a half billion dollars to take it away, hadn't previously talked to each other.

The water-and-landscape story is even bigger. Professor Malin Falkenmark in Stockholm notes that the unused "green water" falling on the landscape is so much larger than the "blue water" captured in pipes that retaining and more productively using even a small fraction of the former can dwarf the major efficiency gains available from the latter. Better management of green water could lift billions out of water poverty and make food production far more resilient to climate change.

Or consider the ubiquitous asphalt car parks outside big-box stores and shopping malls. Their dark color absorbs solar heat, baking the store, customers, and their cars in hot air and radiant heat, and reducing paving life. It also absorbs light at night, boosting security-driven night-lighting standards until customers driving off the lot are so dazzled they'll have accidents anyway. In contrast, light-colored paving keeps the store, customers, and cars comfortably cool; makes the paving last almost indefinitely; and by increasing optical reflectance, can cut lighting energy to just 1 percent of official



norms with superior visibility and aesthetics. And while repaving the parking area one might as well consider photovoltaic shades and, for that matter, pervious surfaces—which in turn can shrink or eliminate costly stormwater-management infrastructure.

However many resources it encompasses, integrated design of whole systems often starts with energy. That's not the only good handle to grasp: as Chapter 8 of this book describes (and as Chapter 14 of *Natural Capitalism* described in 1999), Curitiba, Brazil, achieved astonishing results through integrative design that was first established with water, food, wastes, and other factors as priorities, then expanded, optimized, and maximized over forty years.

The needed questions are often arrestingly simple. For example, how much thermal insulation should you install in your house in a cold climate? The textbooks say to add only as much as will repay its extra cost from saved fuel over the years. This is methodologically incorrect, because it omits the avoidable capital cost of the heating equipment. My own house—at an elevation of 2,200 meters (7,100 feet) in the Rocky Mountains in Western Colorado, where temperatures used to go down to  $-44^{\circ}\text{C}$  ( $-47^{\circ}\text{F}$ )—was optimized for both operating and capital costs together (doubling its insulation) and is now simultaneously ripening its thirty-seventh through forty-first passive-solar banana crops with no furnace. When completed in 1983–4, this building used 1 percent the normal space- and water-heating energy, about 10 percent the normal household electricity, and half the water, yet repaid its 1 percent extra construction cost in 10 months. Eliminating the heating equipment saved about \$1,100 more in construction cost than it added for superinsulation, superwindows, airtightness, and ventilation heat recovery.

That building helped inspire 32,000 European “passive buildings” that have and need no heating equipment, yet provide superior comfort with comparable or sometimes slightly lower construction cost. In the 1980s and 1990s, the same approach eliminated space-cooling equipment up to  $46^{\circ}\text{C}$  ( $115^{\circ}\text{F}$ ) in dry climates—not an upper limit—and cut a Bangkok home's air-conditioning energy by 90 percent, in both cases with better comfort and normal or lower construction cost. In all these cases, today's technologies are even better and cheaper. My house has retrofitted them and is measuring their performance—complicated by the annoying tendency of the monitoring equipment to use more energy than the lights and appliances it's measuring.

Similar techniques apply to big buildings too. A few years ago, RMI co-led with Johnson Controls the conceptual and schematic design of an integrated advanced energy retrofit as part of the \$0.5 billion renovation of the Empire State Building. Normal checklists of incremental measures were initially proposed to save less than 10 percent of the energy, yet integrated savings achieved over 40 percent. Remanufacturing the 6,514 clear double-glazed windows on-site into superwindows that passed light but blocked heat—cutting winter heat losses by at least two-thirds and summer heat gains by half—combined with lighting and plug-load improvements to cut the peak cooling load by one-third. This allowed the retrofit team to renovate and shrink the old chilled-water equipment rather than replacing and expanding it, saving \$17 million in capital cost. This cut the total retrofit cost to \$13 million and the payback to three years, with stunning economic advantage to the owner, Tony Malkin, who is spreading this approach to the whole industry.

The late Greg Franta, FAIA and I designed a similarly surprising retrofit for a curtain wall office tower near Chicago in 1994, saving three-fourths of its energy with slightly less investment than its scheduled renovation, which saved nothing. Instructively, the design, though approved by the owner, was not executed. A leasing broker, short of cash and incentivized on deal flow, scuttled the retrofit to avoid delaying commissions. The property then couldn't be re-leased because of poor comfort and high gross occupancy cost, so it was sold off at a distressed price. This illustrates why successful integrative retrofit requires meticulous attention to detail—each of the two dozen parties in the commercial real estate value chain can be a showstopper, though each is a business opportunity—and mindfulness of each party's remarkably perverse incentives. But with trillions of dollars of net present value on the table, there's plenty of reason to pay attention. And today's techniques are even better—permitting, for example, an expected energy saving around 70 percent in the General Services Administration's flagship retrofit, with RMI, of the Byron Rogers Federal Building in Denver, all within federal investment guidelines. That could make it the most efficient office building in the United States despite its poor orientation, 1964 vintage, and requirements for full asbestos abatement, federal blast-resistance retrofit, and historic preservation.

Everywhere, innovation is oozing if not gushing up through the cracks. Walmart's purchasing power drove innovation that cut the cost of radiant floor-slab cooling by 69 percent (see Chapter 14). Nearly 5,000 actions by the mayors of the world's 40 largest cities are uplifting citizens, saving money, and cutting emissions (see Chapter 8). Stanford University expects to save over a fourth of its climate-harming emissions and 18 percent of its water just by integrating its buildings' heating and cooling needs in a campus-wide system (see Chapter 8). Consistently, integrative thinking trumps reductionism.

In short, this book reviews the fundamentals and opens a cornucopia of creative ideas for doing more and better with far less for longer, with lower cost and risk. To be sure, the cornucopia is the manual model—you must actually go turn the crank—but these gifted practitioners point the way to astonishing opportunities.

A concluding word about the organization of this book: Chapter 1 is an enjoyable review of climate science. It is also an update on what has happened since the last IPCC report in 2007. It brings bad news. It may depress you, and it's hard to depress people into action. So if you want to review climate science fundamentals and understand how and why our species has a serious problem caused by experimenting with the planet's climate, read it. But if you already know there's a climate problem and just want to get on with solving it—or if you want to do the same things anyway (whether you believe the climate science or not) for other reasons, such as making money or improving national security—then you can skip straight to Chapter 2. In that and the rest of this excellent book, you can learn to create abundance by design, through practical transformation, in a spirit of applied hope.

**Amory B. Lovins**

Chairman and Chief Scientist

Rocky Mountain Institute

Old Snowmass, Colorado

March 18, 2012

**AUTHORS' NOTE:** We invited Amory to author the foreword due to our deep respect for his and Rocky Mountain Institute's contribution to a sustainable built environment. Founded thirty years ago, RMI continues to be an independent, entrepreneurial, nonprofit think-and-do tank that drives the efficient and restorative use of resources. Its practices in the built environment, transport, industry, and electricity have led to such game-changing publications as *Natural Capitalism* ([www.natcap.org](http://www.natcap.org)), *Reinventing Fire* ([www.reinventingfire.com](http://www.reinventingfire.com)), [www.retrofitdepot.org](http://www.retrofitdepot.org), and hundreds of papers free at [www.rmi.org](http://www.rmi.org), all complemented by the emerging initiative "10×E: Factor Ten Engineering."

For those keen on further reading, we recommend RMI's *Reinventing Fire* (2011), which shows how a 2050 U.S. economy 2.6 times today's could need no oil, no coal, no nuclear energy, and one-third less natural gas than now; emit 82 to 86 percent less fossil carbon; cost \$5 trillion less (in net present value, counting no externalities); need no new inventions or acts of congress; and be led by business for profit.



# Preface

I decided not to tell lies in verse. Not to feign any emotion that I did not feel; not to pretend to believe in optimism or pessimism, or irreversible progress; not to say anything because it was popular, or generally accepted, or fashionable in intellectual circles, unless I myself believed it; and not to believe easily.

Robinson Jeffers (1887–1962), poet

There are many books on theory. This is not one. This book is about getting to a better place, stepping aside from the politics of climate change, and stepping into the practice of creating buildings, infrastructure, and communities that will last us into a human-stewarded future. All of the authors are practicing professionals from diverse backgrounds who have worked on some of the most well-known (and some not so well-known) high-performance projects in the world. They've seen some success and some more valuable failure. And their experience is blessed by the critical comments and prior work of their peer community of "doers"—designers, planners, policy makers, business professionals, appointed and elected officials, builders, farmers, and everyday citizens.

If I were a reader, what would capture my attention, impress and intrigue me? What are my expectations, and what would I like to discover in this book? I will not say opportunity or optimism. These words are too easy to throw around and often difficult to back up. Oversold and under-realized, one might say. A critique of either likely labels the critic a recalcitrant, or worse, a pessimist. I prefer to start at the origin of opportunity—a "coming toward a port"—and the suggestion of safe harbor. This image evokes both where we are and where we need to be. That is, dark seas with a storm brewing—and calm waters ahead, if we can reach them. However, this book is less about the storm and the safe harbor than the sails, oars, and spirit that separate the two. To better set the scene, I pull two words from the following pages, the word *synergy* and the word *compete*. The two define this book, because they tell us how to reach our goal, not just how nice it will be when we arrive. Their meaning is closer than one would expect: *synergy*, "to work together," and *compete*, "to strive together."

Our companies, countries, and people certainly do strive, but do they realize they strive together? That they push each other toward a higher *shared* goal?

Historically, the solution to shortage and growth has been efficiency. Less use per unit output. More comfort per unit input. But what if the whole idea of efficiency is incomplete? Like a fundamental law of physics, it makes sense, but only until you look outside the car and realize that it is driving toward a cliff, very efficiently.

Among the authors there is over 110 years of experience. The reviewers triple that. But more important is the range in years of experience, gender, origin, education, and age. A single voice often focuses on efficiency, but diversity seeks synergy and fosters competition. Although any of us could have written a book with a similar title (and others have), I don't believe any of us could have written this book alone.

Within its chapters, the book reviews many topics in the built environment. It lays out a methodical path for lowering carbon emissions toward zero and moving toward climate-positive communities, while simultaneously making money from the investments and creating healthier places for our families. It describes a proven process for building resilient communities that are not hobbled by extreme weather and the domino effect of accumulated risks. It showcases examples of success and failure among cities, home builders, major institutions, and large corporations.

The questions this book answers are the questions many of us ask. Can we afford a low-carbon economy? How do the trillions of square feet of buildings and billions of people *really* change—not just how *should* they change? How can carbon neutrality be both possible *and* profitable? Why do we make the decisions we do, and can we work *with* our irrational tendencies and default decisions? If we do need to adapt, what will adaptation really feel like?

In writing this book, we aimed to answer questions that each of us had in our heart. We also wanted to share our learned insights so that the ideas can go farther and wider than each of us can physically. That is, we wanted to both gain knowledge and share it.

Alisdair's windsurfing brings him often to the beach. There on the doorstep of the Pacific, he tells me he can see the ocean of his children's old age: nearly 2 meters (6.5 feet) higher and over his head by recently revised estimates, the sand beneath his toes long since washed away and the nearby buildings either flooded or barricaded behind seawalls. Fiona's hometowns of New York City and London are just as threatened by rising seas. When I visit my family's farms



and ranches in North Dakota, Minnesota, and Wyoming, I wonder how such distant effects will reach them. Will farms fail when reefs do? It's hard not to worry in general, and not to be confused by debate. The impacts are also easy to ignore on a sunny day among friends and family. Would it be as easy to ignore an impending asteroid strike, an "impact event" that squeezes all the change of a century into just a few years?

When Alisdair first outlined this book nearly four years ago, the content was much as you'll read it today. It is a play in three parts—Fundamentals, Mitigation, and Adaptation—with an emergent voice from its many authors. Chapters are (1) reviews of fundamental science, (2) position chapters that carry the weight of their authors' opinions, or (3) guideline chapters that are intended to convert easily to the professional and personal practice of the reader. References and a glossary are provided for further reading and corroboration.

The bulk of the insight and inspiration—arguably the credit for this book as a whole—stems from the projects, people, collaborators, and competitors of Arup. Although the authors work or have worked for Arup, this is not a book by a firm. The time has been largely our own, as will be the responsibility for error and omission.

We hope you will open the pages of this book and find it valuable now and in the years ahead—in terms of creativity, methodology, and how easy and how hard practice is compared to theory. We also hope that you will be inspired to continue the conversation among friends, family, and colleagues with passion and shared experience. Only through synergy and competition, working together and striving together, will we arrive safely in our harbor.

**Cole Roberts, PE, coauthor**

Twenty-two years after 1990 baseline emissions (2012)

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PART 1

# Fundamentals



A view of our atmosphere at high altitude.  
From up here, it looks fine. Can we keep it that way?  
Image: MarcelClemens/Shutterstock.com