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March—2017

High Performance

Making the Buildings-Energy Equation Sustainable

Practices, Paths and Technologies Available Now

To Achieve

Transformative Building and Energy Innovation

70%

of electricity in US is used in buildings.

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Introduction

Introduction: Buildings-Energy Transformation is Possible *Now*

***Transformation* of the building-energy equation at an affordable price** is possible *today*. It is not prohibitively expensive. It is overdue. It *does*, however, require change on multiple levels within industries long viewed as static.

The pace of change across American industry belies the idea that building sector resistance to change is irreversible. Rapid change as the norm is axiomatic in 21st Century management. Building industry practices are more likely the result of an information deficit than of things inherent in the building marketplace: even knowledgeable building professionals are frequently concerned that technologies are not on the shelf, not up to the task, too expensive for large scale market uptake, and linked to a vision for buildings that is at least a generation away.

Opportunity exists. The goal of this report is to provide a brief on what is possible, one that engages stakeholders and market actors to take seriously the prospect that building-energy transformation – not just improvement, but economic growth driving market *transformation* – can begin now. **The formula for change is not linear**. Transformation will not result from doing better what is already being done. Rather, it requires new *thinking* – a new approach to buildings and energy, both separate and linked. The hallmark of building-energy transformation is that it must be based on *systems viewed holistically*. And though the basic formula can be stated simply, it has far-reaching implications for buildings in relation to energy, beginning at conception and carrying through to their retirement. Indeed, the life of the building needs to be crafted into the building at "birth." That means first and foremost a shift in thinking about the role of building *design*.

Building transformation requires shifting from component specification to integrated design. That shift has vast consequences. To be effective, integrated design requires a new orientation toward building delivery, maintenance, and improvement over the life of the building. It implies new categories of thinking, new operations, and new standards.

What building transformation delivers is *high performance* in energy productivity, life quality, and economic impact. Buildings cannot genuinely be sustainable without transformative performance on energy, life quality, and economy. And the proposition outlined here is that they can deliver on all three: building transformation can revolutionize what we get from energy, the quality of life it provides, and the economic growth it drives. Deep transformation will begin when the marketplace is persuaded. This report is being presented to help make that happen.

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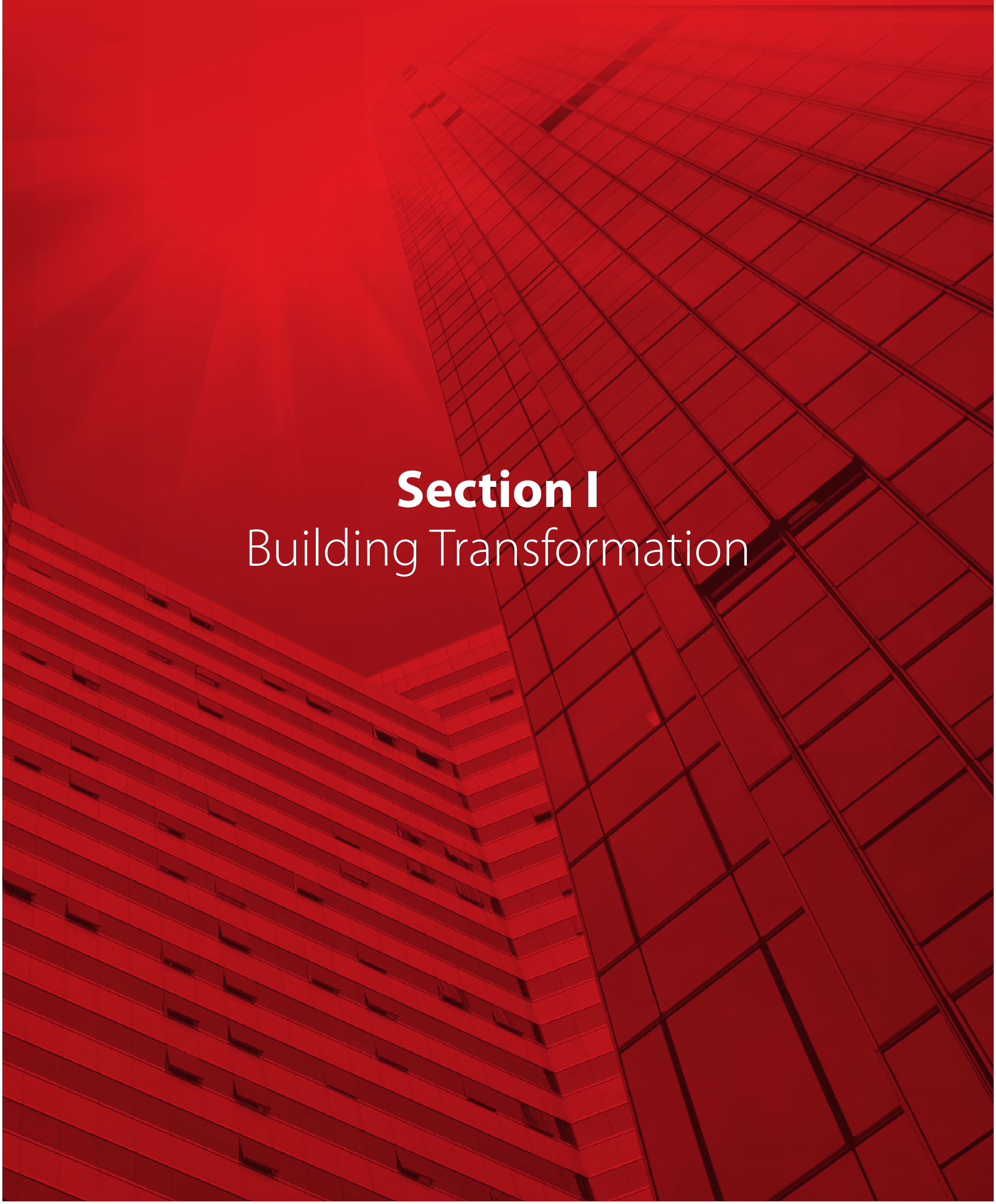

Section I

Building Transformation

Building Transformation – Why and How

Buildings consume 70 percent of the electricity generated in the US – 66 percent of which was generated, according to the U.S. Energy Information Agency, from carbon-based fuels in 2015, 33 percent from coal and 33 percent from natural gas. The United Nations estimates that current carbon emissions have placed the world on a path toward a 4-degree Celsius increase in global temperature. The agreed upon United Nations Sustainable Development Goals set the upper targeted limit at a 2-degree Celsius increase. But over half the carbon budget consistent with meeting that goal has already been spent.

And a larger challenge looms: with global population expected to reach 9.7 billion by 2050 and industrial development spreading at historic rates around the world, no emissions target within reach (assuming current building energy consumption and only expected improvements in energy efficiency) is even close to being sufficient to meeting the 2-degree Celsius target, or anything that resembles it, ever.

In 2014, energy from renewable sources was 11 percent of total electrical power – with solar at 4 percent and wind at 18 percent of total renewables based electrical power. Neither existing nor anticipated renewable energy technology will support replacement of fossil fuels as the primary source of electrical power. It is possible to improve the mix of carbon based fuels, and it is possible to grow renewables marginally as equipment costs decline and technology improves. But consequently, the 2 degrees C target can be met only by lowering *building energy requirements* dramatically, not by supplying current or anticipated energy demand with renewables based power.

The climate-carbon connection, however, is not the only reason to focus on buildings and energy. First, electricity is a cost, and in some places a substantial one. If the cost is unnecessary, it is waste, and waste is an economic drag. Second, there are important economic and security advantages to shifting the U.S. source fuel global profile. Third, extreme weather events that are growing in frequency and intensity have created serious electricity resilience issues Those can be addressed more effectively if buildings are less dependent on external power, macro grids, and centralized power generation. Looking off-shore, China and India have experienced acute air pollution problems as modernization has required more coal based electrical power. And apart from carbon issues, traditional buildings in both the developed and developing world are well known for significant indoor air quality and related health issues – problems that are all the more challenging if outdoor air quality is likewise a health threat.

Building science thought leaders are largely in agreement that the basics of traditional applied building science – that is, building science that is reflected in traditional buildings and the bulk of the nation's building stock – have not seen much innovation or deep improvement over several generations. Performance improvements across a range of criteria, including energy consumption, has been steady but decidedly incremental. And building performance too often falls off from targets not long after buildings become operational.

In sum, policy has to date not proven to be a sufficiently effective tool for achieving the levels of building performance required for climate security, energy economy, resilience, or optimum health and comfort. Today's buildings do not reflect many important advances in building science, and they do not parallel the transformational improvements witnessed in other products, from autos to airplanes. The conclusion is not that energy efficiency policy should be abandoned in order to see the value of *market driven* improvement in building performance. The questions are: "What exactly is *high performance* in buildings?" and "How do the key factors link to market forces?"

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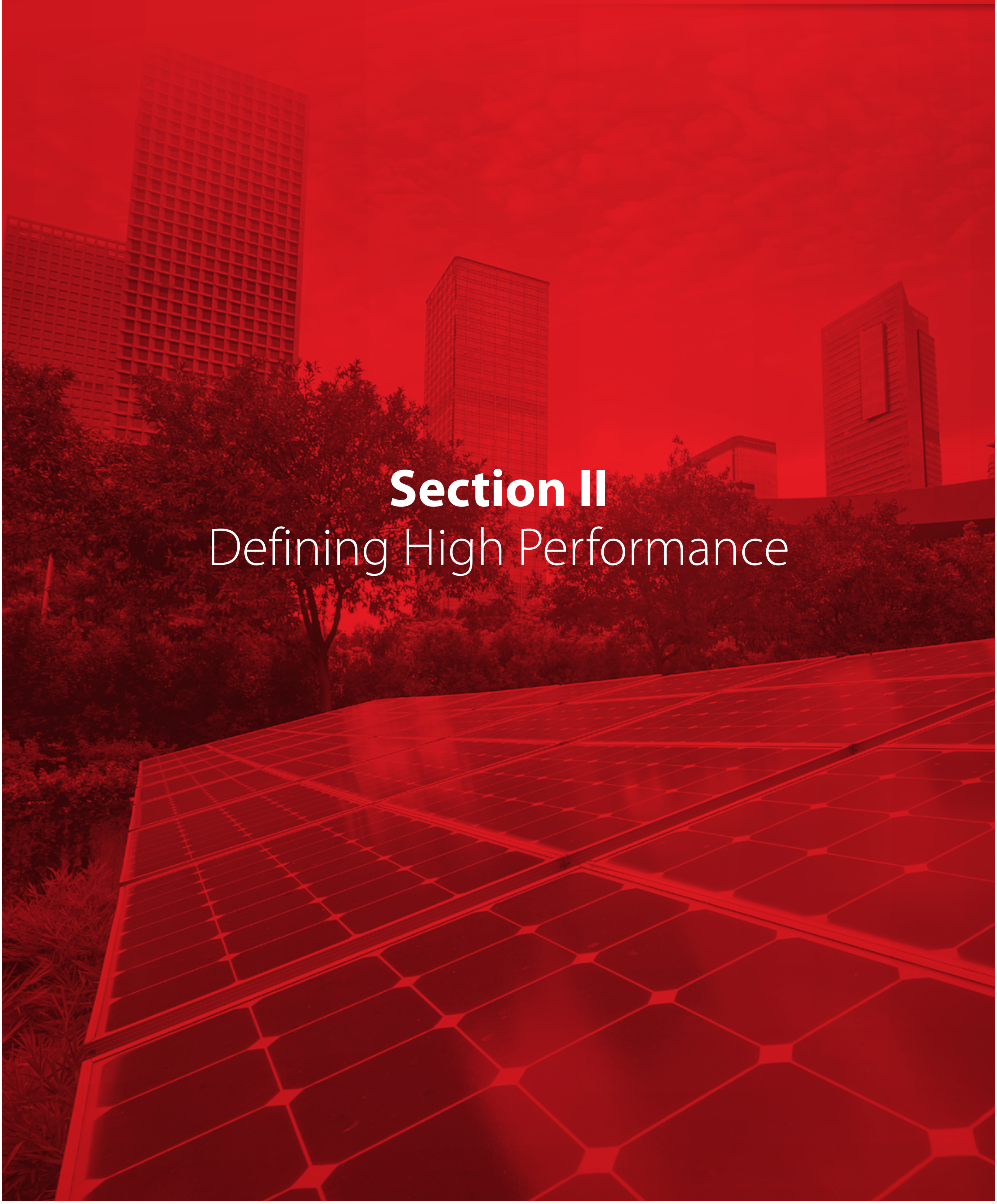

Section II
Defining High Performance

Defining High Performance

The historical trajectory of building performance is reflected in the chart to the right, which illustrates a movement from low carbon consumption and low life quality (health and comfort) within archaic buildings toward high carbon consumption and high life quality within modern ones – with the frequently realized risk that health and comfort taper off over time. In contemporary terms, as countries develop, their buildings improve in life quality performance and decline in carbon performance. Even ignoring life quality issues that emerge in developed countries as buildings age but remain operational, the dominant conception of "high performance" is at best ambiguous, for the defining trajectory of the past century or more is toward a sustainability failure which cannot be remedied by incremental improvements.

Source: Praxis

***High performance* requires breaking out of the traditional performance trajectory** of buildings. It requires buildings in which energy requirements remain low or drop dramatically while life quality improves dramatically – and stays improved. What is the measure of how dramatically energy requirements need to decline from today's levels? Various standards have been proposed, with "net-zero" getting a good deal of attention recently. It can be objected, however, that "net-zero" as a standard of building performance fails to weigh appropriately the costs of achieving high performance – especially the last margins of performance as net-zero is approached. And if the definition of "life quality" includes the opportunity cost of resources spent to achieve performance, then "net-zero" may be too imprecise a standard, failing to make explicit the implied marginal trade-offs. It might further be objected that "net-zero" as a standard for each building fails to incorporate performance opportunities offered by integration within and across communities of buildings and the larger built environment.

High performance* defined in terms of energy, health, comfort, and *economy might be better expressed as buildings that achieve and maintain high health and comfort and dramatically lower energy requirements at a cost low enough to be offset by the value of energy savings. Cost offsets that are recovered over time or out of sync with building ownership, however, are notoriously problematic as market drivers and are therefore unlikely to prompt the level of market transformation required. So, to be market driven, the definition of *high performance* needs as a practical matter to lean heavily toward at least cost parity with traditional buildings.

Returning specifically to energy requirements, "net-zero" as a building standard encompasses the building but not the variety of carbon-free energy sources that can be harnessed within a community if the *building* is integrated not only in its internal design but in its design relationship to the community of buildings, the larger built and natural environment, and the surrounding energy sources – including distributed energy resources of varied descriptions.

It emerges from such considerations that *high performance* would need to reference the full range of building and community factors that can be integrated into building performance to reduce building energy requirements to levels that can be supplied by non-carbon sources at cost parity with traditional buildings (or better) and with high quality in-building health and comfort. Such a definition may not be exhaustive: the cost not only of delivery but of maintenance as well might need to be considered, along with durability, resilience, and other such factors. But it encompasses at least the most obvious factors that bear on the challenge of market driven building transformation.

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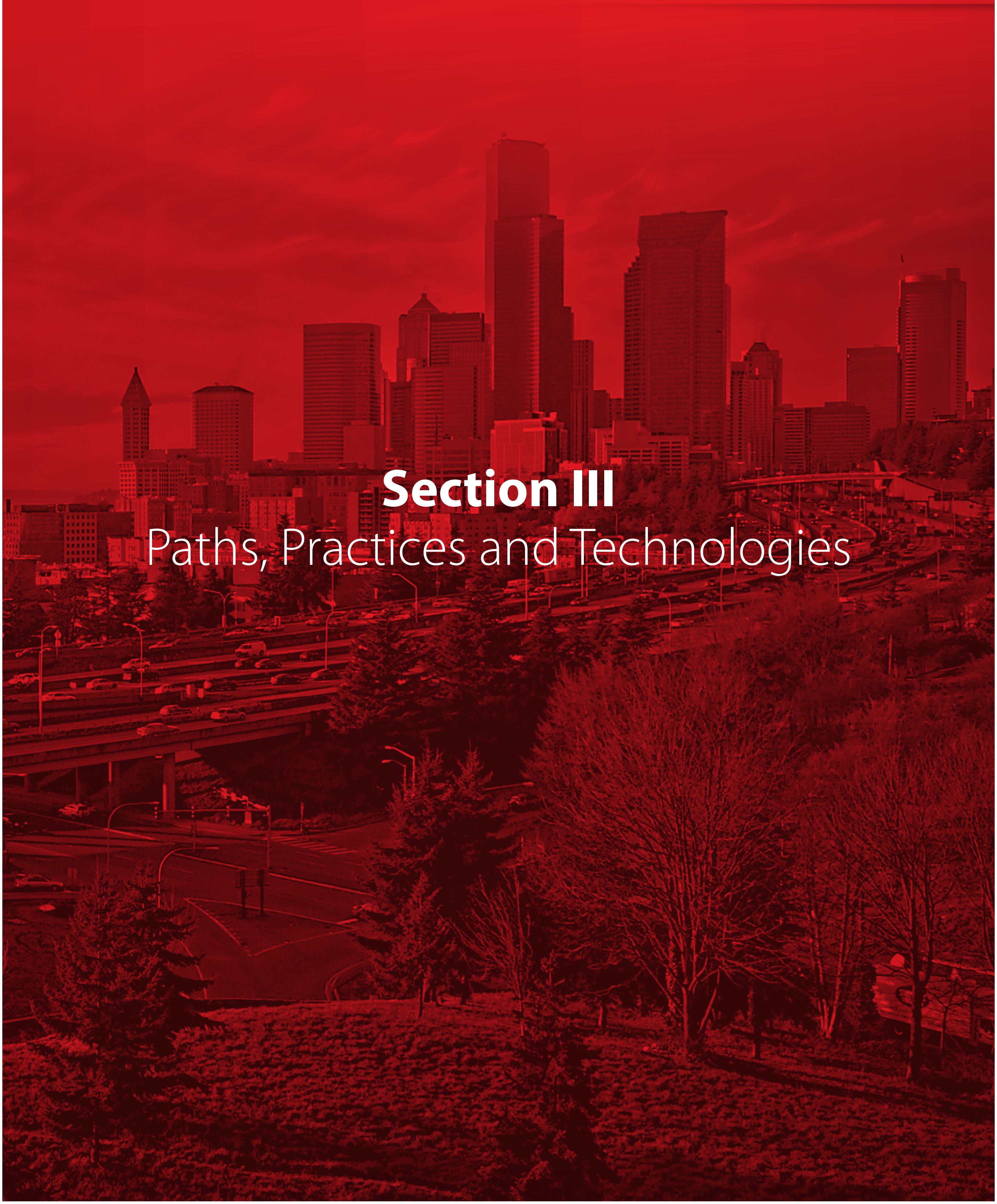
Section III

Paths, Practices and Technologies



Paths, Practices, and Technologies of Transformation

Conception

The primary concern of the present report is building energy performance. In the last generation or so – i.e., since energy performance became a priority of building science, regulation, and practice –, the primary focus has been on improving building *components*. Today, attention is shifting. Several forces underlay the shift, but the key idea is two-fold: there are solid scientific and practical reasons why the efficiencies to be gained through component improvements are now pressing against limits in performance improvement; and it turns out that other approaches yield dramatically better results.

The emerging conception of buildings can be reduced to four principles. Buildings should be viewed as:

1. **a whole composed of integrated systems and sub-systems;**
2. **integrated with a larger community of buildings;**
3. **integrated with electricity generation and distribution systems;**
4. **performing over a lifecycle within a community lifecycle.**

The art of high performance buildings is rooted in integration – over time and across a performance-relevant space.

The most obvious implication of such a holistic-systems approach to buildings and building performance is that the principles governing the *processes* by which buildings are designed, operated, maintained, refurbished and retired need to be redefined. The world of high performance buildings will operate on new paths, through new categories of thought and action, and with new opportunities for technological innovation.

Design

Eighty percent of America's commercial buildings are under 10,000 square feet. And the overwhelming bulk of those buildings are based on simple, easily replicated designs in which building performance is driven primarily by the components specified. Consequently, the performance limits of traditional buildings are defined by the difficulties of correcting design failure with technology.

High performance buildings must begin with integrative design – in which all the factors and forces that will influence building performance are treated as integrated features of the whole building equation. Such an approach implies a pronounced shift in emphasis to a creative, problem solving design process applied to each building. That shift obviously implies another: design costs will be substantially higher. So, the design function by implication assumes the task of cutting costs elsewhere to achieve (at least) cost parity while *substantially improving* building energy performance over traditional design performance.

Integrative design means team design. The factors to be integrated through the design process are diverse and variable – including all the building systems and sub-systems, external community power, building, transport, water, and other systems, and the natural conditions under which the building will operate. Those factors also include non-systemic diversity: owners, operators, managers, financiers, and even neighbors. Stated broadly, the array of conditions, processes, and personnel to be engaged over the lifecycle of the building needs to be engaged in the process through which the building is designed.

If high performance buildings need to be a collaboration, each must also be a unified conception. At the center of the design process is the "master builder" – the architectural engineering function that creatively integrates the varied demands, functions, conditions, systems, sub-systems, technologies, components, and aesthetics of the building into a synthetic whole.

Consequently, the performance limits of traditional buildings are defined by the difficulties of correcting design failure with technology.

Finance

One element of the design process is sufficiently unique in its importance and requisites to justify separate consideration: finance. Of the many reasons that finance requires special treatment, the element of risk especially stands out.

A 2016 Institute for Market Transformation study identified lax demand as the primary reason so few dollars go into financing high performance buildings. A market driven trend toward building transformation, however, will face a different challenge. Finance requires – or is at least *supposed to require* – that the investment be linked to real value, which means that the actual performance of the building needs to be very near or better than the projected building performance. Underwriting must be based on demonstrable facts the discernment of which requires data.

The need to accurately model, benchmark, monitor, and maintain or improve building performance is decisive not only to ensuring building performance but to enabling the system of finance required to make a new world of high performance buildings possible. Systemic lender confidence needs to be a leading element of integrative design. Alternatively stated, systemic lender confidence will be a leading catalyst of market transformation toward high performance buildings that generate higher value as a result of demonstrable energy performance. Finance is the natural ally of reality-based, market-driven building performance transformation.

The conclusion emerges that formalized processes documenting and ensuring building performance must set the profile of the high performance building industry. The practices of modelling, benchmarking, commissioning, monitoring, maintaining/improving, recommissioning, certifying, labeling, and valuating will need to shift from the slightly exotic activities of research and boutique enterprise to dominant industry practice. The reward for the shift will be calculated in energy performance, quality of life, and environmental improvements, and the corresponding gains in real financial value. To these factors can be added the positive economic growth consequences of moving the building industry to a high performance/high value model.

Conclusion: The need for accurate real time information on sustained building performance required both to get and maintain high performance and to justify required financing implies the necessity of formalizing a new suite of best practices and technologies as clearly defined elements of the building industry and building standards.

The New Suite of Standard Practices

Modelling: Building information modelling is the creation of digital representations of a building and of building systems actions and interactions over the building lifecycle. It enables design for high performance, projection of performance levels, and monitoring of performance during building operations. It is the tool by which data on the facts of building performance are collected, analyzed and interpreted.

Benchmarking: The benchmarking of a building is a tool for building performance assurance by comparing current building performance to projections, prior performance, or peer buildings. It provides a basis for energy accounting, commissioning and certification, and for overall quality assurance.

Commissioning & Recommissioning: Commissioning is a suite of practices that ensures that building construction projects, new or retrofit, deliver a building that performs at the level specified by the designer and the owner. Systems and sub-systems are tested and inspected, and their condition and performance are documented. Recommissioning ensures ongoing capacity to reach targeted performance levels.

Monitoring: Building performance monitoring employs a "dashboard" overview of current building system and subsystem performance tied to tiers of metrics at the whole building, building system, and sub-system levels, providing real-time data and enabling real-time correction of failures or weakness in building performance.

Certifying & Labeling: Certification of building performance is the critical third party audit and confirmation of building performance by a qualified architect and/or engineer. It is the professional confirmation of performance in operation that provides baseline transparency and necessary information to the building and financial marketplace. Certification and labeling need to be repeated at intervals and can provide the basis for performance correction as required by owners, financiers, and regulators.

Valuation: Valuation of buildings is the method(s) by which the market value of building performance is determined. Possibly due to the lax owner demand for high performance building financing, it may be the issue on which the least work has been done. But it is a means by which the science of building performance is converted into knowledge-based economic value to the owner – reflected in higher occupancy rates, lease-up rates, sale prices, lower operating expenses, higher operating income, and lower capitalization costs.

The New Suite of Building Technologies – Examples from the Marketplace

Just as the world of high performance buildings requires that important practices be institutionalized as sources of reliable performance information and analysis for decision making, it also requires a more defined focus on certain technologies that are decisive to high performance. Among these are technologies related to the building envelope and systems controls, variable speed and frequency technologies, power generation, energy storage, and the internet of things as it applies to both data and performance control.

Envelope: The envelope is what distinguishes the interior from the exterior of a building and is made up of the walls, roof, doors, windows, skylights, and more. Interior building systems – e.g., lighting, ventilation, heating and cooling – are in large measure a response to conditions created by envelope design. In brief, the envelope design defines the challenges that energy consuming interior systems are designed to solve. To the extent that envelope design resolves the challenges of building design passively – the building is intrinsically high performance.

Controls: Building automation provides a centralized control system to manage the activity and interaction of ventilation, heat, air conditioning, lighting and other building systems and subsystems. It makes the adjustments in the operation of systems required to address problems not addressed by envelope design, and can be crafted into the original building design or retrofitted. It refines performance in comfort, energy, and operating cost, as well as improving the lifecycle of utility power generation and distribution systems.

Variable Speed & Frequency Technologies: Variable speed and variable frequency technologies permit precise matching of building load, need, and capacity through control of fan or motor speeds in building systems and subsystems. It permits precision in equipment sizing and managing energy use for efficiency and savings. It is the precision and flexibility of variable speed and frequency technologies that prevents the waste of excess energy consumption to ensure targeted comfort performance.

Combined Heat and Power (CHP): Combined heat and power, or cogeneration, employs a single energy source to generate both electrical and useful thermal energy. The earliest power generation in the U.S. used CHP to produce electricity and provide heat for nearby buildings. The practice was discontinued as rural electrification spread reliance on centralized generation and large scale power grids. CHP technology facilitates use of multiple generation centers, or "distributed energy," a shift to more varied fuel sources, including natural gas and renewables, and consequently the reduction or elimination of carbon emissions.

Energy Storage: Carbon-based fuel sources are extracted from nature and thus from a "stored" state. Availability of renewable energy sources such as wind and solar energy fluctuates, as can the demand for power. So, renewable energy, CHP, and microgrid deployments require complementing storage technologies to provide for fluctuation in either fuel supply or power demand. Technologies are available to provide energy storage using water, ice, compressed air, thermal mass, and batteries. Energy storage also supports the resilience, reliability, flexibility and efficiency of energy supply.

Internet of Things: The internet and digital technologies make possible the real-time collection of data from all internal and external building and energy systems and the control and optimization of system and subsystem action and interaction, especially from remote locations. It is the culmination of the effort by building science to control the intricacies of building performance at the micro level and in real time, operationally articulating all internal and external building and energy systems and subsystems into a single entity.

Among these are technologies related to the building envelope and systems controls, variable speed and variable frequency technologies, power generation, energy storage, and the internet of things as it applies to both data and performance control.

Section IV
Reports from the Frontier

Action: Reports from the Frontier

Cities have in the past few decades formed the frontier of progress in building-energy sustainability. Urban action has been supported in some instances by state-level policy and a federal framework and research. An international policy framework is emerging, as well, through the United Nations sustainable development initiatives and the 2015 Paris Agreement on carbon emissions. But cities are where the action is. Concretely, "action" means setting targets, resetting codes, and assembling resources to support transformation. The cities at the frontier are being looked to not only for effective paths, best practices, and evidence that building energy sustainability is doable. They are also being eyed for signs that there are advantages to being on the frontier – that local action on a global challenge pays local dividends. The jury may still be out on how sustainability action pays off, but the outlines of the wagers being placed are clear and form the playbook to which the next wave of cities will look as they plot their paths in the competition for talent, investment, and recognition for leadership.

New York City

As the long-established population, commercial, and financial center that radiates from the Atlantic Coast across the continent and around the world, New York City has deep roots, a wealth of old buildings, and constant building construction and innovation. In its diversity, it is a microcosm of North America. And it has set its sights on a level of urban sustainability that has surprised many.

It's *One City: Built to Last* program focuses on a central fact: 70 percent of the city's greenhouse gas emissions result from the energy consumed by buildings. The city has responded with challenging targets, including a 30 percent emissions reduction by 2025 against a 2005 baseline, and an 80 percent reduction by 2050. NYC aims to be a center of transformative building-energy innovation. And the city's leaders maintain that the steps they are taking will not only advance sustainability, they will also energize the economy, fueling new enterprises, creating jobs, making homes more affordable, and attracting talent.

Specific fronts on which the city is moving include laws on benchmarking, energy audits, retro-commissioning, energy conservation code upgrades, data collection and dissemination, and innovation finance. Large buildings are being required to benchmark against other buildings and against themselves year over year on both energy and water. Buildings with 50,000 square feet or more of floor space are now required to perform periodic energy audits evaluating energy consumption and building equipment selection, installation, and performance. The city building energy code is subject to regular upgrades to keep it at or above standards set nationally or at the state level. Financial resources are being provided for customized energy studies for commercial, industrial, institutional, academic, healthcare, and government buildings. And federal funds and tax incentives are being married with state funding of $250 million annually to create direct incentives for energy use reduction and market transformation.

The overarching picture that emerges is of a city deploying a wide range of policy tools to activate a historic shift in the building-energy paradigm. The focus is on the one million existing structures and especially the 15,000 buildings with more than 50,000 square feet of floor space – buildings that together constitute 2 percent of the city's properties but over half its square footage and 48 percent of total energy use. And the effort belies in scale, scope, and depth the common assumption that the building-energy arena is too fragmented and its commercial incentives too diverse and misaligned for concerted action on building-energy sustainability.

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Los Angeles

On the other side of the continent, another of America's leading cities has set out to drive transformation in buildings and energy: Los Angeles. The city has put in place its Sustainable City pLAn that sets goals of 14 percent reduction in energy use across all building types by 2025 and 30 percent reduction by 2035.

The city's suite of policies includes benchmarking and disclosure of energy use information, audits and retro-commissioning for large buildings, and initiatives for (1) ongoing review and disclosure of building energy use data, (2) new voluntary energy efficiency programs, (3) strengthening energy codes and (4) making municipal buildings more energy efficient.

The Los Angeles Department of Water and Power has joined in by setting the country's most aggressive municipal utility goal: reduction of energy use by 15 percent by 2020. The State of California has similarly required that all new residences be "net zero energy" by 2020 and new commercial buildings by 2030.

The city is providing workforce training required for transformation, and in the next few years integrated design options will be explored for incorporation into codes, including integrated design processes, passive house design strategies, and high performance approaches emphasizing high performance insulation, air tight building envelopes, heat recovery and ventilation, passive-solar heat, and modeling software for energy gains and losses and passive design.

Like the steps being taken by New York City, Los Angeles' strategy aims at a fundamental shift in the building-energy paradigm. It combines regulation and voluntary action, government programs and utility initiatives, and a reliance on data and commitment to transparency. Neither city seizes on every potential tool in the policy or technology tool kits, but each puts in place powerful elements of a strategy to achieve transformative goals and, as important, shift the tide in building-energy strategy to drive decarbonization and economic growth simultaneously.

Pittsburgh

Perhaps the quintessential Northeast "rust belt" city, Pittsburgh is a crossroads for iron and coal, known historically for steel and other heavy manufacturing. Despite suffering deeply in the restructuring of the global economy that has occurred since the 1980s, the city's economy has found new footing in biomedical technology, healthcare, education, high tech and robotics, and other 21st Century industries. Still, the legacy infrastructure is old and some would say built for another time. It is not the first place one might look for building-energy innovation.

Nonetheless, such innovation is happening. Pennsylvania has plentiful Marcellus Shale gas that fits neatly into a distributed energy strategy aiming simultaneously to cut carbon emissions, expand available electrical power, promote economic growth, and prepare a path for widespread adoption of renewable energy technologies as they become more economic. Out of the combination of Pittsburgh's existing infrastructure and the region's abundant natural gas, a vision has emerged for Pittsburgh of a collaborative effort to create a "grid of microgrids" using shale gas to provide both thermal energy and electricity.

The U.S. Department of Energy's National Energy Technology Laboratory and the City of Pittsburgh signed a Memorandum of Understanding in July 2015 to work jointly to design a 21st Century Energy Infrastructure demonstration project creating multiple distributed energy centers throughout the city. Penn State University's Philadelphia Navy Yard research facility has joined the effort.

One initiative within the project framework is Pittsburgh Allegheny County Thermal Distributed Energy, also known as PACT. First established in 1983, the system has 59 buildings, many owned by local government, and a 500,000 lbs/hour of steam capacity. Another, Northside Distribution NRG Pittsburgh has a capacity of 240 Mlbs/hour of steam serving over 30 buildings totaling over 6 million square feet. A third facility, Oakland District Energy Bellefield Boiler Plant – built in 1906 - serves most of the Oakland region's major industries with 460,000 lbs/hour of stream. A fourth is the Uptown Energy District Eco-Innovation District, where the University of Pittsburgh Medical Center, the Consol Energy Center, the Chatham Center, and others are part of the Lower Hill Redevelopment.

There are seven such distributed energy systems being developed in Pittsburgh as part of the NREL/Penn State collaboration. They are built on legacy infrastructure and harness the capacities of a first-class national energy lab and one of the world's top ranked architectural engineering university programs. The goal is to explore new ways to capture the capacity of microgrids to facilitate the shift to low carbon footprint distributed energy and ultimately to electrify with CHP enabled renewables in the very heart of the Rust Belt.

Taken together, they are converting the existing infrastructure of a mature urban space into a testbed for low carbon or zero carbon power generation sufficient to drive a very modern city – and providing a model of how science, innovation and vision can recreate the building-energy equation to gain sustainability, economic vitality, and a rising quality of life in a city many thought a relic of a now gone economic era.

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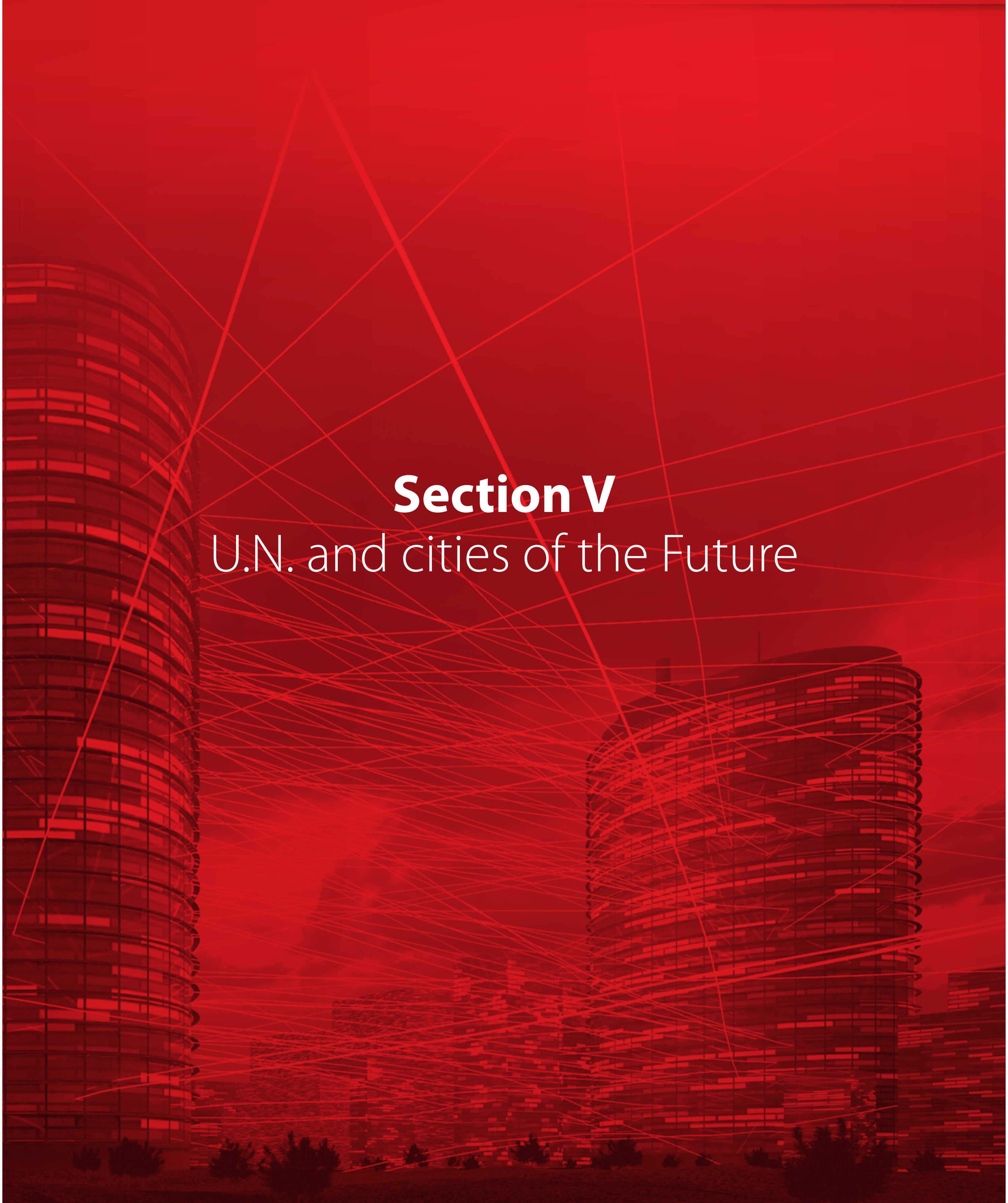

Section V
U.N. and cities of the Future

The United Nations and Cities of the Future

Events in New York, Los Angeles, and Pittsburgh are exemplary of steps being taken to advance building-energy sustainability, economic transformation, and an improving standard of living. There are many cities making such efforts – Vancouver BC, Brussels, Boston, Philadelphia, and more. They amount to sophisticated, large scale grassroots efforts to open a new paradigm for cities – in and around which about 80 percent of the US population lives. It may be too early to be certain of success, but there is ample evidence of progress and a path ahead.

However, the question of transference remains – how to migrate ideas, knowhow, technology, and capacity from a handful of leading cities to the vast community of cities in the U.S. and around the world. For with population rising, urbanization spreading, carbon emissions growing, and the global demand for electricity exploding, nothing less than global impact will be sufficient to sustainability and the rising quality of life, in buildings and beyond, to which people everywhere aspire.

The United Nations is best known for the General Assembly, the Security Council, the Secretary-General, and a few other highly institutions. Much of the body's operational capacity, however, is found in five regional Commissions that work to implement the policies and agreements reached by the better known structures.

One of these is the United Nations Economic Commission for Europe (UNECE), with 56 members reaching from the North Asian Pacific across Eurasia and the Atlantic to the U.S. and Canada. The UNECE is in the course of developing and adopting a framework for building standards that will offer guidance on how to create a world of high performance sustainable buildings consistent with carbon free energy, economic progress and better quality of life within buildings and across the built environment. The framework presents a systematic overview of a new world of buildings, one rooted in integrated design, ongoing performance evaluation, and life-long performance improvement, integrated with zero-carbon renewable energy.

With expected support by education and technical assistance initiatives, the framework is an effort to build on the experience and knowhow of cities such as New York, Los Angeles, and Pittsburgh to create a new building-energy equation. It was inspired by the UN's Sustainable Development Goals and the 2015 Paris Agreement on carbon emission reduction.

The UNECE building standard framework initiative is an example of the macro influence of global aspirations married to local experience in building-energy sustainability. It projects a world of science-based low- or zero-carbon buildings enjoying a rising quality of life amid economies activated increasingly by 21st Century industry. The emergence of the world thus projected might seem generations away, but the press of circumstances is joining with the inducement of opportunity to draw a distant future forward faster than many thought possible.

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