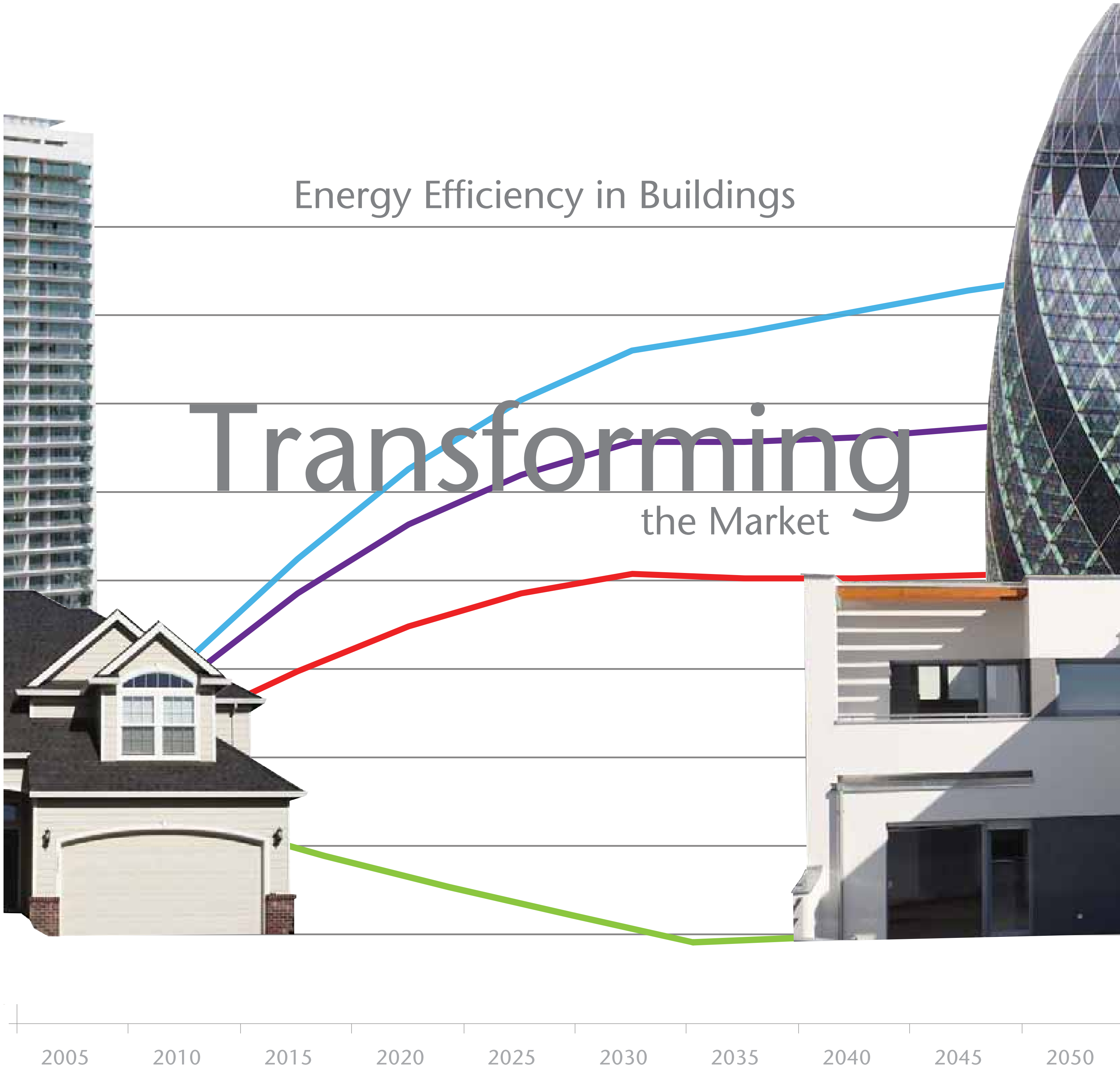
Energy Efficiency in Buildings

Transforming the Market



World Business Council for
Sustainable Development

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About the WBCSD

The World Business Council for Sustainable Development (WBCSD) brings together some 200 international companies in a shared commitment to sustainable development through economic growth, ecological balance and social progress. Our members are drawn from more than 36 countries and 22 major industrial sectors. We also benefit from a global network of 58 national and regional business councils and partner organizations.

Our mission is to provide business leadership as a catalyst for change toward sustainable development, and to support the business license to operate, innovate and grow in a world increasingly shaped by sustainable development issues.

Our objectives

Business Leadership – to be a leading business advocate on sustainable development

Policy Development – to help develop policies that create framework conditions for the business contribution to sustainable development

The Business Case – to develop and promote the business case for sustainable development

Best Practice – to demonstrate the business contribution to sustainable development and share best practices among members

Global Outreach – to contribute to a sustainable future for developing nations and nations in transition

The Energy Efficiency in Buildings project

This is the summary final report of the Energy Efficiency in Buildings (EEB) project. *(Full details available at www.wbcsd.org/web/eeb.htm)*

The project has focused on six markets that produce more than half of the world's GDP and generate almost two-thirds of global primary energy: Brazil, China, Europe, India, Japan and the US. The first stage analyzed the markets and issues, including the first-ever comprehensive, global market research to explore energy efficiency in buildings among building sector professionals. We reported the results in 2007 in *Energy Efficiency in Buildings: Business realities and opportunities*.

EEB has considered high-level scenarios but has taken a bottom-up, market-driven approach to understanding the barriers to lower energy use, based on the most detailed view ever of the current state of energy demand in the building sector. The project developed a unique computer model that simulates decisions about energy investments in a specific building subsector to identify the likely mix of design and construction options under alternative policy packages *(see chapter 2)*.

Outreach to building industry stakeholders – business leaders, government officials and non-governmental organizations – has been an important feature of this project. Four major events were held, in Beijing, Brussels, Delhi and São Paulo, as well as several workshops and hearings on specific subjects. We participated in or organized events in the following cities: Amsterdam, Barcelona, Beijing, Bonn, Boston, Brussels, Bucharest, Eindhoven, Geneva, Glasgow, Hartford, Hong Kong, Ljubljana, London, Madrid, Melbourne, Moscow, New Delhi, New York, Oslo, Paris, Porto, Poznan, Rio de Janeiro, Shanghai, San Francisco, São Paulo, Singapore, Stockholm, Tokyo, Washington, Wilmington and Zürich.

We recognize that building energy is part of a complex system that includes transport and urban planning and has major social consequences as well as climate change impacts. The energy mix is also important in determining carbon dioxide emissions. But this project has focused primarily on the energy used in buildings.

EEB is a project of the World Business Council for Sustainable Development (WBCSD). It is chaired jointly by Lafarge and United Technologies Corporation and has 12 other members, shown on the acknowledgements page at the end of this publication. An Assurance Group has provided advice and overall scrutiny of the project. The Group was chaired by the former head of the UN Environment Programme, Klaus Töpfer, and included Hon. Eileen Claussen, President of the Pew Center on Global Climate Change (US), Thomas B Johansson, Professor of Energy Systems Analysis and Director of the International Institute for Industrial Environmental Economics (IIEE) at the University of Lund (Sweden), Vivian Ellen Loftness, Professor and Head of the School of Architecture, Carnegie Mellon University (US), Shin-ichi Tanabe, Professor in the Department of Architecture at the Waseda University (Japan), and Jiang Yi, Vice Dean of the School of Architecture at Tsinghua University (China).

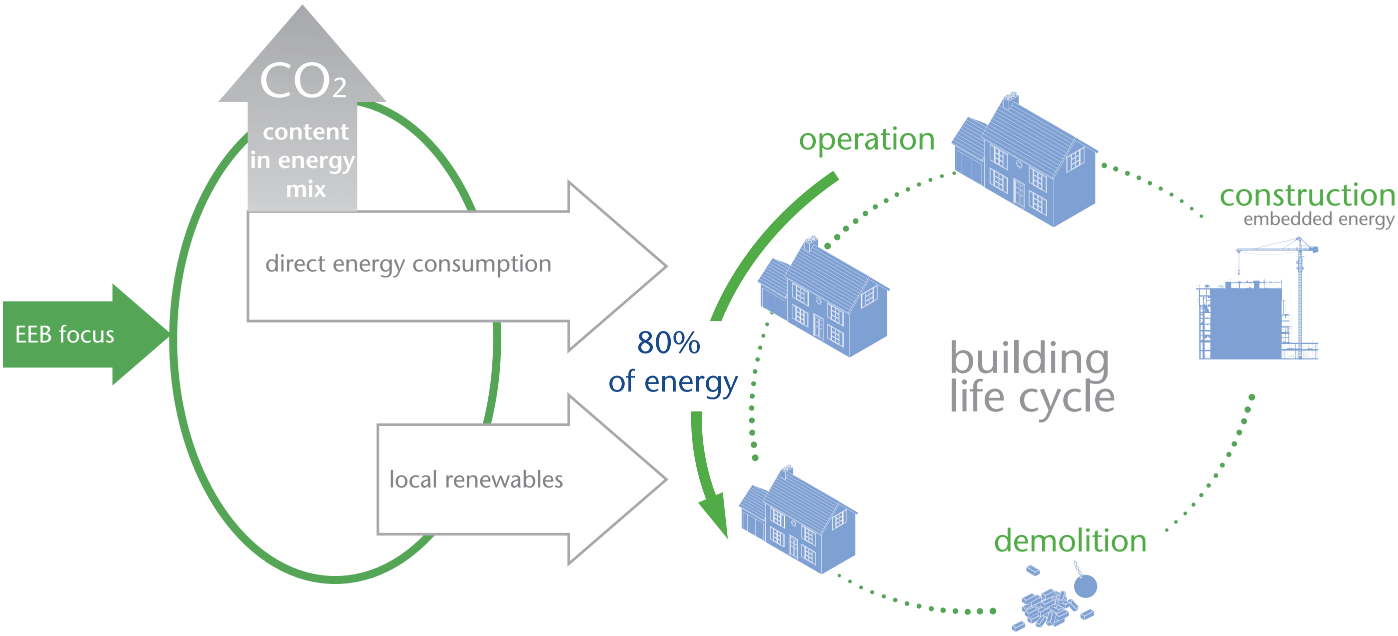


Figure 1

Energy use in operation is the EEB focus

Our report

The EEB project has focused on energy use so we have not covered the many other important aspects of sustainable building. The energy implications of transport, water use and food choices can be as important as the direct energy savings in buildings, but they are beyond the scope of this project.

The supply side of the energy equation is important but we have concentrated on the demand side. Energy sources and mix, including the potential of district heating and cooling are also beyond our scope. (A separate WBCSD project is working on energy supply.) We recognize that using more grid electricity from non-fossil fuels (such as solar and wind) will help to address climate change. But cutting energy consumption is also vital because it helps to preserve finite resources, lowers costs for businesses and consumers, can be accomplished relatively quickly and because the contribution of non-carbon fuels is likely to be constrained for several decades.

Our report and the project concentrate on energy used in buildings during their operation. Depending on the level of energy services, this can be 80% of the total energy, along with construction and demolition and the embodied energy in the materials (see figure 1). We consider the contribution that local renewable energy can make to cutting CO_2 emissions, for example through rooftop solar power, but reducing emissions in grid energy generation is outside the scope of this project (although in projecting emissions levels, the EEB model takes account of the CO_2 released by locally generated power).

Assumptions for the future

In EEB scenario exercises, working groups developed three alternative pathways for energy use in buildings (described in chapter 1). This thinking influenced our simulations but we have not attempted to predict developments in technology, social structures, values and attitudes in society. All these will change over time and our detailed conclusions need to be viewed alongside the reader's own assumptions about those changes. Our broad recommendations are for action today and are therefore relevant to today's conditions.

While we have simulated the impact of price signals for energy and carbon in our simulations, we do not address the broad issue of carbon pricing. We have assumed, in line with WBCSD thinking, that a post-Kyoto agreement will result in some form of tax or trading that provides a price signal.

We began our project in 2006, when the global economy was booming. We publish our report in very different economic circumstances. Our focus is on the period to 2050 so we must assume a return to stable economic conditions at some point. We base our analysis and recommendations on that assumption and in the context of "normal" economic growth. Yet we know that much stronger and bolder measures are needed to cut emissions and stabilize the climate. There is growing pressure on economies to stimulate markets using investments that offer long-term returns. The large investments we project could act as a stimulus as well as provide long-term energy security and CO_2 benefits.

Executive summary

To achieve an energy-efficient world, governments, businesses and individuals must transform the building sector through a multitude of actions, which include increasing energy awareness globally. Buildings today account for 40% of the world's energy use. The resulting carbon emissions are substantially more than those in the transportation sector. New buildings that will use more energy than necessary are being built every day, and millions of today's inefficient buildings will remain standing in 2050. We must start now to aggressively reduce energy use in new and existing buildings in order to reduce the planet's energy-related carbon footprint by 77% or 48 Gigatons (against the 2050 baseline) to stabilize CO_2 levels to reach the level called for by the Intergovernmental Panel on Climate Change (IPCC).

Based on extensive research conducted over the past four years, the Energy Efficiency in Buildings (EEB) project has developed recommendations and an actionable roadmap to transform the building sector. The project began with a comprehensive inventory of current and future building stock and modeled the impacts of consumer preferences and behaviors, designs and technologies, and policies on energy consumption. The project is focused on six markets — Brazil, China, Europe, India, Japan and the US — that represent nearly two-thirds of the world's energy use. This degree of data and model detail and sophistication has never been achieved before.

Detailed analysis shows there is a path to achieving the necessary reductions and that, by 2050, energy savings in buildings can equal the total energy consumed in today's transportation and industrial sectors combined. It is clear that financial, behavioral and knowledge barriers must be overcome for individuals, governments and businesses to aggressively adopt energy saving options. It is also clear that delaying action will only increase the ultimate CO_2 emissions reductions and associated costs needed for climate stability.

The study and analysis modeled three scenarios for the world's response to the climate challenge in buildings:

- Complacency and inaction leading to a failure to tackle climate change
- Inadequate action resulting in only incremental improvements in energy efficiency and a substantial failure to curb climate impacts
- Coordinated, intensive action that transforms the building sector and contributes proportionately to solving climate change.

The third scenario is understandably the only option that can result in the energy and carbon footprint reductions needed. A mix of measures tailored to specific geographies and building subsectors, including increased energy awareness globally, is required for a complete solution. Additional approaches include building energy codes, labeling and reporting mechanisms, appropriate energy prices and carbon costs, investment subsidies, increased and trained workforce capacity, and evolving energy-efficient designs and technologies that use passive and active approaches.* Combined, these measures provide the changes needed to reduce energy consumption in buildings, increase energy awareness globally, and influence behavior change and the choices of consumers and investors. However, these changes cannot and will not come through market forces alone.

*Passive designs include natural ventilation, use of daylight, building's shape and orientation, thermal mass, solar gains, shading, etc.

Facts

- Buildings' share of final energy consumption: 30-40%
- Global CO_2 emissions from energy in buildings (2005): 9Gt
- Estimated growth by 2050 in all 6 EEB regions: 76%
- Growth in global population by 2050: 2.7 billion or 42%

Many energy efficiency projects are feasible with today's energy costs. At energy prices proportionate to oil at US$ 60 per barrel, building energy efficiency investments in the six markets studied, totaling US $150 billion annually, will reduce related energy use and carbon footprints by 40% with five year discounted paybacks. A further US$ 150 billion with paybacks between five and 10 years will add 12 percentage points and bring the total reduction to slightly more than half. Additional investments to achieve the 77% target will not be justifiable on economic return grounds at today's energy prices and will require the additional steps outlined in this report.

EEB modeling shows that increasing the price of energy or carbon will only slightly increase the implementation of energy-efficient options. In fact, reductions would only marginally increase — from 52% at today's energy prices to 55% with an incremental carbon cost of US $40/ton.

Action for change

As described in the project roadmap, transformation will require integrated actions from across the building industry, from developers and building owners to governments and policy-makers. This set of recommendations outlines the necessary steps to substantially reduce energy consumption and resulting carbon emissions.

Strengthen codes and labeling for increased transparency

Policy-makers and governments must extend current building codes to include strict energy-efficiency requirements (adapted to regional climate conditions) and commit to enforcing and tightening these over time. The building industry and governments must also develop energy measurement and labeling mechanisms requiring non-residential building owners to display energy performance levels.

Building energy inspections and audits must be introduced to measure performance, identify improvement opportunities, and establish priorities for implementing efficiency measures. In multi-family residential buildings, tenants must be given access to energy controls for each unit and charged for energy use individually. Such energy inspections in commercial buildings should be incorporated into existing fire and health and safety inspections.

Incentivize energy-efficient investments

Governments will need to provide tax incentives and subsidies to enable energy-efficiency investments with longer payback periods. Charging structures should be introduced to encourage lower energy consumption and on-site renewable generation. Suitably promoted marketplace behaviors can be expected to accomplish a significant portion of the US$ 300 billion in investments annually leading to a 52% reduction from the IPCC's 2050 baseline. The balance, and investments exceeding the 10-year discounted payback threshold at today's energy prices, will require additional incentives to become reality. Businesses and individuals must work together to develop creative business models to address and overcome the first cost barrier to energy efficiency.

Encourage integrated design approaches and innovations

Property developers need to be encouraged to restructure business and contractual terms to involve designers, contractors and end users early and as part of an integrated team. Governments should introduce incentives for developers to submit applications for energy-efficient buildings. Subsidies and other incentives for domestic energy–efficient improvements should be related to an integrated approach aiming to improve the overall energy performance of the building.

Develop and use advanced technology to enable energy-saving behaviors

Only a third of the investments required to achieve the IPCC's 77% emissions reduction target have discounted paybacks of 10 years or less, a measure of the opportunity to improve energy-efficiency technologies in building. Government authorities need to provide support and investment for research and development of effective energy-efficient building technologies so that greater rates of advance are technically and readily achievable.

New and refurbished buildings should be designed to use information and communication technology that minimizes energy use and is easily updated with technological advances for buildings to operate at an optimal energy level. Technologies exist today but can be improved and extended to countless existing structures accordingly. Utilities can participate by confirming deviations from best practice in regular usage statements.

Develop workforce capacity for energy saving

The building industry must create and prioritize energy-efficiency training broadly for all involved in the sector and create vocational programs specifically for those who build, renovate and maintain buildings. It is also important to develop a "system integrator" profession to support retrofitting in residential properties.

Mobilize for an energy aware culture

Businesses, government authorities and others must establish sustained campaigns to promote behavior change and to increase awareness of the impact of energy use in buildings. It is essential to demonstrate their commitment to addressing this urgent challenge by cutting the energy consumption of their own buildings.

1. A big opportunity

"The challenge is to drive people to make them understand that it's an opportunity."

Participant at EEB Finance workshop
October 2008

The building sector must radically cut energy consumption – starting now – if countries are to achieve energy security and manage climate change. Some developed countries will have to slash building energy use to at least 80% below the business-as-usual (BAU) projection. High-growth countries such as China and India also must orchestrate a step-change in energy efficiency. The work and investment necessary for this can also contribute to economic growth and employment, especially in the building sector. Saving energy is the lowest cost way to cut greenhouse gases.[1]

These significant cuts are achievable. Much building energy is wasted because of poor design, inadequate technology and inappropriate behaviors. Businesses need to apply expertise and finance to develop and promote new approaches to energy efficiency, but transformation will not be achieved through the market alone. Building professionals, owners and users do not grasp the urgency and remain unmotivated to act. BAU inertia is a drag on progress, and short-term financial criteria rule out many energy-efficiency investments. Government action is necessary to improve transparency of energy consumption in buildings and to stimulate the transformation of business models to quickly change energy consumption throughout the building sector – in every country, in existing buildings as well as new ones and in residential as well as commercial property.

All building sector stakeholders need to adopt a sense of urgency and a new mindset in which building energy is a top priority. Businesses will only succeed if they align with a sector transformation, adopting disruptive technologies and business models. Policy-makers need to introduce strong regulatory frameworks that support the market transformation.

Action is essential as part of the world's response to climate change because energy use in buildings is 30-40% of final energy consumption[2] and carbon dioxide emissions in most countries. Emissions can be reduced by cutting the carbon content of energy sources (including the use of renewable energy) but the EEB project focused on these three elements:

1. Cutting energy demand – including the use of designs, materials and equipment that are more energy efficient
2. Producing energy locally – from renewable and otherwise wasted resources
3. Using smart grids – generating a surplus in some buildings and feeding it into the grid.

It is good business to be part of a stable transition to a low-energy world. Energy is vital to business, which prospers best in stable social and economic environments. That stability is threatened by energy insecurity and climate change. Volatility in energy supplies and prices is disruptive; the social upheaval that would follow serious climate change would be damaging to economies, people and the environment. Using more renewable energy will help, but cutting energy consumption is vital because these energy sources are likely to grow slowly, and serious action is necessary now.

Unique quantified analysis

Our conclusions and recommendations are the result of a four-year analysis of building energy, supported by a comprehensive building energy database and a sophisticated computer model developed by this project. The model is the first of its kind to predict how variables such as policy and regulatory factors, price signals and behavior change can affect global energy use in buildings, based on detailed data on the building characteristics and energy use in specific subsectors.[3] Our analysis *(see chapter 2)* clearly shows the scale of the challenge and the impossibility of meeting it at current rates of progress.

Our conclusion: under current financial and policy conditions, building decision-makers will not spend sufficiently on energy efficiency, even on investments that pay off over a project lifetime. Financial timescales for owners of both residential and commercial buildings are generally too short to allow improvements that would save energy and pay off over the lifetime of the investments.

A huge opportunity exists

Ways must be found to achieve the necessary investments within the constraint of short financial timescales. This presents an excellent opportunity for business to develop new products and services that cost-effectively reduce the energy burden on consumers, countries and climate. This market could be worth between US$ 0.9 trillion and US$ 1.3 trillion. *(See chapter 3.)*

Both new and existing buildings can be made more energy-efficient using a combination of passive and active measures in design and operation. Incorporating the best design and technical solutions in new and existing buildings can cut energy use by about two-thirds, without considering improving the performance of small appliances and equipment used in the building. Some very low-energy new homes already exist in many countries, demonstrating that our energy targets are technically achievable *(see examples throughout this report)*. But these examples show little sign of being scaled up globally. Low-energy buildings must become the norm rather than the novelty project.

"Business is typically incremental, not radical. But we need disruptive technologies."

Participant at the EEB Behavior workshop
August 2008

Three levers for transformation

In our first report we identified three business levers, supported by an appropriate policy framework, to transform the building sector. They were the foundation of the work described in this report:

- The right financial mechanisms and relationships to make energy more valued by those involved in the development, operation and use of buildings, and to stimulate investment in energy efficiency.

- A holistic design approach, from city level to individual buildings, to encourage interdependence and shared responsibility among the many players in the building value chain. This relates to integrated design, incentives that stimulate whole building action rather than encouraging changes only to individual elements and using advanced technology as part of an integrated solution to energy reduction.

- Behavioral changes to achieve action on energy efficiency by building professionals and building users. A variety of approaches are needed to motivate people, including mobilization campaigns, clear incentives training and education.

These three levers have to be supported by policy frameworks, including specific regulations, taxes and subsidies, education and training.

False optimism breeds complacency

Several barriers stand in the way of rapid progress. They range from market and policy failures, through professionals' inadequate knowledge and understanding, to the behavior of building users.

Some analyses have identified helpful energy-efficiency investments such as building insulation, which have very low or even negative costs over the lifetime of the investment.[4] Others suggest the design and technology potential is so great that a relatively small increase in the cost of carbon (through a carbon tax or a cap-and-trade system, for example) would make additional investment cost-effective.

These projections are optimistic for the following economic and structural reasons, but also because they assume that building energy efficiency is seen as important and urgent, a mindset that does not exist today.

First, our modeling work, based on specific building subsectors and realistic decision criteria, suggests that measures that have a substantial impact are unlikely to meet normal financial investment requirements and are therefore unlikely to be implemented. Opportunities that can be justified under normal financial criteria are likely to reduce total energy consumption only marginally. Building investment decisions in both residential and commercial sectors are usually based on short time horizons. "First cost" is particularly significant for residential investments.[5] Thus energy-efficiency investments are not made, even though they would pay off over the lifetime of the project.

Second, there are several structural obstacles that significantly inhibit the likely take-up rate even of financially attractive investments:

- A lack of transparency about energy use and cost, resulting in a limited focus on energy costs by all those in the building value chain, with viable investment opportunities overlooked and installed technology not operating at optimal levels
- Public policies that fail to encourage the most energy-efficient approaches and practices, or actively discourage them
- Delays and poor enforcement of policies and building codes, which concerns all countries
- Complexity and fragmentation in the building value chain, which inhibits a holistic approach to building design and use (described in our first report[6])
- A lack of adequate offers today (affordable and quality energy-efficient solutions for new constructions and retrofitted works, adapted to local contexts)
- Split incentives between building owners and users, which mean that the returns on energy efficiency investments do not go to those making the investment *(see chapter 2)*
- Insufficient awareness and understanding of energy efficiency among building professionals – identified in EEB research published in our first report – which limits their involvement in sustainable building activity and results in poor installation of energy-related equipment.[7]

The result is poor progress on energy efficiency and a failure to achieve essential energy savings. For example, our simulations suggest that current policies will not prevent energy use from increasing in single-family homes in France and multi-family homes in China. Energy for offices in Japan will fall, but by nowhere near enough.

Building energy development: Three scenarios

We developed three scenarios for how the building energy market could develop over the coming decades, highlighting the need for a transformative approach *(see figure 2)*. Scenarios are alternative futures, not predictions. They help identify threats and opportunities and help businesses plan for various contingencies. The futures described here provide a structure and ideas that have been used in our modeling *(see chapter 2)* and help us understand the huge challenge the world faces in eradicating building energy waste.

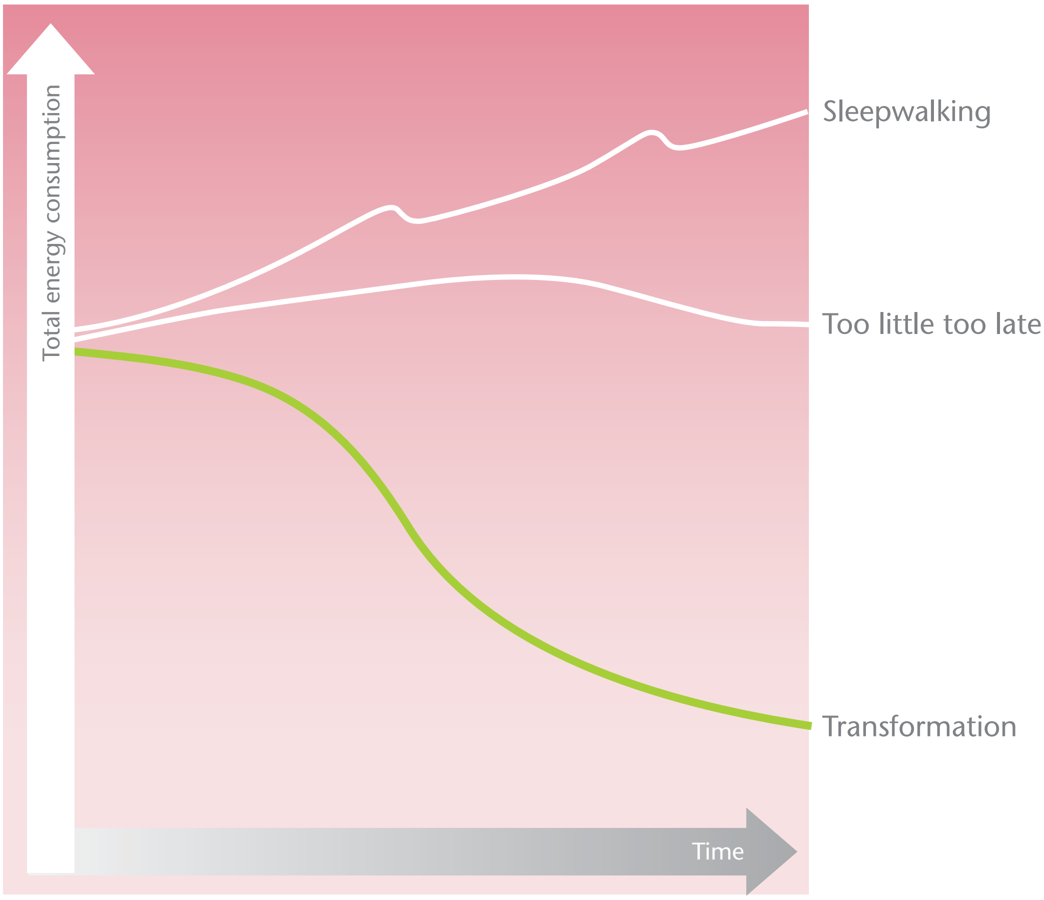


Figure 2

Three scenarios for energy in buildings

Sleepwalking into crises

The Sleepwalking path achieves occasional advances, but these are soon lost and total energy consumption is much higher by 2050. The number of low-energy buildings grows erratically and slowly.

This scenario envisages a continuation of current trends in urbanization, economic growth and energy use, with no sustained attempt to address energy efficiency. The result is a series of economic crises provoked by energy price surges, supply disruptions and extreme weather events. A pattern of severe and highly reactive measures develops creating volatility and uncertainty that hampers business and lowers investment. The transition to higher energy efficiency is costly and painful, including panic measures that may be counterproductive. After the crises, people fall back into old habits and little progress is made.

The panic responses cause rushed regulation and legislation, uncertainty and instability that hamper business investment.

Too little too late

The development of low-energy buildings is still too slow in this scenario, with energy consumption returning to current levels by 2020.

This scenario describes a continuation of the current pattern of much talk and little action. Awareness keeps growing but action is piecemeal rather than coordinated. Tentative moves achieve progress through voluntary or mandatory labeling and other regulations. Behavior changes to some extent, with greater awareness of sustainability and the role individuals can play in saving energy. There is more investment in energy-efficient buildings and an acceleration of technological development.

These changes occur in several countries but remain small-scale, fragmented, and fail to penetrate. Improvements are too slow and small-scale to offset the growing numbers of buildings and increased service levels. For businesses, the opportunities are too fragmented to justify significant investment.

Transformation of the market

Transformation is the only scenario that includes the substantial energy savings necessary across the building stock.

In this scenario, energy prices remain high and stable, encouraging people to cut consumption. Tougher building codes are enforced for new and existing buildings; new energy and climate change policies are implemented; new design approaches and technologies are developed and applied; new skills are learned; and new financing mechanisms emerge. Over time, performance requirements require buildings to achieve high energy performance. This is all part of a coordinated global approach to the economic, social and environmental threats from climate change.

Widespread awareness of energy priorities changes behavior and causes the rapid uptake of increasingly energy-efficient technologies and practices. The Transformation scenario results in the most substantial and sustained business opportunities across the energy and building sectors.

Energy services and energy influences

This report focuses on energy use and energy efficiency, based on the project mission and the overriding purpose of cutting resource use. But energy is valued for what it enables rather than for itself. People do not want “more energy”; they want more of the services energy provides: heating, cooling, lighting and communicating.

The good news is that people are happy with less energy as long as this energy provides the same level of services. The bad news is that since energy is not intrinsically valued, conserving energy tends to be a low priority for most building owners and operators.

Total energy use in buildings is determined by three broad factors: population size, square meters of building per person, and energy per square meter. It can be expressed in this formula:

$$\text{total energy use} = \text{population} \times \text{space per capita} \times \text{kWh per m}^2$$

These components are affected directly by several forces and indirectly by economic activity and a range of government policies.

The main direct drivers are demographics, social and cultural trends, the design of buildings and equipment, and climate. Cultural factors influence which comfort levels are acceptable. Social trends influence household size, and therefore floor space and energy consumption per person. For example, ageing populations and changing lifestyles lead to more single-person households. Urbanization, especially in developing countries, means more multi-family buildings, which tend to be more energy-efficient than single-family homes. But this trend can be reversed if prosperity encourages people to leave city centers, creating urban sprawl.

Economic conditions influence shifts in population and determine underlying prosperity. For example, Europe has seen migration from East to West, while the economic downturn has seen many workers in China returning to the countryside as factories close.

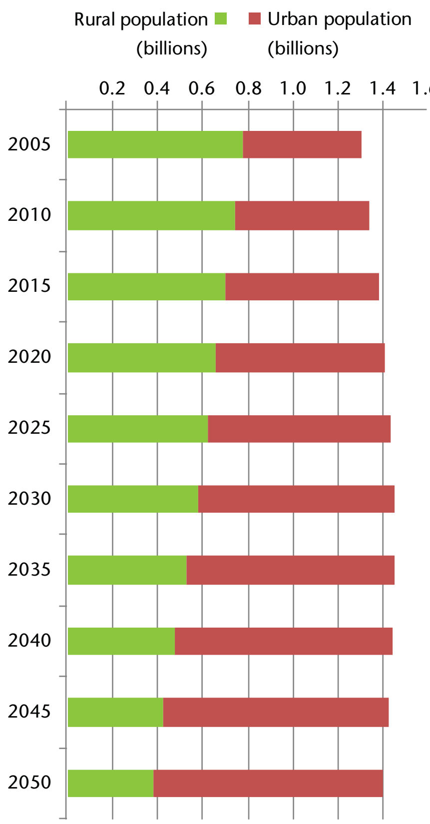
Climate influences demand for energy services, especially heating and cooling. Building design and choice of equipment in them determine the level of energy required.

These factors combine to produce two broad trends resulting in the alarming increase in building energy consumption:

- Increasing population growth, prosperity and urbanization in developing countries
  - China is expected to add twice the amount of current US office space between 2000 and 2020.[8] By 2030, roughly 60% of the Chinese population will be urban, compared to under 40% in 2005
  - Urban living, higher incomes and more access to technologies are associated with higher residential energy use, especially for space and water heating, appliances and equipment.
- Inefficient building stock in developed countries, allied to continued growth in the use of services and appliances
  - In developed countries, many old properties built before energy-efficiency regulations were enacted will still be in use in 2050. For example, in France buildings constructed before 1975, when the first thermal regulations were introduced, are likely to represent over 50% of the building stock in 2050
  - In developed countries, appliances used just 16% of household energy in 1990, but that had grown to 21% in 2005, despite increased appliance efficiency.[9] *(see figure 4)*

Figure 3

Projections of urban and rural population in China



The building energy gap

Buildings account for 30% to 40%[10] of primary energy use in most countries. Unsustainable energy increases in all sectors stem from the growing global population (expected to be nearly 50% higher in 2050 than in 2000) and from increasing energy use per person.

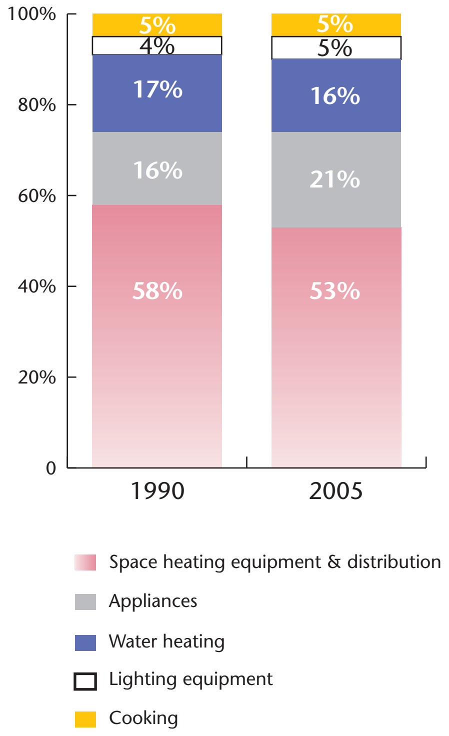
The International Energy Agency (IEA) calls for buildings to contribute 17% of the total emission reductions below business-as-usual (BAU) in 2050 (see figure 5). This is in addition to emission savings from reducing the carbon content of energy supplies, which is accounted for in the power sector wedge. Allowing for population growth, this translates into an average 55%[11] cut in building energy for the EEB regions, suggesting that the most energy-intensive countries (such as the US) will need to be at least 80% below BAU in 2050.

The scale of this challenge must be seen in the context of both population growth and social and economic development. Our goal must be for countries to achieve significant reductions in energy usage without reducing living standards in developed countries or hindering rising living standards in developing countries.

Our projections show that current trends will result in Brazil, China and India reaching the "Level of High Development" as defined by the UN, but the level of energy consumption in buildings in all six EEB regions except India will have soared

Figure 4

Growth in appliance use



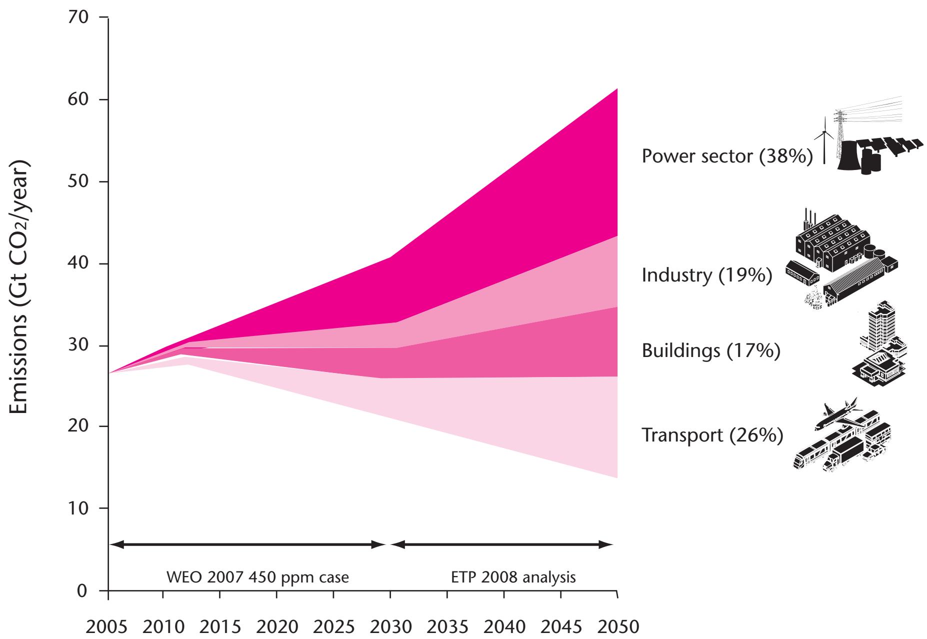


Figure 5

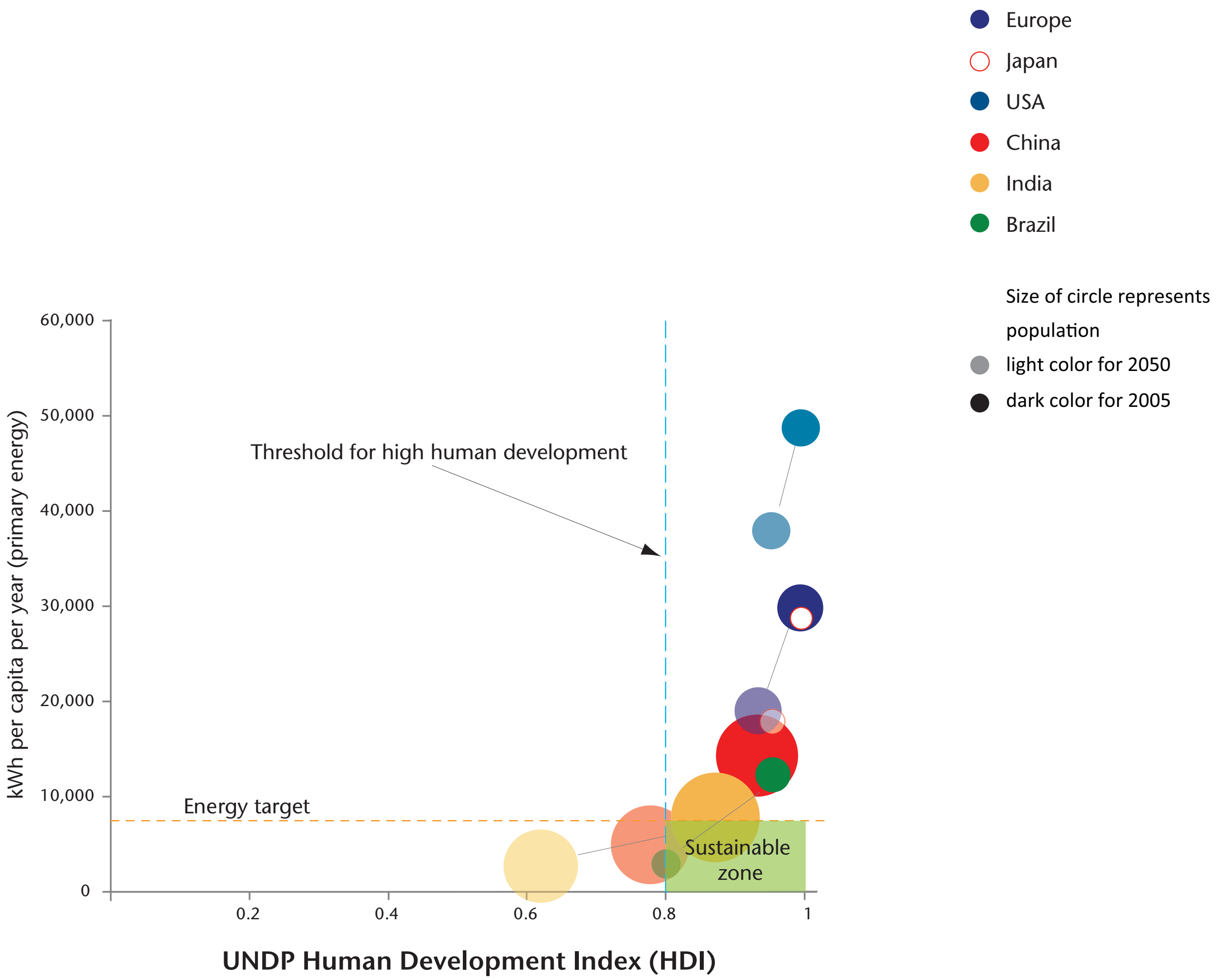
The building energy gap: Buildings need to contribute 17% of emissions savings by 2050 (Source: Energy Technology Perspectives 2008, IEA 2008) beyond the level necessary to achieve the IEA target *(see figure 6)*. To achieve that target, average building energy consumption per person in 2050 will need to be 17% lower than the current average for the six EEB regions. This is a huge challenge given rising living standards and business-as-usual energy use patterns.

"Too little too late", with incremental continuous improvement in energy efficiency, will come nowhere near offsetting growth in building energy demand, making it impossible to achieve the necessary reductions in total energy consumption.

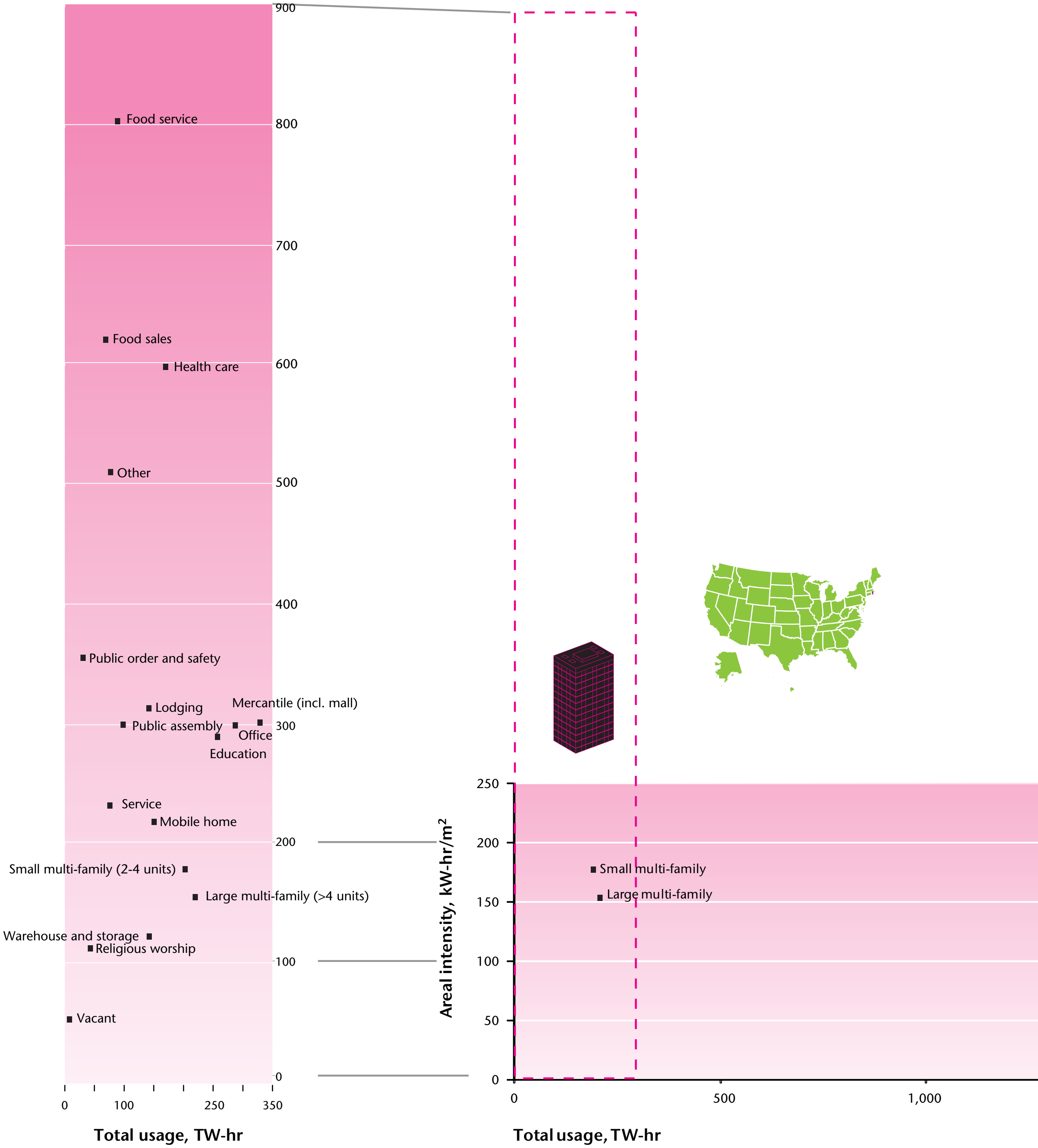
Urgent action is needed because of the timescales involved in the building sector. Buildings, unlike cars, last decades or even centuries in some countries. A country's entire car fleet can be renewed in a dozen years, rapidly making room for new technology and greater efficiency. But buildings constructed now will probably still be standing near the end of the century.

BAU, with incremental improvements, will not be good enough.

Figure 6
Unsustainable development 2050



Figures 7&8
Energy intensity (per unit area) vs. total energy usage, US commercial & residential buildings
(Source: Energy Information Administration (2007) Commercial Buildings Energy Consumption Survey)



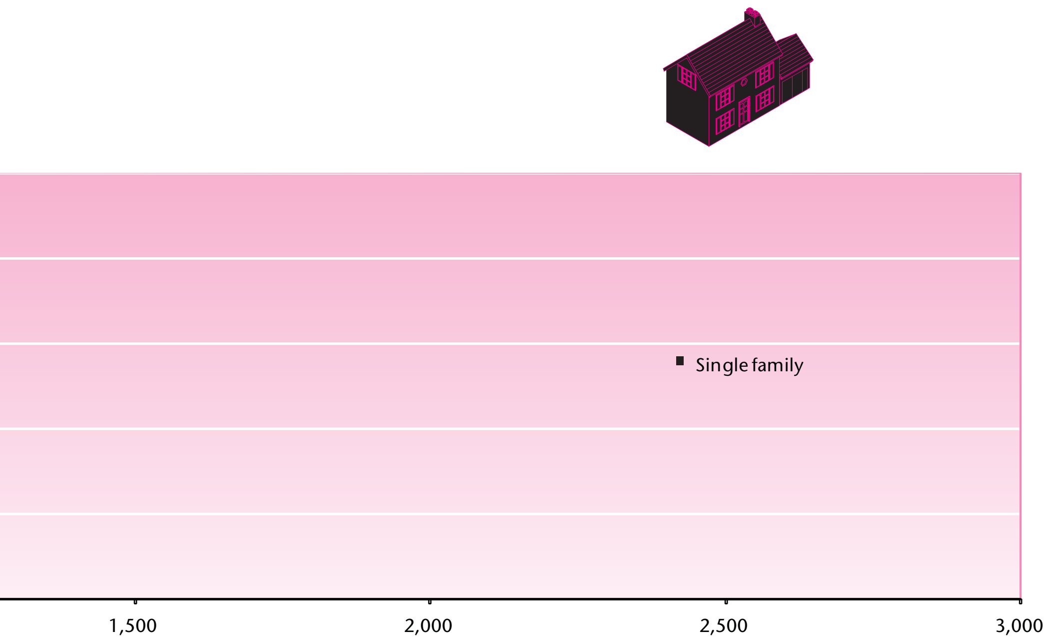
Complex sector needs a segmented approach

This is a complex sector with wide variations in buildings and energy consumption from country to country, from one climate zone to another and between types of buildings.

The nature of decision-making about energy use in buildings means it is important to take a "bottom-up" approach to identifying the barriers to energy efficiency and the means to overcome them, rather than proposing "top-down" prescriptions based on economy-wide data and analysis. This bottom-up analysis must be applied to individual building subsectors, based on their specific energy use characteristics.

We chose to concentrate on the largest subsectors based on total energy use: residential (divided between single family and multi-family homes), office and retail. Together they account for more than half of the energy used in buildings across the six regions covered by the project. Some other subsectors (such as food service) are more energy intensive but do not use as much energy in total *(see figures 7&8)*

We considered the policies, construction options, financial considerations and behaviors directly relevant to each of these subsectors and used this analysis to identify common themes that might apply to all buildings. The subsectors are analyzed in the next chapter.



Achieving transformation

The necessary progress will not be achieved purely through the market. Market forces will need to be supplemented by effective regulatory environments and fundamental behavior change. To understand how low-energy buildings can become a crucial component of continued human development, we need to answer these key questions:

1. How can we improve transparency of energy consumption in buildings, spreading knowledge on how and where energy is used?
2. How can we create incentives that reward progress and penalize poor performance?
3. How can we finance the cost of developing and commercializing new technology?
4. How can we overcome the first-cost barrier and short-term investment horizons that impede energy-efficient investment?
5. How can we spread best practice and innovation in financing measures and mechanisms, new technologies and behaviors?
6. How can we develop a low-energy mindset so that energy efficiency is part of the modern lifestyle and a source of competitive advantage?
7. How can we achieve action: behavior change by everyone in the building sector as well as building users?

2. Homes, offices, shops: The subsector analysis

To understand the energy influences and how to overcome the barriers to transformation, we examined the characteristics of four key subsectors that collectively represent over 50% of building energy consumption in our six regions. This chapter reports our detailed analysis and modeling. It includes summaries of case studies in France (single family), China (multi-family) and Japan (offices), showing the energy trends to 2050 under current conditions and after transformation. (See the box on page 21 for an explanation of the model)

Having identified the barriers, we make recommendations for each subsector, which are the basis for our global recommendations in the final chapter.

Split incentives

One significant barrier common to all building types that are not directly owned is known as the split incentive. It applies to both residential and commercial buildings and means that the benefit of energy savings does not go to the person making the investment. For example, the owner is likely to be responsible for making energy-efficiency investments, but the occupier may receive the benefit of lower energy bills. This means the owner has no direct incentive to invest (although landlords may benefit from higher rents[12]). On the other hand, if the landlord is responsible for the energy bills, the tenant has no direct incentive to save energy. See table 1 for a summary of split incentive relationships.

Landlord/tenant relationships are also complicated by billing practices that can mean tenants do not pay specifically for the energy used. Many apartments and offices in multi-occupied blocks do not have individual heating systems or meters to measure consumption. Heating costs may be included in the rent or charged to tenants based on criteria such as floor space; so the tenant will have no incentive to save energy. When tenants are billed for actual consumption, energy use for heating typically drops by 10 to 20%.[13]

Table 1

Split incentives for energy investment and saving

	Consequence	
Responsibility for energy bills	Landlord	Tenant
Landlord	Incentive to invest	No incentive to save energy
Tenant	No incentive to invest	Incentive to save energy

The EEB model

The EEB quantitative simulation model is a unique approach to building energy analysis. It simulates the actions of decision-makers faced with a choice of investments in a range of design and construction options, projecting the market response to a mix of financial, technical, behavioral and policy packages.

The model analyses the energy use of nearly 20 million properties, growing to 30 million by 2050, considering 609 potential construction options. See figure 9 for a simplified illustration.

Decisions are simulated by comparing the net present value of available options, with the choice based on financial criteria and limited (for the base case) to those in the lowest 25% by first cost. (The assumptions are varied in alternative simulations.) The model calculates the net present value over a 5-year time horizon. We extend the time horizon to 10 and 20 years to test the impact of more relaxed criteria or financial models that accommodate returns over a longer period.

For each submarket several "reference cases" were created to represent the range of building and energy combinations in that market. The building databases were developed by EEB in conjunction with four leading universities.[14] The energy consumption of each reference case and each potential design and construction package was calculated using a commercially available building energy analysis tool, which accounted for all complex building system interactions. Each option was priced using market data and cost experts.

The model considered all building systems that contribute to energy usage. The energy efficiency options included known or pending improvements in building envelope systems, lighting, heating, ventilation, air conditioning, domestic hot water and appliances. On-site electricity generation considered primarily solar photovoltaic systems.

The model projects results at 5-year intervals to 2050, taking account of expected net building growth during the period as well as natural replacement rates for each item of equipment. Model outputs are:

- Total and net energy consumption (primary and onsite levels) and CO_2 emissions (per building and total for the submarket), including on-site generation
- Investments and operating costs (per household and total for the submarket)
- Loans, subsidies and taxes linked to policies of the scenario
- The total cost of policies
- The business opportunity

Full details of the model and of the simulations for submarket cases are available on the EEB website at www.wbcsd.org/web/eeb.htm.

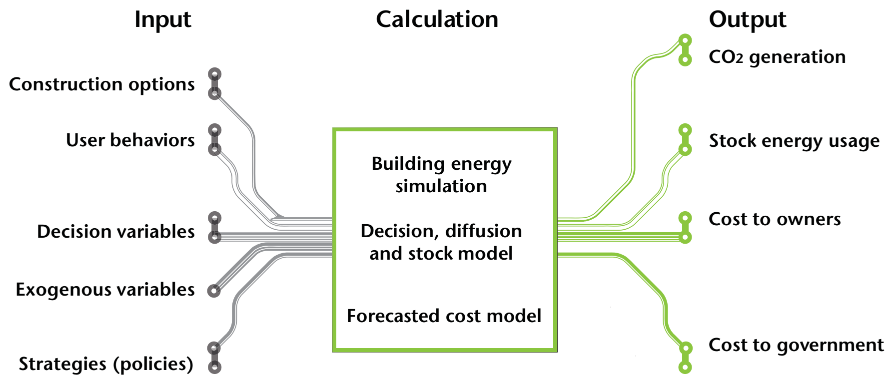


Figure 9

An outline of the EEB model

Residential subsectors

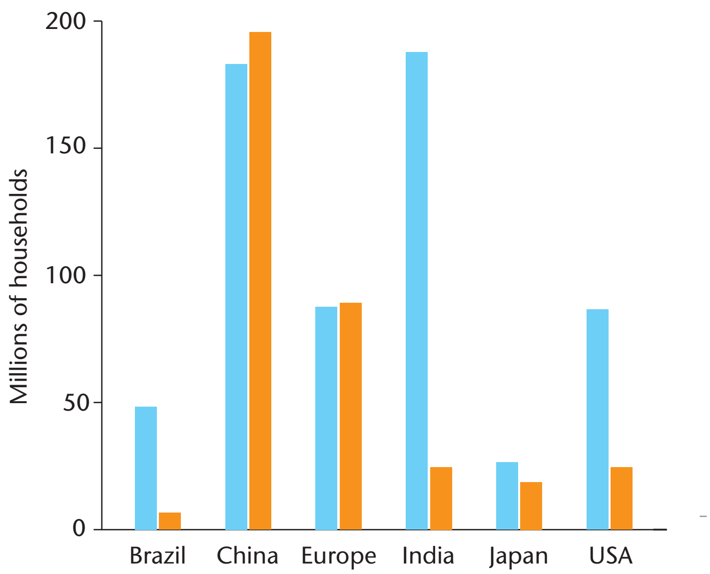
The residential subsectors use significantly more energy than commercial buildings in each of the six EEB regions. Fragmented ownership is a key challenge – individual decision-makers in housing have responsibility for relatively little energy use, with the exception of large public housing stock controlled by local government authorities.

We have examined single-family houses separately from multi-family to understand the specific energy influences and barriers. Single-family houses dominate in Brazil, India and the US, while single and multi are roughly equal in the other regions. *(see figure 10)* The balance could change due to several contrasting trends:

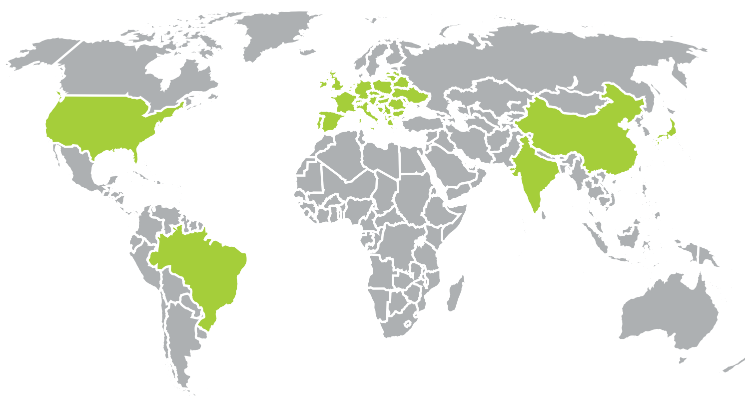
- Population increases will encourage more multi-family building because of its more efficient use of land
- Growing urbanization will add to multi-family living because of land shortages in cities
- Economic development may have the opposite effect as people tend to move into single-family homes when they become wealthier
- Ageing populations will result in lower occupation densities and more single-person households.

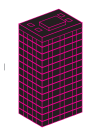
Figure 10
The numbers

(Sources: US DOE EIA (2005), Residential Energy Consumption Survey; Federcasa, Italian Housing Federation (2006), Housing Statistics of the European Union 2005/2006; Statistics Bureau, Ministry of Internal Affairs and Communications (2003), 2003 Housing and Land Survey (Japan); EEB core group research)

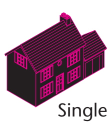


Single family
Multi-family





Multi-family



Single family

For example, the average household size in urban China has fallen from 3.5 in 1990 to 2.95 in 2006. In the same period, per capita annual income has gone from 1,516 Yuan per capita to 12,719 Yuan per capita.[15] *(see figure 11)*

Energy consumption

Residential energy consumption has been rising in all regions. This reflects larger homes, higher expected levels of comfort and more household appliances. In developed countries, multi-family dwellings use less energy than single family homes, due primarily to the smaller wall and roof space that limits energy losses and gains, and smaller floor space, which means less volume to heat and cool. Based on US data, an average apartment uses about half the annual energy of a single family home although the smaller size means energy per square meter is higher *(see table 2)*. All the main energy uses are significantly higher in single-family homes.

Facts

- Average household (number of people) size varies from 2.4 in western Europe to 5.2 in rural India
- 70% of homes in India have no more than two rooms

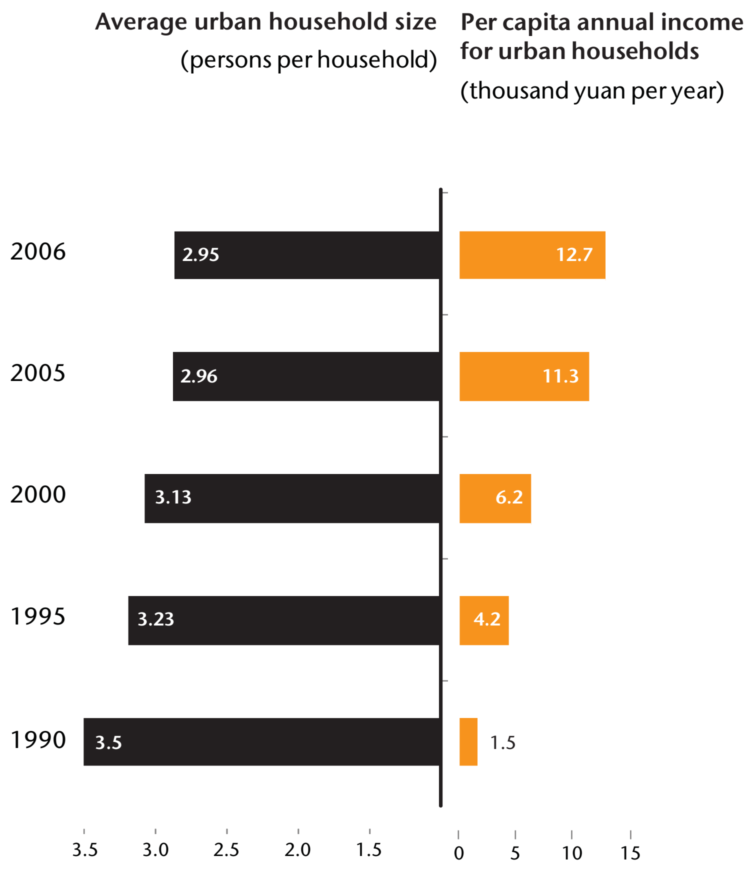


Figure 11

Smaller households in China and higher incomes

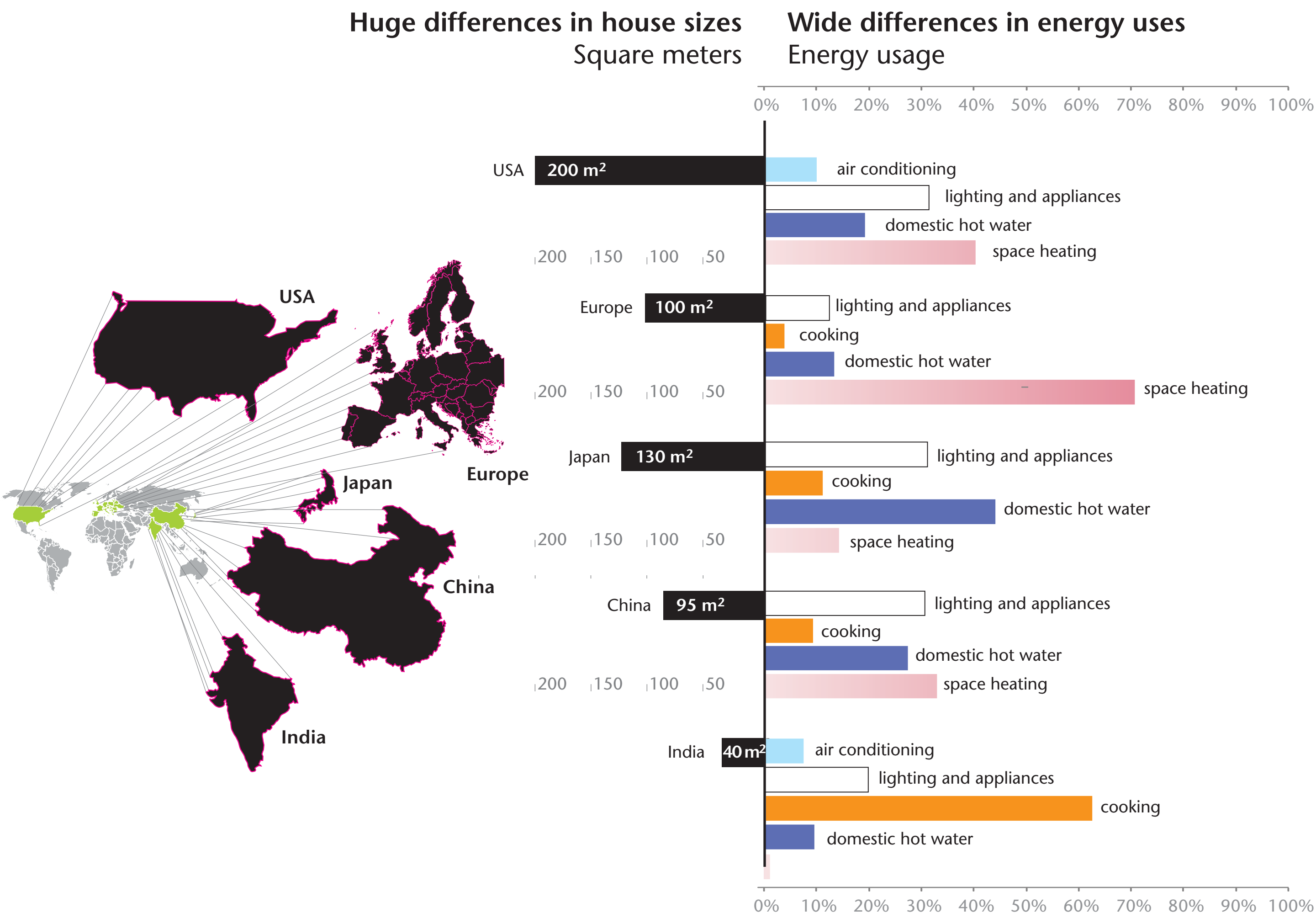
Table 2
Apartments in the US use more energy per square meter

(Source: US Energy Information Administration (2005), Residential energy consumption survey.)

	Apartments	Detached homes
Total consumption (TWh)	264	2285
Per household (KWh)	15760	31730
Per person (KWh)	7740	11630
Per square meter (KWh)	212	126

Energy uses differ widely due to culture, climate and wealth *(see figure 12)*. Space heating is dominant in Europe and northern China, while water heating is very significant in Japan. In rural India, as in many developing countries, where many people do not have access to electricity, the main energy use is cooking (using biomass). Rising wealth in developing countries should lead to higher energy use for basic equipment, appliances and electronic goods.

Figure 12
Wide differences in residential energy uses among EEB regions



In many countries property built before energy regulations were in place will constitute half the housing stock in 2050. In Europe, 50% of current housing was built before 1975 *(see figure 13)*.

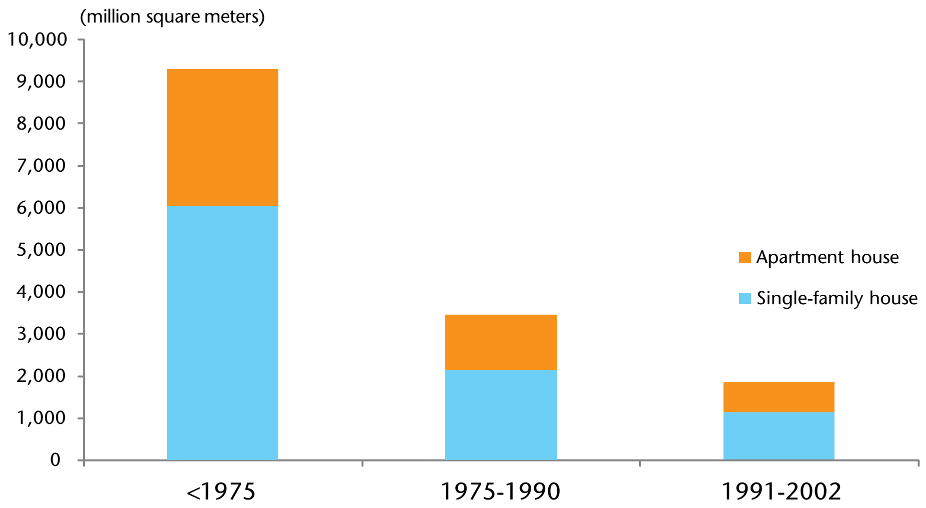
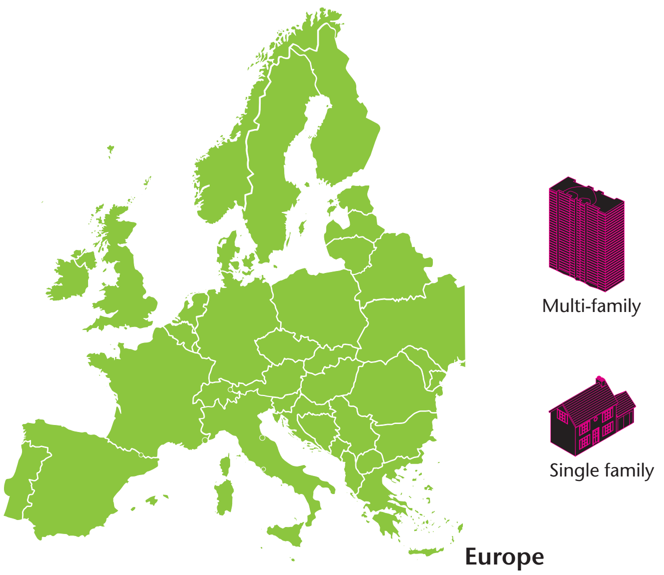


Figure 13
Older housing is the norm in Europe



Single-family homes

The single-family subsector is the largest by number of buildings, area per person, energy consumption and CO_2 emissions. It is the largest residential sector in most markets. An increasingly prosperous population will tend to favor larger and better-equipped single-family homes, resulting in a substantial increase in energy consumption without bold action to cut energy use. Action could be very effective because the high rate of ownership (up to 90% in some countries) means split incentives are not a significant factor *(see figure 14)*.

The size of homes is one of the greatest differences between countries. US homes are substantially larger than others, with homes in India standing at the other end of the scale *(see figure 12)*.

Energy characteristics

People in developed countries consume much more energy in their homes than in developing countries. This reflects larger sizes, higher expected levels of comfort and more household appliances. Japan's energy consumption is radically lower because people only heat one room rather than the whole house. Developing countries' consumption has been increasing as they become wealthier.

Changing behavior has increased energy use, and this is especially noticeable for space heating, which is the main use in colder climates. For example, in the past 10 years, indoor temperatures have increased by 3°C in the UK, requiring a 20% increase in heating energy consumption.

Facts

In the EEB regions, single family homes typically:

- Represent between 50–90% of the residential sector
- Consume over two-thirds of overall residential energy
- Are responsible for over 40% of total buildings' CO_2 emissions

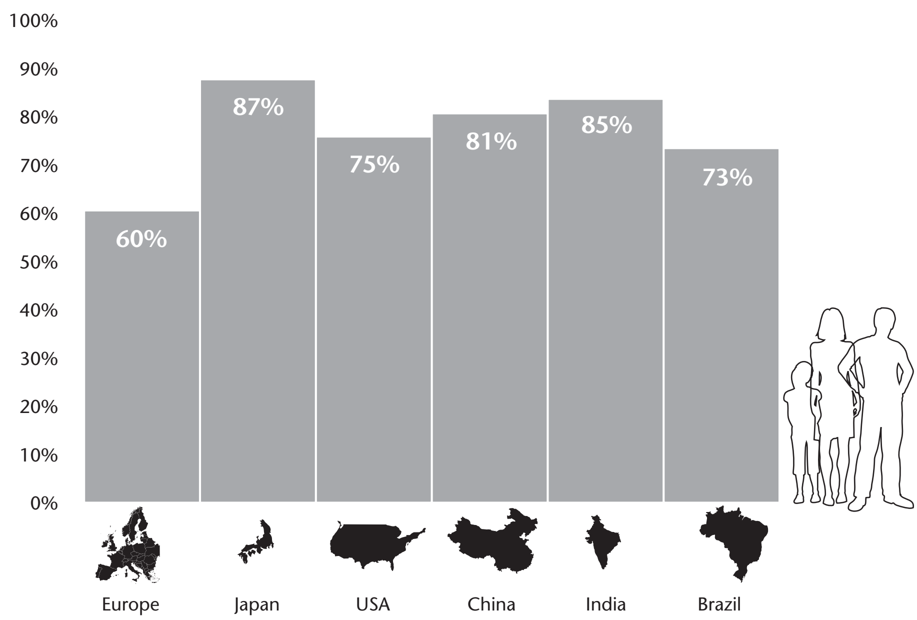


Figure 14

High levels of ownership in single-family homes among EEB regions

Barriers to cutting energy use

Europe

Retrofitting older, inefficient houses is the biggest challenge in Europe. Homeowners are influenced mainly by financial criteria and perceptions of the consequences for comfort and appearance (rather than by energy savings specifically). For example, in France people have installed solar panels partly to demonstrate their commitment to renewable energy but also because it is fashionable and they receive very favorable feed-in tariffs from their energy supplier. Similarly, there has been widespread window replacement, supported by tax rebates that reduce the first costs. Window suppliers say most homeowners want to improve the appearance of the home rather than save energy. Better windows do provide both sound and heat insulation, but cut heat loss by only 10%, compared to 30% for the walls or roof.

The lack of an adequate “offer” is especially important for individual homeowners. People need easily identifiable energy-efficient solutions relevant to their own specific circumstances. The offer must include information, advice and skilled workers to carry out the installation, together with a performance guarantee.

There are two key barriers to transforming what is currently a refurbishment market into an energy-efficiency market:

- People do not know where to find relevant information on options, prices and suppliers; there are no “one-stop shops” for retrofitting
- Homeowners base decisions largely on the first cost rather than overall financial returns.

Emerging countries

The key barriers here are the lack of regulation or lack of enforcement, plus inadequate access to finance. In China, building codes are not effectively enforced. In Brazil, 75% of single-family homes are believed to be built by the informal sector.

Also, the need to provide people with decent homes takes precedence over energy efficiency.

Japan and the US

These countries have a high rate of new construction, which will continue in the US because of continued population growth. The problem is the affordability of the available technical solutions and the capacity to implement them on a large scale. The extreme variety of the submarket is the main barrier to standardization of energy efficiency for new single-family houses.

In the US, energy consumption per head is very high, due partly to a proliferation of appliances and electronic devices. Residential building codes are applied at the state and local level and generally include energy-efficiency requirements for the building envelope. Some states do not have residential building codes and the patchwork of requirements leads to varying construction practices and equipment. The key issues are strengthening regulation and changing behavior.

In Japan, energy efficiency is high and energy consumption is relatively low in single-family homes, but the lifespan of houses is typically only 30 years. So the goal is to retrofit rather than demolish and increase the lifespan of houses.

Single-family homes case – France

French single-family submarket energy consumption is representative of the European average. It is also in the middle of the range for the six EEB regions so far as GDP and comfort levels, energy consumption per capita and existing regulations are concerned. It differs in its lower CO_2 emissions rate because of the low CO_2 content of energies used in France.

Characteristics of the sub-market

- This is the largest building subsector in France by number of buildings (14.5 million, 60% of the residential sector), floorspace, population, energy consumption (2/3 of the residential sector) and carbon emissions.
- It is a very fragmented market with many different house construction characteristics (envelope, heating systems, efficiency, etc.)
- Space heating is the dominant energy use, more than two-thirds of total final energy consumption
- The replacement rate is low (0.2% a year), and over 60% of stock was built before 1975. The main energy efficiency challenge is retrofitting existing homes; 12 million buildings, or more than 80% of the current stock, need retrofitting for high energy efficiency.

These buildings offer great potential for energy efficiency: first by reducing space heating needs through insulation, air-tightness and more efficient equipment, then by improvements in domestic hot water and lighting. But the costs are substantial. Comprehensive improvements for energy efficiency are likely to cost between 15,000 and 30,000 Euros per home (US$ 20,000 to US$ 40,000) before any subsidies (whereas only about 3,800 Euros (US$ 5,000) is spent on average for energy efficiency retrofitting works today).[16] Novel forms of finance are needed. The challenge is to identify the right mix of policies and other measures that will induce decision-makers to make these heavy investments in view of long payback periods.

Experience suggests that homeowners tend to spend smaller sums on less comprehensive improvements that are often not efficient enough; an estimated 70% of energy efficiency investments cover mainly double-glazing (which is not the most efficient option), then door and wall insulation. The quality of the work is also often below the level required for energy-efficient buildings.[17]

EEB modeling

We simulated many options for the French single family submarket, testing different combinations of regulation, financial and fiscal measures and technology choices.

In this document we focus on two cases: continuing current policies (Base case), and policies to achieve deep reductions in energy and CO_2 emissions (Transformation). Note that we are not advocating that France (or any other country) implement the specific Transformation policies that were modeled. They are representative of the kinds of aggressive actions that could be taken to achieve Transformation. Individual countries will need to evaluate approaches suited to their own regulatory and political environment. Key data for these two cases are summarized in *table 3*.

Facts

Single family houses in France represent:

- 42% of all building energy consumption
- 56% of all dwellings (14 million)
- 60% of inhabitants (36 million)
- 67% of final residential energy consumption (344 TWh)
- 75% of residential building CO_2 emissions (66 million tonnes, average 38 kg $CO_2/m^2/year$)
- 70% of floorspace in residential buildings (1.6 billion m^2 = average 110 m^2)

The Base case represents existing French policy, which includes subsidies for energy efficient equipment and materials and a feed-in tariff for solar PV at five times the retail price of electricity.

For existing policies, the net energy consumption of single-family homes increases from 2005 to 2050 to about 429 TWh/yr (due to market growth), while we see a CO_2 emissions increase of about 14%. Meanwhile, the unitary energy consumption per capita decreases. The current levels of incentives are too low to change homeowner decision-making. *(See figure 15.)*

For Transformation, additional aggressive policies are added to the Base case, including policy measures as defined by "Grenelle de l' Environnement" (for example, a requirement in 2020 for all new construction to be "net zero energy"), as well as a US$ 30 per tonne carbon tax. In addition, a combination of incentives and bans are imposed based on a five-level building energy efficiency classification system (comparable to the European Energy Performance of Buildings Directive A-G labeling scheme). Class 1 and 2 buildings receive an incentive of 50% and 25% of capital costs respectively, and Class 4 and 5 homes are banned. These very aggressive policies drastically reduce energy (-53%) and CO_2 emissions (-71%) by 2050 *(see figure 16)*. A steep reduction in energy consumption until 2020 is achieved, followed by a slight increase due to market growth (new homes are built with the most efficient energy equipment; therefore there is no more gain in energy efficiency).

The housing stock transitions mostly to class 1 and 2 buildings by 2025 *(see figure 17)*. Solar PV, space heating improvements, and building envelope enhancements are the top contributors to reductions in site energy *(see figure 18)*. (The building subsystems are ranked in figure 18 from highest to lowest impact on site energy reduction, with the width indicating the number of installed units as of 2050.) Solar PV is a key element in approaching zero net energy.

The development of site energy to 2050 in these and other simulations is shown in figure 19. The uppermost line is the result when no policies are imposed, while the lower one is the Transformation case. The intermediate lines are for Base and two other policy combinations.

The total subsector results illustrate the need for packages of bold measures to achieve substantial cuts in energy and CO_2 emissions. Providing incentives achieves some reduction in the growth of energy used per capita, but the most substantial progress is achieved with a combination of incentives and bans. We make seven specific recommendations for this subsector.

The incremental investment to achieve the Transformation case in this submarket is US$ 13 billion a year on average, with annual energy savings of US$ 8 billion a year on average. The investment is high relative to the savings largely due to the significant adoption of solar photovoltaic systems under the Transformation case, which featured a strong subsidy and high feed-in tariff. However, approximately 15% of the total Transformation cost is for efficiency measures with simple paybacks of 5 years or less, which achieve 65% of the total energy savings.

Table 3

Continuing current policies vs. policies to achieve deep reductions

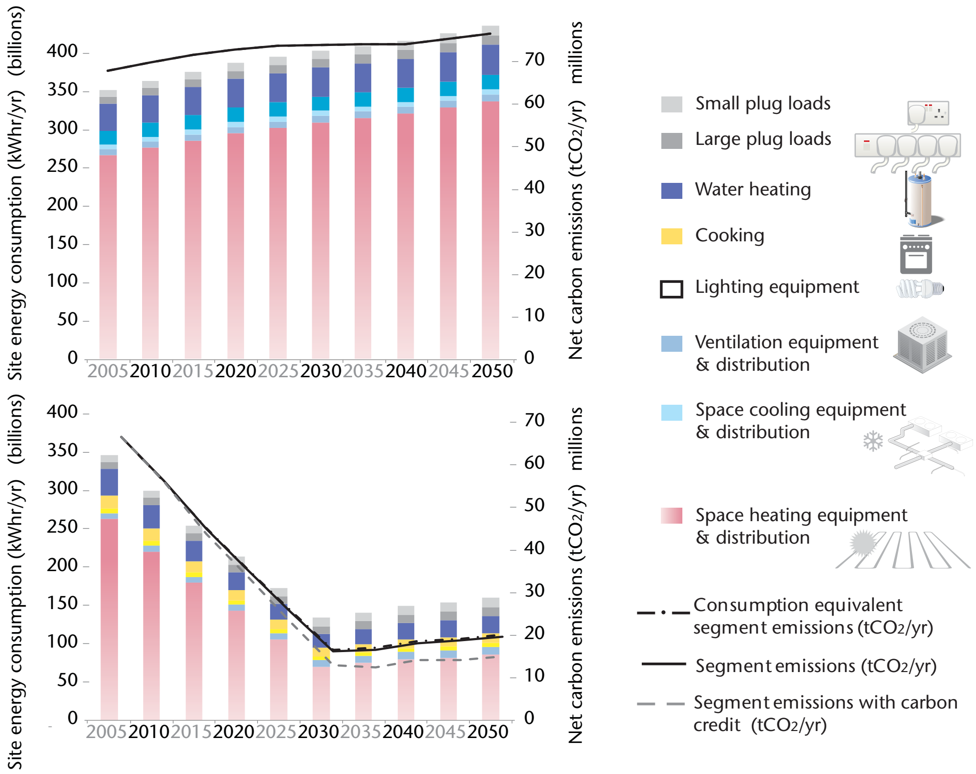
	2005	2050	
		Base case (current policy)	Transformation
Onsite energy consumption– total for submarket (TWh)	346	429	163
Onsite energy consumption –net for submarket (TWh)*	346	428	100
Above/below 2005 (%)		24	-53
Above/below 2005 (%) net		23	-71
Above/below baseline (%)			-62
CO_2 – net for submarket (million tonnes)[18]	67	75	14
Above/below 2005 (%)		12	-79
Above/below baseline (%)			-81

Base case

Submarket site energy consumption and CO_2 emissions under existing policies case - France single-family residential

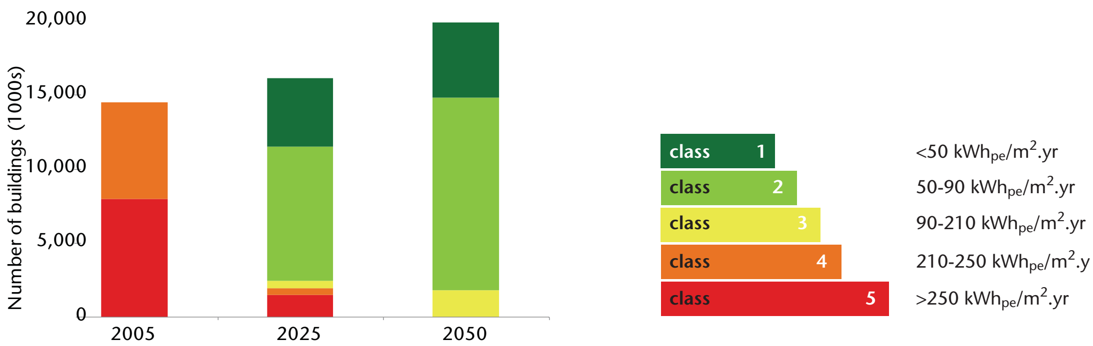
Transformation

Submarket site energy consumption and CO_2 emissions under Transformation case - France single-family residential



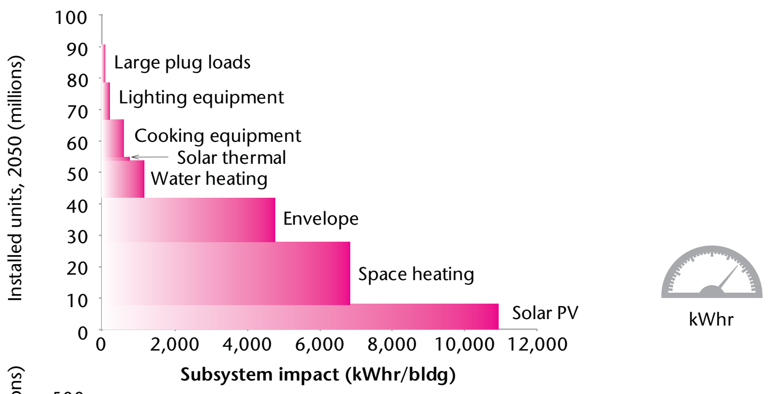
Shifts

Shifts in building stock energy class under Transformation case - France single-family residential



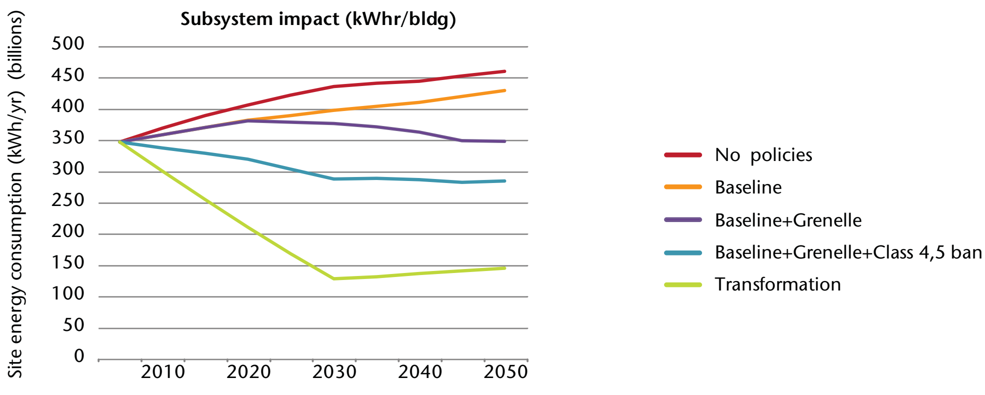
Subsystem impacts

Individual building subsystem installed base in 2050 and impacts to site energy - France single-family residential



Policy cases

Submarket site energy outcomes for different policy cases - France single-family residential

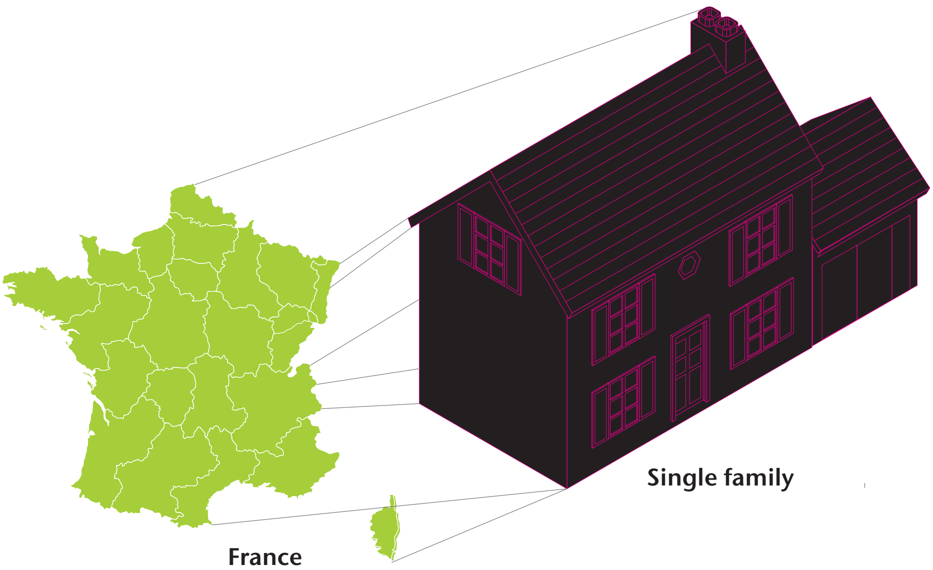


Figures 15, 16, 17, 18, 19

Transformation recommendations for single-family homes

Our analysis of the subsector and the results of the modeling of single family homes lead to these conclusions on how to transform the subsector:

1. Create technical offers with guaranteed performance, transferring existing technologies globally, using R&D to drive down first cost and identifying specific solutions relevant to retrofitting, including efficient technologies and local solutions for emerging countries
2. Perform audits of energy performance and CO_2 emissions of houses to prioritize actions
3. Introduce gradually strengthening regulation for new and existing homes:
   - Labeling systems to provide independent information
   - Increasingly strict regulation on building energy codes, appliances and materials
   - Phasing-out of low-performing houses
   - A requirement for zero net energy new homes from 2020, using passive and active measures
4. Introduce heavy subsidies for achieving high performance in existing and new houses
5. Create staged retrofitting plans with financial packages based on a staged, whole-house approach, such as:
   Stage 1: Envelope thermal performance
   Stage 2: High-efficiency equipment
   Stage 3: On-site generation of renewable energy
6. Introduce campaigns to raise awareness and develop good habits regarding energy, implemented through energy agencies
7. Educate, train and regulate those working in the construction/ retrofitting sector
8. Promote onsite renewable generation for all new low-rise buildings



Multi-family housing

Facts[21]

- The global urban population is expected to grow from 47% of the total in 2000 to 70% in 2050
- In 2050, 73% of China's population is expected to live in cities, compared to less than 45% now[22]
- By 2025 Mumbai is expected to grow to 26 million (from 19 million in 2007) and Delhi is projected to grow from 16 million to 23 million

Multi-family buildings mainly serve cities, permitting high population densities to make the best use of limited space. Multi-family housing in the US, Europe and Japan ranges from subsidized housing to luxury apartments. Low-efficiency older buildings are the greatest concern in these locations. In general, despite the poverty of slum dwellers, urban housing in developing countries is associated with higher incomes and greater household energy use than in the countryside. This makes the multi-family residential sector in developing countries one of the most important for reducing building energy consumption, since this is where the bulk of new residential building will happen in the coming decades.

The scarcity of land for building in many cities encourages multi-family blocks wherever possible, such as the relatively new areas of Dwarka and Rohini in New Delhi. Brazil is already a much more urban country than China and India, and its rate of urbanization is beginning to reach saturation level. The urban populations of China and India are expected to continue growing rapidly to 2050 *(see figure 20)*.

Both China and India are developing novel ways to manage the huge demand:

- "Superblocks" in China: 1 km^2 land parcels provided by the city with arterial streets in place. Developers build everything needed inside the blocks, with 2,000 to 10,000 housing units. Between 10 and 15 of these superblocks were being completed every day in 2008, adding 10 to 12 million housing units per year.[19]
- Integrated townships in India: combined housing and office developments in large land parcels on the outskirts of major cities. Some 400 township projects with populations of 0.5 million each are predicted over five years in 30 to 35 cities.[20]

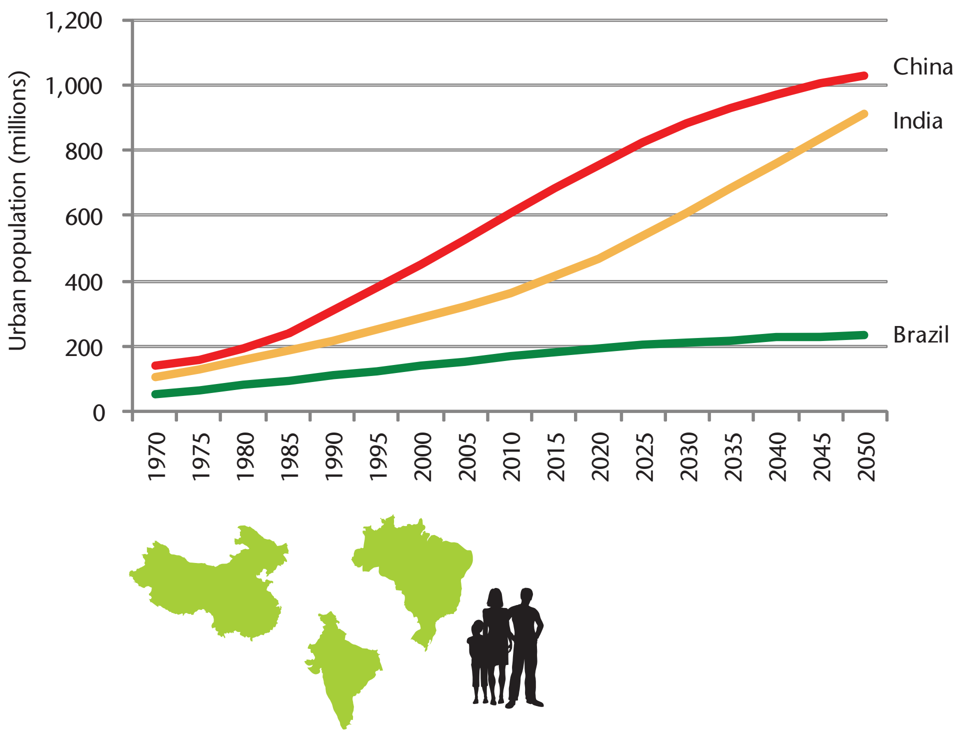
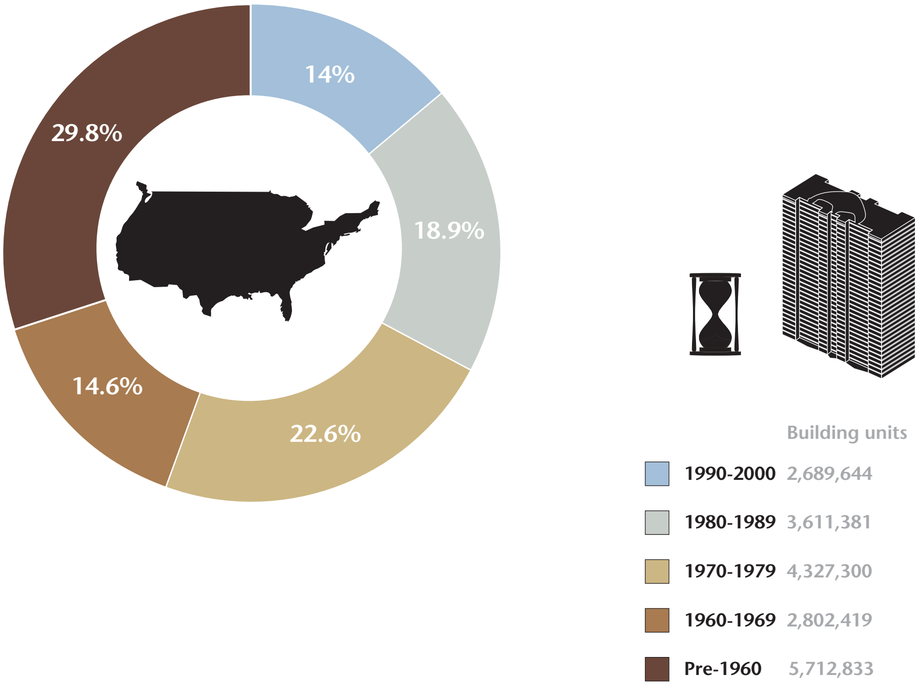


Figure 20

City living is on the rise in developing countries (China, India, Brazil)

Figure 21

Ageing apartment buildings in the US



Existing housing stock

In developed countries, the primary challenge is the large stock of older buildings, and the difficulty and expense in raising their energy efficiency.

In Europe, multi-family buildings represent about half of the building stock, but because apartments have smaller areas than single-family homes, they represent a little over a third of the residential floor space. The majority of apartment buildings pre-date 1975.

In the US, 45% of multi-family housing stock was built before 1970, and only 14% was built after 1990, with more modern building efficiency.[23] *(See figure 21.)*

Japan has 47 million occupied housing units,[24] and 40% of these are in mostly low-rise and mid-rise multi-family apartment buildings. Over 98% of apartments were built after 1960.

The average apartment in Japan is 48 m^2, and area has been rising at about 0.4% per year over 2000-2005. This compares to an average single family home size of 128 m^2. The vast majority of apartments are rented rather than owned.

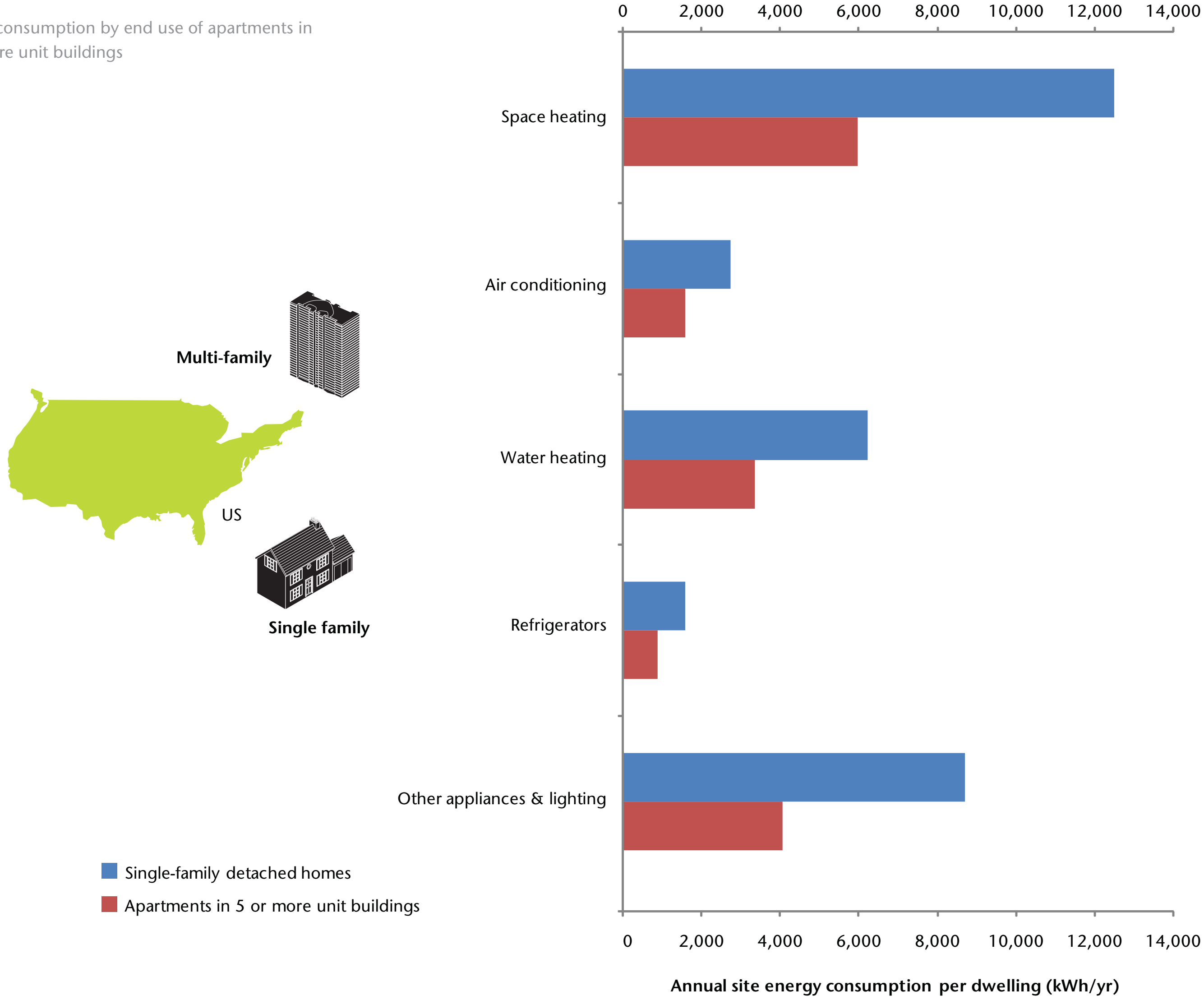
In 2005, the average private household in Japan contained 2.55 people. This compares to 2.99 in 1990 and 4.14 in 1960. The number of one-person households grew 12% from 2000 to 2005, reaching almost 30% of all households.

Facts

- Of the 14 million apartments in France, 68% were built before 1975
- 45% of the apartments in the US were built before 1970
- In Japan, over 98% of apartments were built after 1960[25]

Figure 22

Energy consumption by end use of apartments in 5 or more unit buildings



Energy consumption

Individual apartments use considerably less energy than single family homes owing to their smaller floor area, smaller household size, and lower exterior wall area. In the US, apartments in buildings containing five or more units use about half the heating energy and half the energy for lighting and other appliances of an average single family home. Energy requirements for air conditioning, water heating and refrigerators are over 40% less. (*See figure 22.*)

In developing countries, standards of living and comfort levels are rising among urban populations, driving increased market penetration of energy consuming appliances and equipment (see table 4). High penetration levels equate to greater energy consumption per household, although increased energy use may be mitigated by appliance efficiency improvements over time. In China, however, purchases of more air conditioners will result in increased total energy consumption, more than tripling by 2020, even with a 40% increase in efficiency.[26]

Facts

- Urban space heating intensity in northern China is 31.6 W/m^2-degree day, compared to 2.34 in the countryside
- Housing units in Japan are sold and rented without heating or cooling equipment. Occupants buy their own appliances and take them when they move

Appliance	Penetration (%)
Color TVs	137 (more than 1 per household)
Washing machines	97
Refrigerators	92
Air conditioners	88

Table 4

Appliances are widespred in urban China

Barriers to energy efficiency

The high rental rates of multi-family buildings (see table 5) create a split incentive between the owner and the tenant. The way energy is supplied and charged is also problematic. (These two issues are covered in the introduction to this chapter.)

Other barriers include:

- Financial constraints — multi-family housing residents often have low incomes (especially in developed countries). Although they stand to save the highest percentage of income, they are likely to have the greatest difficulty paying for effective investments, especially as best results are achieved by a full renovation: modernization of the building envelope (insulation and windows) and replacement of heating and air conditioning systems. Efficiency improvements of 50-75% have been documented, and 30% is routine.[27]
- Market structures – the market is highly fragmented: many small landlords, some corporate property owners managing multiple buildings, usually in local or regional markets, and public housing authorities, also mostly local.
- Misperceptions – energy efficient, multi-family housing is still perceived in the marketplace to be much more expensive to build than standard construction, despite evidence to the contrary. In new construction, 20% improvements in energy consumption are achievable, substantially higher when a whole-system approach is taken. The cost is minimal, a modest 2.4% in one study (16 buildings containing from three to 90 units).[28]

Fact

- In the US, energy costs are included in the monthly rent of more than a quarter of apartment residents, primarily in older buildings[29]

Country	Multi-family units that are rented (%)
France	75
Japan	75
US	83

Table 5

Multi-family buildings are mainly rented

Multi-family case – northern China

Most of the housing in China's urban areas is in multi-family apartment buildings (over 90% in many cities). Rural-urban migration has spurred rapid construction, significantly increasing energy demand. City dwellers in China are expected to grow by 350 million between 2005 and 2025 – more than the current population of the United States.[30]

Space heating accounts for more than two-thirds of domestic energy consumption in urban northern China. Much of this is supplied by coal-fired district heating systems.

Improving living standards and an ageing population are driving up the per capita living area in urban settings, from 20 m^2 in 2000 to 26 m^2 in 2005. Residential energy consumption in China is also increasing due to rising prosperity. By 2020, urban ownership of TV sets is predicted to rise to 1.6 per household, and air conditioners to 1.2 units per household.

Barriers to Energy Efficiency

The major barriers here are those that allow and encourage inefficient use of space heating, including:[31]

- Construction practices that produce inadequate building envelopes, and building codes that are not strong enough
- Lack of systematic and rigorous enforcement of building energy codes
- A lack of incentives to save energy, due to heat energy in China being priced at a fixed rate irrespective of consumption and at levels not fully reflective of the actual costs of generation and delivery
- Out-dated heating system design, including coal-fired, heat-only boilers, and a lack of proper heating controls within apartments.

EEB modeling

We based our analysis on an average apartment building in Beijing:

- Six stories with 36 individual apartments
- Average floor area per apartment of 77.3 m^2, with three people per unit
- Annual average building growth rates consistent with projections of urban population growth in China.

The existing building stock is represented by eight reference cases. The future mix of buildings reflects the increasing standard of living and higher household energy consumption, resulting in conditions comparable to present-day Japan by around 2020:

- Air conditioning and central heating become much more common
- Hot water consumption rises by more than 76%

- Electricity use for lighting increases 200%, and for appliances and electronics goes up 325%
- Improved building shells (insulation, windows).

Simulations

We examined several conditions that simulate the effects of:

- No new policies (the base case)
- Offering financial incentives for energy-efficient capital goods
  Adding a price on CO_2 emissions to the cost of energy
- Subsidizing construction with high whole-building efficiency and banning construction with low efficiency
- Restricting specific technologies, materials and practices detrimental to building energy efficiency.

The modeling results for the base case show total energy consumption for this subsector rising more than three times from 2005 to 2050 *(see figure 23)*. Basic incentives on individual building components, included in the base case (from 20 to 35% for building envelope components, heating and cooling equipment, HVAC controls, and water heating), have very little impact.

Even bold policies that represent Transformation (subsidies for high-efficiency buildings and no construction of low-efficiency buildings) result in energy growing by 61% by 2050, because high growth in housing stock and rising living standards overwhelm improvements in energy consumption per building *(see figure 24)*. However, energy and CO_2 in 2050 are half the level of what they would be without new policies. The shift in building class over time *(see figure 25)* must be viewed in the light of energy consumption rising due to increasing level of service. This results in a downward shift, with buildings becoming predominately class 3 by 2050. (The classification is based on 2005 energy consumption per household.)

We examined several other cases relevant to northern China, including the impacts of improving the customer side of district heating through the addition of heat meters, thermostatic valves to permit apartment owner control, and billing for consumption. *(see figure 26)* The results suggest that a large improvement can be obtained by making these mandatory for new buildings and refurbishments of existing buildings. The model shows an average reduction in space heating energy consumption of 76% per building from 2005 to 2050 as the building stock is upgraded. The energy savings outweigh the costs by a large margin. *(See figure 27 for summary energy development in each simulation.)*

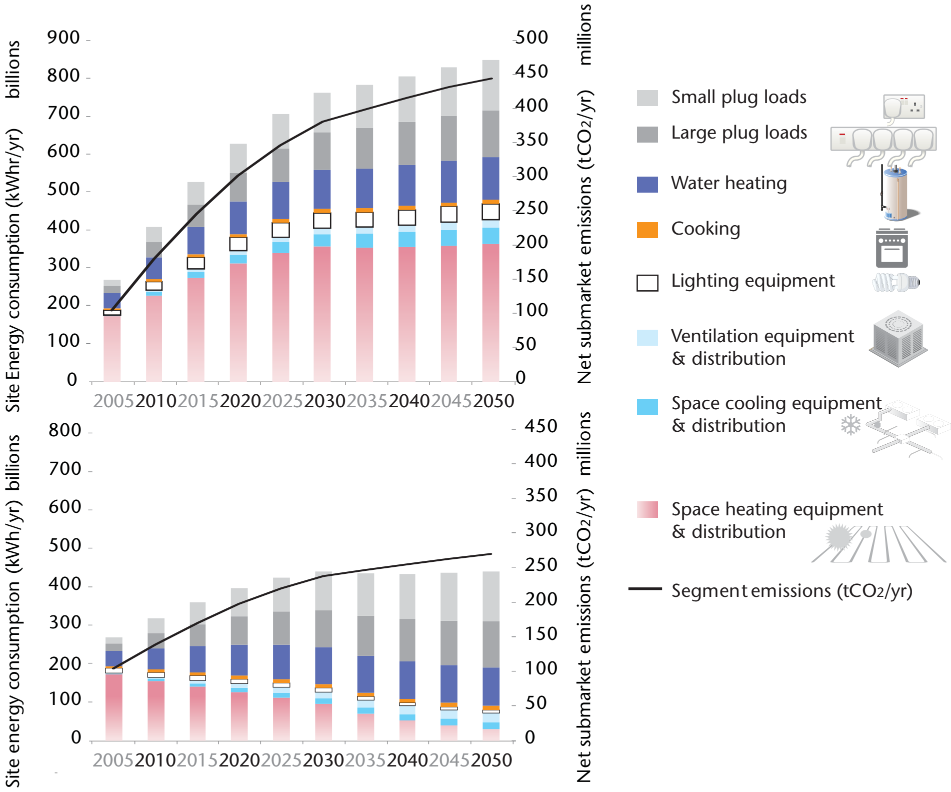
The cost premium under the Transformation case relative to the base case is an average of US$ 12 billion per year; but this is almost fully offset by a comparable amount of annual energy cost savings. Efficiency measures with simple paybacks of 5 years or less, amounting to approximately 5% of the total investment, deliver close to 60% of the energy savings.

Base case

Submarket site energy consumption and net CO_2 emissions under existing policies case - Northern China multi-family residential

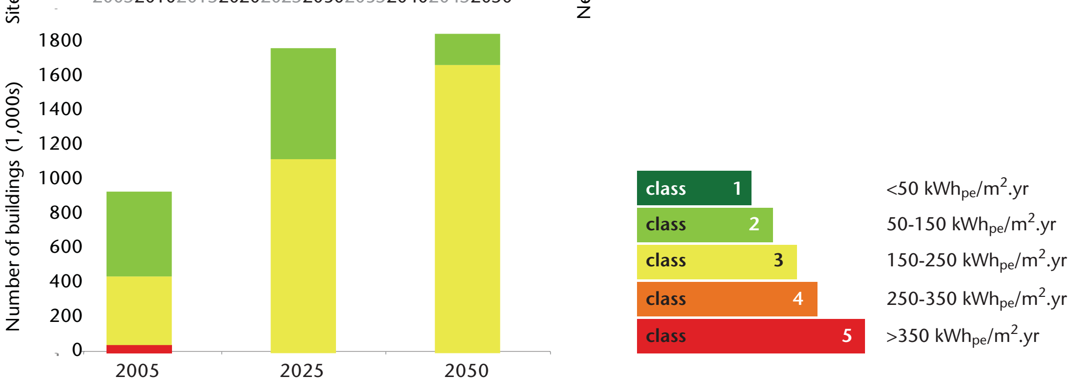
Transformation

Submarket site energy consumption and net CO_2 emissions under Transformation case - Northern China multi-family residential



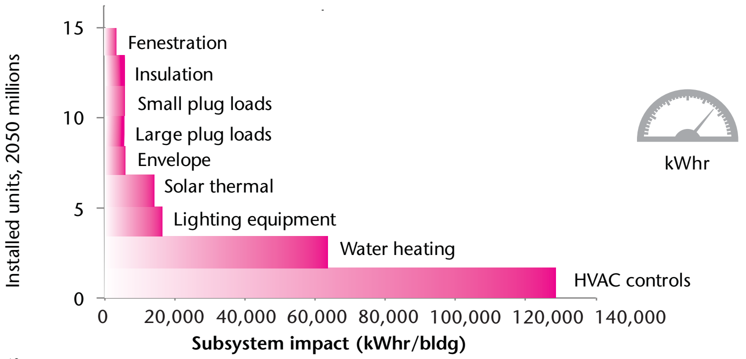
Shifts

Shifts in building stock energy class under Transformation case - Northern China multi-family residential



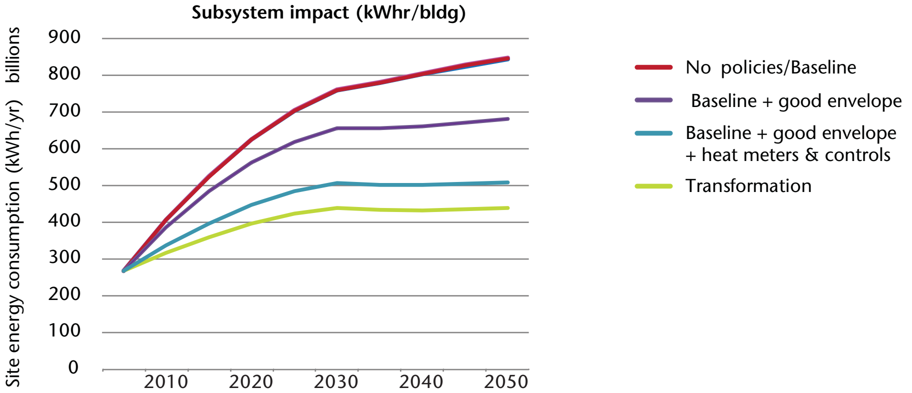
Subsystem impacts

Installed base of individual building subsystem in 2050 and their impacts on site energy - Northern China multi-family residential



Policy cases

Submarket site energy outcomes for different policy cases - Northern China multi-family residential

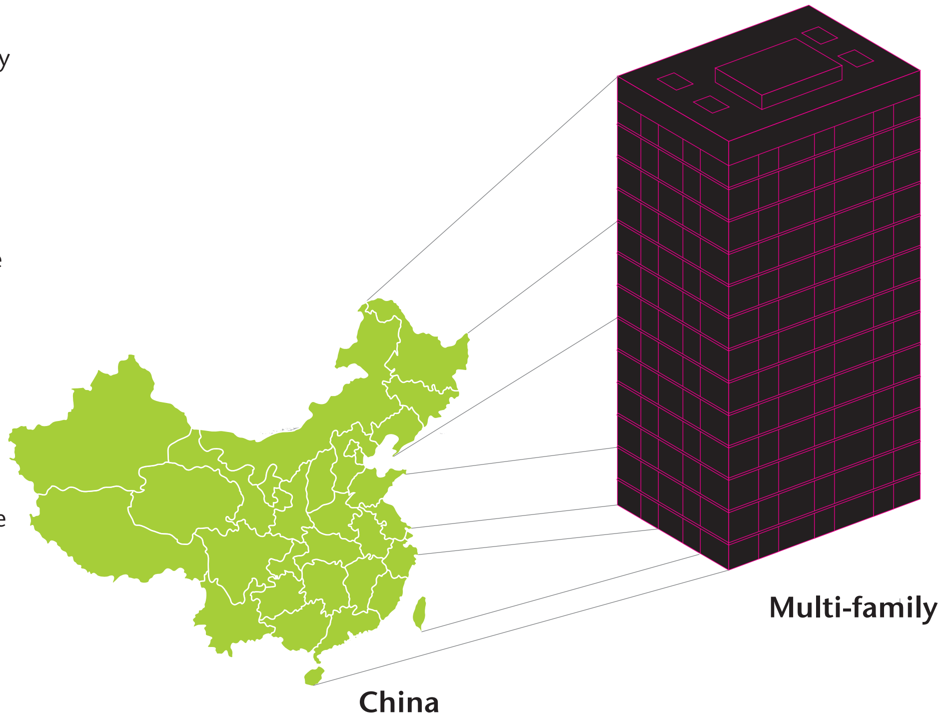


Figures 23, 24, 25, 26, 27

Transformational recommendations for multi-family buildings

The modeling suggests that strong measures will be needed to achieve Transformation:

1. Audit energy performance of apartment buildings; introduce labeling systems to provide transparency, and enforce increasingly strict building energy codes
2. Strengthen building codes and ensure adequate audit and enforcement capacity
3. Introduce heavy subsidies to achieve high performance in existing and new buildings, including significant feed-in tariffs for on-site generation
4. Require sub-metering, apartment-level controls and charging according to use
5. Revise legal frameworks to overcome barriers to collective refurbishment of apartment buildings
6. Impose regulations to phase out low-performing buildings, including a requirement for zero net energy, new, low-rise buildings from 2020
7. Government authorities and other owners of social housing must act on their property portfolios
8. Initiate a mobilization campaign to motivate behavior change by owners, project developers, tenants and reinforce the message to fully establish a change in behavior
9. Educate and train developers, architects, engineers and the building trades to improve understanding of code requirements, illustrate the advantages of integrated design and alleviate concerns for higher costs
10. Promote energy service companies (ESCOs) as effective energy managers for building owners, especially public housing authorities
11. Promote onsite renewable generation for all new low-rise buildings.



Office

"Corporations outsource real estate; they don't see it as a primary business function."

Participant at EEB Finance workshop
New York, October 2008

The office subsector is the largest in the commercial sector in floorspace and energy use in most countries. It has been expanding extremely rapidly in China, where two billion square meters a year have been added in the last few years, equivalent to a third of Japan's existing building area.

Offices range from small, single storey multi-occupied buildings to the skyscrapers that form the skylines of all major cities. They tend to be newer than other buildings. Roughly 60% of office buildings in the US have been built since 1970, meaning that efficient technologies are likely to be more prevalent than in the residential sectors.

The structure of the market is changing due to new work patterns that are reducing the average floor space per person. Outsourcing, mobile working, using information and communication technology (ICT) mean that people can work at home more. The result may be fewer large offices and more flexible space.

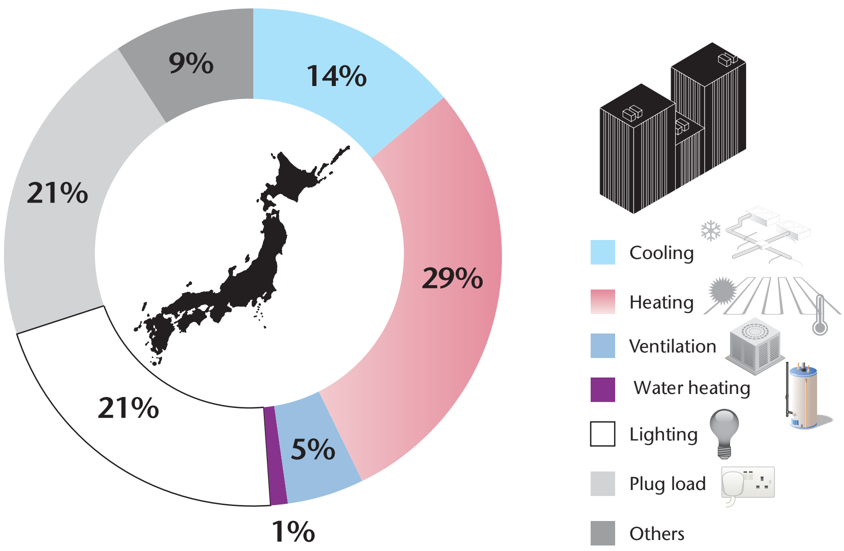
Many offices are government-owned, especially in India, which indicates a need for public sector leadership. Many others are owned by property investment companies and occupied by tenants, in which case split incentives apply.

Energy uses

Heating, cooling and lighting are the largest energy uses in offices. The balance varies depending on climate and the type or size of office building, but space heating is typically the largest in the EEB markets. In the US, space heating takes 25% of all office energy, while cooling is only 9%. In Japan, heating accounts for 29% of the total, the largest proportion. *(See figure 20.)* In new buildings, heating tends to be much lower, while cooling remains rather high and plug loads tend to become the main energy use. The growing use of computers and other office equipment presents a challenge in this subsector. Total greenhouse gas emissions from IT equipment (including data centers) are growing at about 6% a year.[32] As well as their direct energy use, heat from equipment adds to cooling and ventilation needs. Manufacturers are driving down the energy consumption of individual products but these advances are offset by increasing processing needs.

Figure 28

Office building energy consumption in Japan



Regional highlights

China

Office buildings account for about one-third of China's commercial building stock, a proportion expected to decline to 29% by 2020 as retail space and schools grow faster. Nonetheless, from a current 3.5 billion m^2 of floor space, offices are expected to grow by over 70%, adding over 2.5 billion, m^2 by 2020.

Energy consumption is expected to grow at an average annual rate of 7% to 2020, but total energy requirements for heating are expected to stay fairly stable as building heat management improves. In contrast, the expected increase in cooling demand over a larger proportion of office building floor space will send cooling energy consumption up by 12% per year on average. Consumption of other services such as lighting and office equipment is expected to grow by 10% per year *(see figure 29)*.

France

The office submarket is the most dynamic of the building sector, having grown by 54% between 1986 and 2004.[33] Renewal of the stock is high, especially compared to residential buildings, and most office buildings are less than 15 years old.

Space heating is the largest energy consumer in French offices. Ventilation and air conditioning, often believed to be the main users, are responsible for only 10% of office energy consumption.

India

This sector is one of the fastest growing sectors in India, reflecting the increasing share of the services sector in the economy. The office stock must increase by nearly 20 million square feet a year in New Delhi, Mumbai and Bangalore to keep pace with demand. More than 7,000 IT service companies dominate the office market in India, and these companies need modern, high-quality buildings.

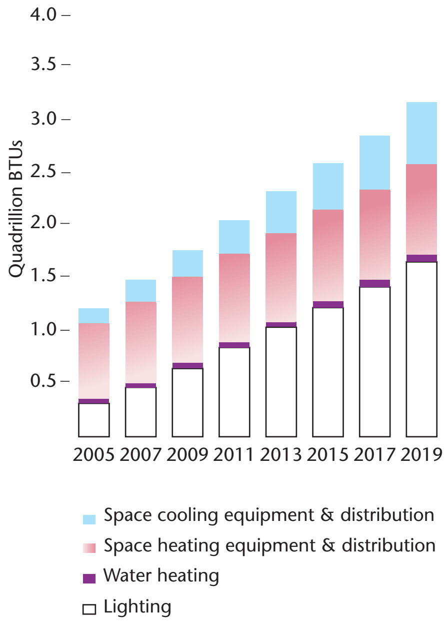
Japan

The largest proportion of energy is used for space conditioning (48%) with heating the largest consumer (about 30% of all office energy use) *(see figure 29)*. More detailed analysis of Japan is presented in the submarket case on page 43.

United States

Offices tend to have been built more recently than other commercial buildings. More than half have been built since 1970.

Space conditioning is the largest energy use (40%), and space heating is the largest proportion of this (25% of all office energy use) followed by cooling and ventilation. After space conditioning, lighting is the largest energy use followed by office equipment and then water heating.



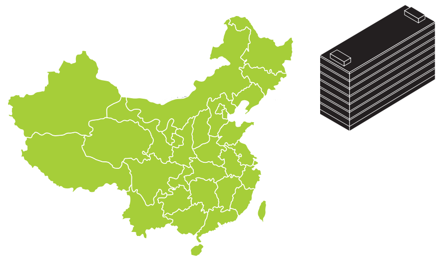
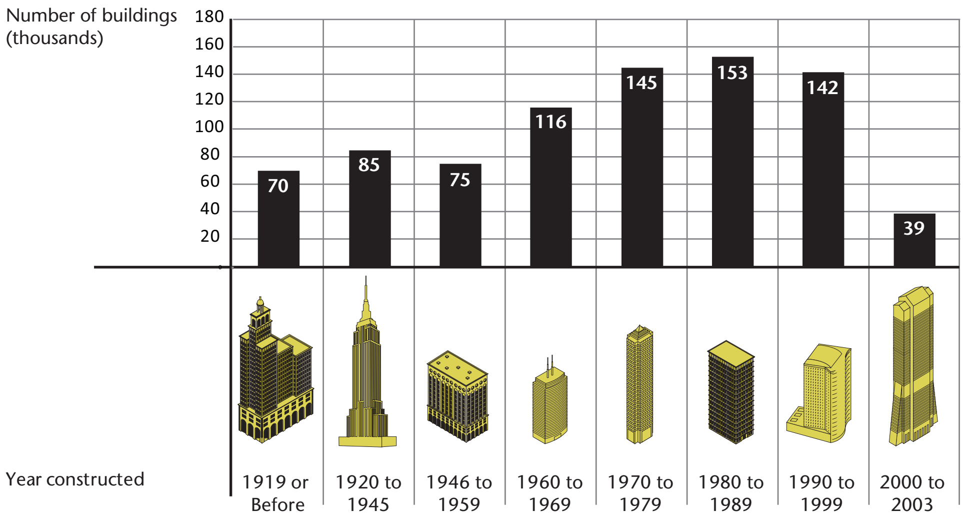


Figure 29

Growth projections for China office building primary energy use by application

Figure 30

US office building stock by year built



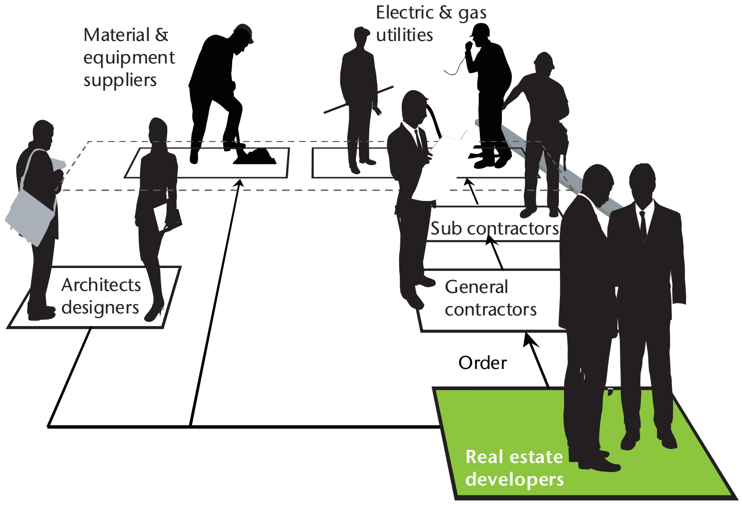
Barriers

Developers or investors who have the final decision-making authority on office buildings hinder the adoption of energy efficiency designs, technologies and practices. They pursue short-term profit maximization and tend to emphasize the initial cost rather than life cycle cost. Energy costs are not very important for them. There is no rating system that could make energy efficiency more important for developers and investors.

The complexity of the office building market complicates the challenge. There are many players, especially in the leased segment – developers, construction companies and material and equipment suppliers *(see figure 31)*. And there are many owners & agents. Developers and owners, who have the final say, are the top of the procurement hierarchy. However, they are not in leading positions in business. There are few international players, unlike in the automobile industry or the electrical industry, where global leaders have taken the initiative to conserve energy.

Figure 31

Procurement hierarchy for office building development



Professional know-how, support and leadership for low-energy offices are lacking. There are no in-house energy auditors or engineers, as there are in industrial factories, where specialists are responsible for energy facilities. Energy consumption in each office building is much smaller than in industry, so there is less attention paid to energy costs.

Physical constraints are also a barrier for very low-energy offices. It is quite difficult to install large PV systems on top of office buildings, since the roof space is limited, compared to building size.

Office case study – Japan

During the 1980s and 1990s the Japanese government backed efforts to promote the use of gas-fired cooling to conserve electricity in the summer peak season. As a result, gas absorption chillers were installed in many large office buildings in Japan. But this trend has been changed due to rapid technological innovation in electric-driven heat pump systems, which are a more favorable technology in terms of global warming impacts. Modeling suggests the advantages will continue to grow *(see figure 32)*.

Modeling

We used the model to examine office energy use in Japan and contrast it with the US situation.The model is based on 30-storey office blocks with floor space of 30,000 m^2 in the Kanto Area of Japan and the northeast of the US with average floor space of 130,000 m^2. The building stock of Japan is represented by nine different types of construction (reference cases) that correspond to various combinations of heating and cooling systems, insulation levels, lighting and other characteristics. There are seven US reference cases.

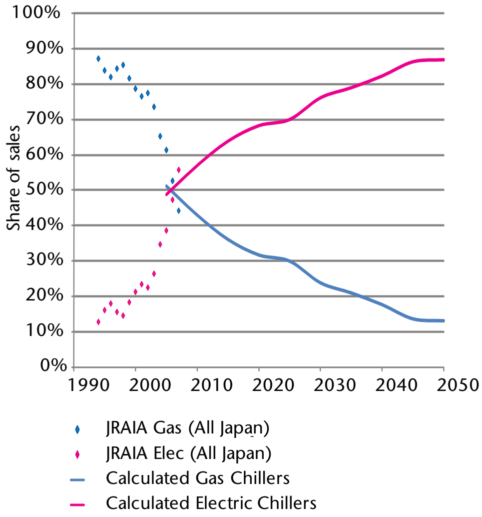
The modeling output shows that a 33% reduction in site energy is possible per building without radical action, continuing existing energy policies on pricing, low levels of building enforcement and no incentives for the purchase of energy-efficient buildings. As the Japanese building growth rate is 0.4% per year, total CO_2 emissions will slightly decrease by 2050. Total grid electricity consumption will not change very much by 2050 whereas gas consumption will decrease by almost 50% because of the low-carbon intensity of grid electricity in Japan.

Introducing capital incentives for energy-efficient equipment raises the energy reduction per building to 37%,*(see figure 33)* relatively little improvement on the base case. Adding a carbon cost of US$ 60 per tonne does not make any difference. In Japan a 43% reduction in CO_2 in total and 51% per building is possible with transformative actions and policy *(see figure 34)*. In the Transformation case, the building stock changes from class 4 and 5 in 2005 to almost all class 2 in 2050 *(see figure 35)*. We found that more than 50% energy savings in each building is possible with existing technology and radical policy packages. But the total energy consumption and CO_2 reduction cannot reach transformation levels in those countries or areas where the growth of the building stock is high, such as the US. New technologies and efficiency improvement are also needed.

Heating and cooling equipment have the highest potential to curb energy in office buildings in Japan *(see figure 36)* and the US. Cooling has the highest potential in the US northeast. The simulations for Japan suggest absorption chillers will be replaced by centrifugal chillers in this region and gas-fired absorption chiller heaters will be replaced by heat pump chillers for cooling. Because highly efficient electric-driven centrifugal chillers will dominate cooling demand, technologies such as heat pumps are key for low-energy offices.

The submarket site energy for a variety of scenarios in Japan changes only slightly with different policy variations *(see figure 37)*. Only the Transformation case showed a significant effect. Our simulations suggest that a 33% reduction in CO_2 emissions per building is possible in Japan and 43% can be achieved in the US northeast, even without radical action. But it is much more difficult to cut total emissions by the same amount because the US office building stock is growing by 1.5% a year. Stronger action will be required in the US to reduce total energy consumption. These findings are reflected in our office recommendations.

The investment required to achieve Transformation for this submarket in Japan is estimated at approximately US$ 110 million a year. With annual energy cost savings of US$ 80 million, the net annual cost is US$ 30 million. As with the other submarkets, a high proportion of energy savings can be achieved with measures having simple paybacks of under 5 years.



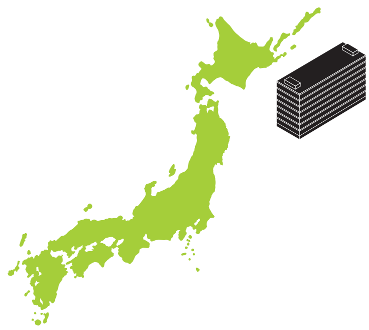
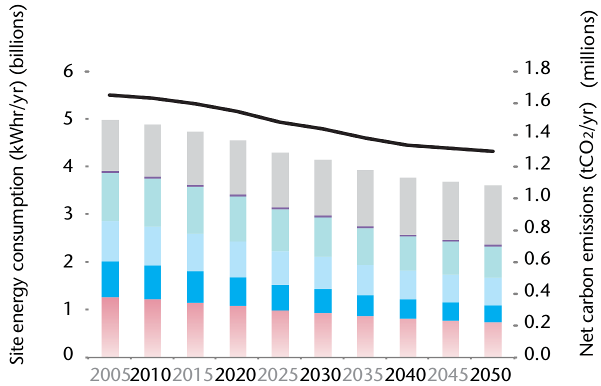


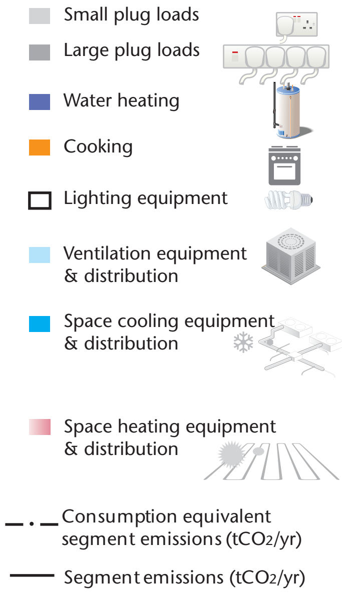
Figure 32

Historical and predicted market shares for gas and electric chillers in Japan
(Source: Japan Refrigeration and Air Condition Industry (JRAIA), EEB model based calculations.)

Base case

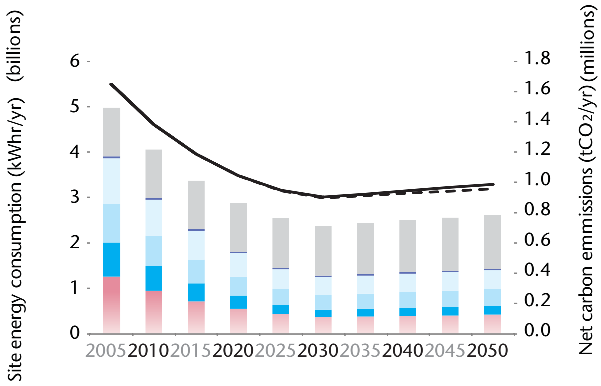
Submarket site energy consumption and CO_2 emissions under existing policies case - Japan office





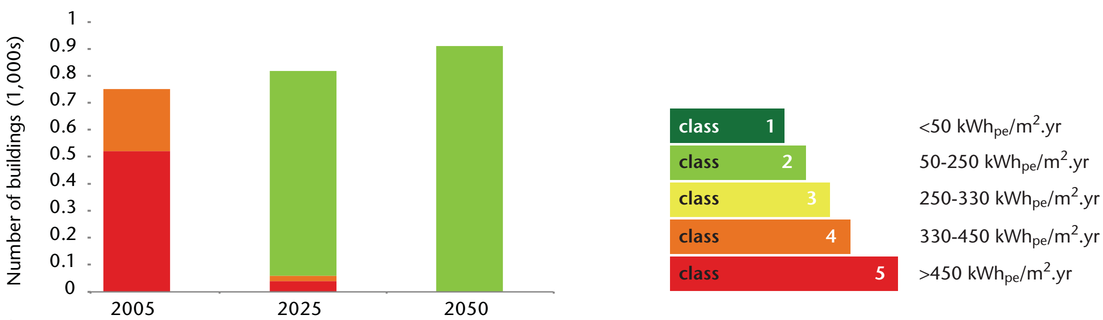
Transformation

Submarket site energy consumption and CO_2 emissions under Transformation case - Japan office



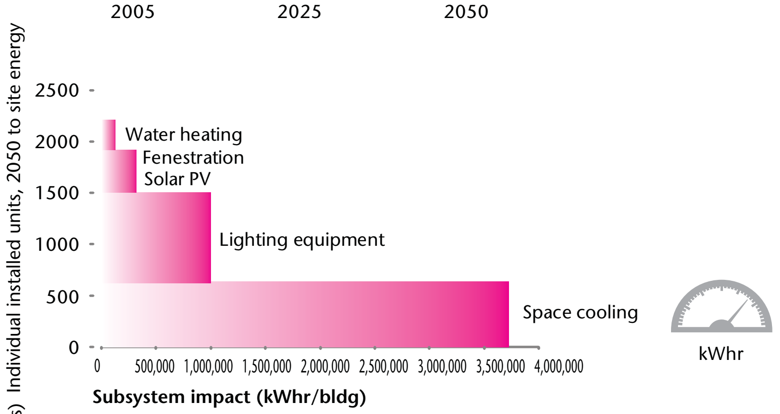
Shift

Shifts in building stock energy class under Transformation case - Japan office



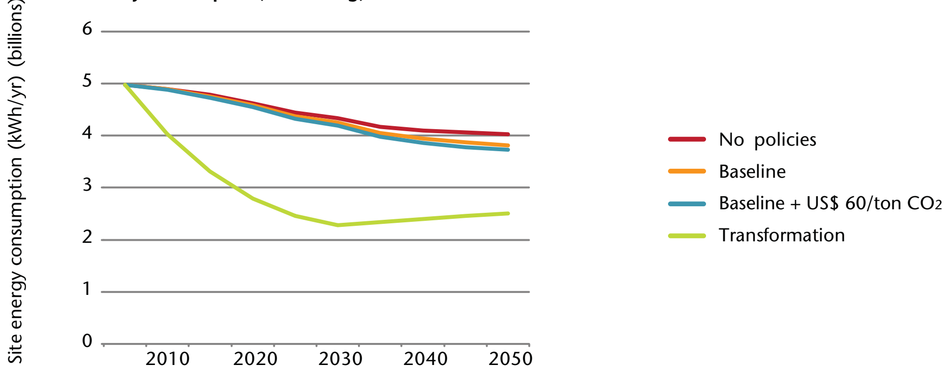
Subsystem impacts

Individual building subsystem installed base in 2050 and impacts to site energy - Japan office



Policy cases

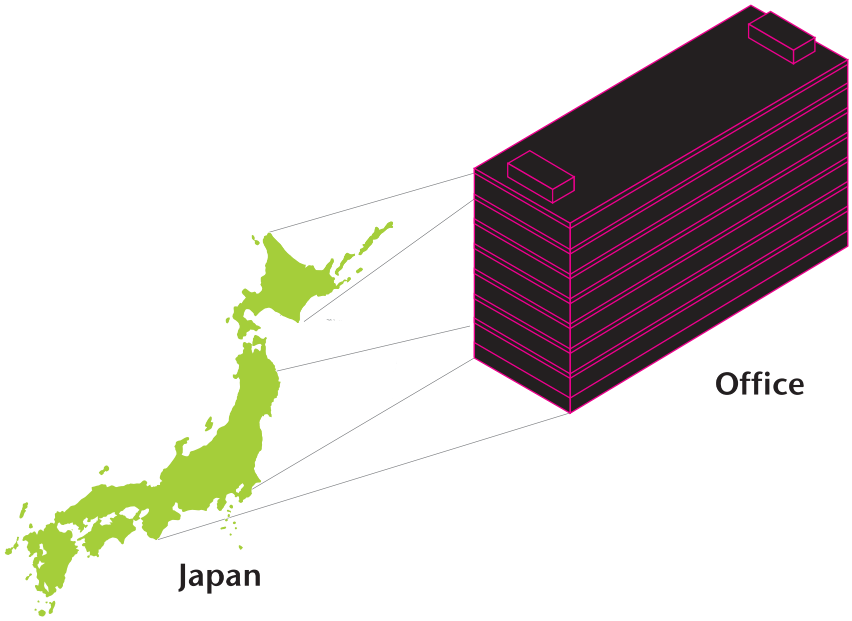
Submarket site energy outcomes for different policy cases - Japan office



Figures 33, 34, 35, 36, 37

Office transformational recommendations

1. Audit energy performance of office buildings; introduce labeling systems to provide transparency; and enforce increasingly strict building energy codes
2. Introduce heavy subsidies for achieving high performance in existing and new buildings
3. Regulations to phase-out low-performing buildings, equipment and lighting
4. Require office-level controls and charging according to use in multi-occupied buildings
5. Introduce process incentives for developers to adopt integrated design approaches achieving high energy efficiency
6. Promote energy service companies as effective energy managers for large office owners, especially public buildings
7. Promote research and development of highly efficient equipment and lighting
8. Promote onsite renewable generation for all low-rise, new office developments
9. Create a technical offer for onsite renewable generation, using R&D to drive down first cost and identifying retrofitting solutions
10. Include energy efficiency in routine health, safety and fire inspections and re-commission as necessary to ensure achievement of design standards
11. Launch an education and awareness campaign to raise awareness of energy use and cost, elevate the status of facilities management engineers and encourage wider comfort tolerances



Retail subsector

Retailing is growing and becoming more energy-intensive as it develops from small shops to sophisticated malls. In this EEB analysis we concentrate on the "mercantile" segment, which primarily covers non-food retail, although a shopping center may include food service and a supermarket.[34]

Developing countries are following the trend in Europe and the US away from street shops toward larger supermarkets and malls. We concentrate on these segments as they are growing, international phenomena. Also, on-line sales continue to grow market share, a trend likely to affect the established stores sector.

Stores' energy use is driven mainly by the volume of sales and the sales area, and both are growing. Total retail sales grew 35% between 2001 and 2005.

Ownership

Retailing is still a relatively fragmented sector, but concentration and internationalization have been increasing. This may support energy efficiency due to economies of scale.

Concentration is highest in the US. At the other extreme, there are around 15 million retail outlets in India,[35] most of which are family business with few branches and few employees for each. *(See table 6.)*

Table 6

Retail concentration (Source: Eurostat completar)

Country	Number of stores per 1,000 inhabitants
India	22
South Europe (Portugal, Greece)	17
Japan	10
UK, Netherlands	7
US	3.8

Facts

- The top 100 retail companies take 34% of total retail revenue in the US[36]
- In China the top 100 companies make up only 10.5% of the retail market

Retail energy use

The mercantile retail segment accounts for 16% of commercial energy use in the US. In Europe, total retail is responsible for 23% of energy use in the commercial sector. Energy intensity depends on the kind of retail outlet. Food service and food sales use much more energy than other formats, while street shops use least.

Retail's main energy uses are HVAC and lighting. This is true in street shops as well as malls, but cooling takes a larger share in malls than in smaller shops
(see figures 38 and 39)

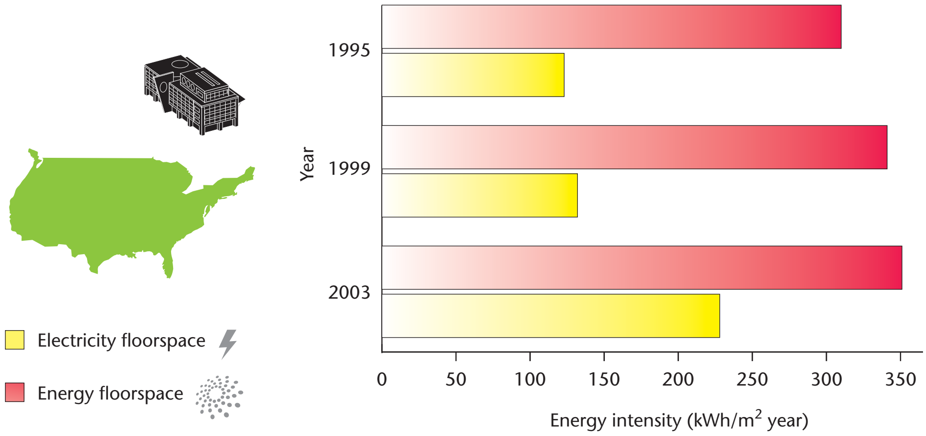


Figure 38

Retail subsector energy intensity has grown

Trends

Unlike other sectors, retail energy intensity is higher in new stores than in old ones *(see figures 38 & 39)*. In the US, energy intensity increased from an average 310 kWh/m²/yr in 1995 to an average of 351 kWh/m²/yr in 2003 (almost a 15% increase). The increase in electricity intensity was even more spectacular, reflecting higher levels of lighting and equipment.

Growing electricity use is especially evident in malls *(see figure 39)*, with electricity use per m² more than double in malls built after 1990, compared with ones built before 1959.[37]

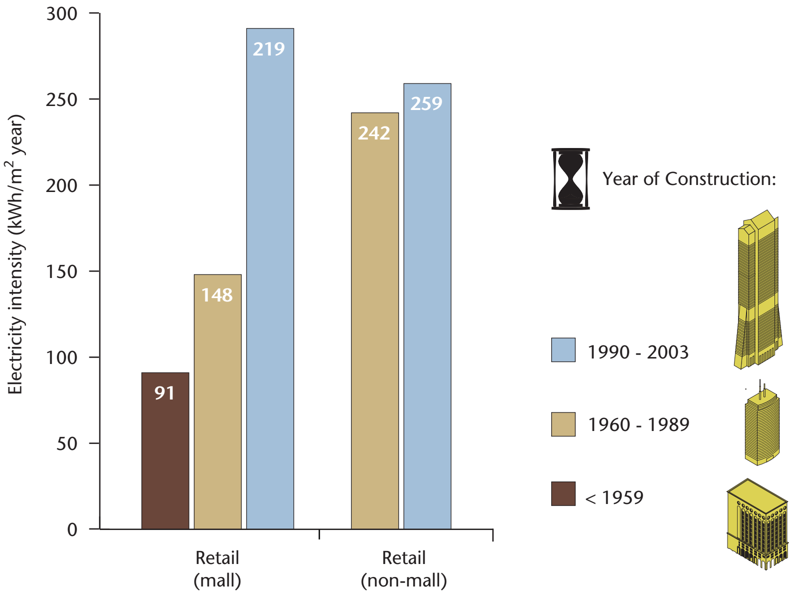


Figure 39

New retail buildings use more electricity

Barriers

There are several reasons for the increase in retail energy intensity:

- Energy is not a top priority for retail managers, because it is a small share of total operating costs
- Most retail managers know little about complex energy issues, especially in small businesses but also in multinationals

- Lighting, responsible for a significant share of final energy use in retail, is considered to be a "sales force", a factor of customer attraction; so, lighting levels (and energy consumption) are increasing in many retail formats
- Thermal comfort supports retail sales (customers should be neither too hot nor too cold) and large shopping malls need comfortable common areas as well as the shops themselves being comfortable and well lit
- Stores are extending opening times (more hours per day, more days per year) leading to higher energy use.

Cutting energy use in malls

As economies develop, retailing tends to move from small street shops to new malls, which attract people with the variety of stores and other features.

Lighting accounts for almost half the total energy consumption in a typical shopping mall in a warm climate. Most of this is in the stores rather than the common areas, and in total the stores use approximately three-quarters of total energy. The other major use is HVAC. Restaurants are energy-intensive users and can consume up to a fifth of total mall energy. *(See figure 41.)*

There are large variations around these averages, even for similar malls with similar technology in similar climates. For example, the difference between the most and least efficient anchor store (the main tenant in the mall) can be a factor of three.

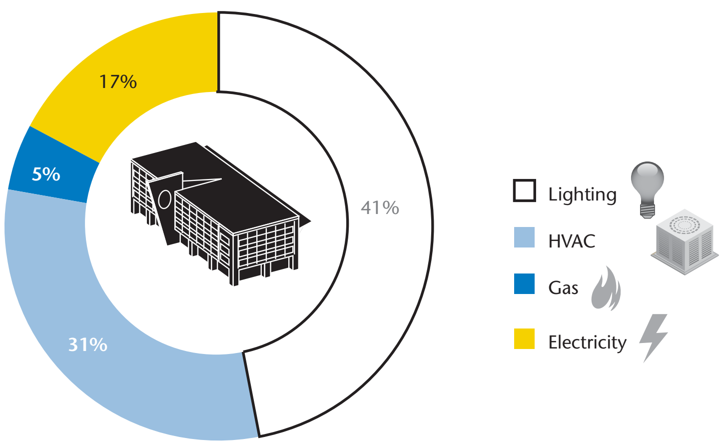
Several measures can save considerable energy with short investment paybacks:

- Smart metering so that stores in the mall are aware of their energy use and are motivated to take action
- Solar PV and combined heat and power to replace some electricity from the grid Changes to lighting inside and outside the mall
- Improvements to the cooling and ventilation systems
- Shading external glass.

Smart metering provokes behavior changes by store managers and provides the best financial payback, as short as four months on investments between US$ 40,000 and US$ 130,000 with energy savings costing less than US$ 40 per MWh. But this is unlikely to result in substantial energy savings. The effect could be enough to move a mall from

Figure 40

Lighting is the main energy use in shopping malls



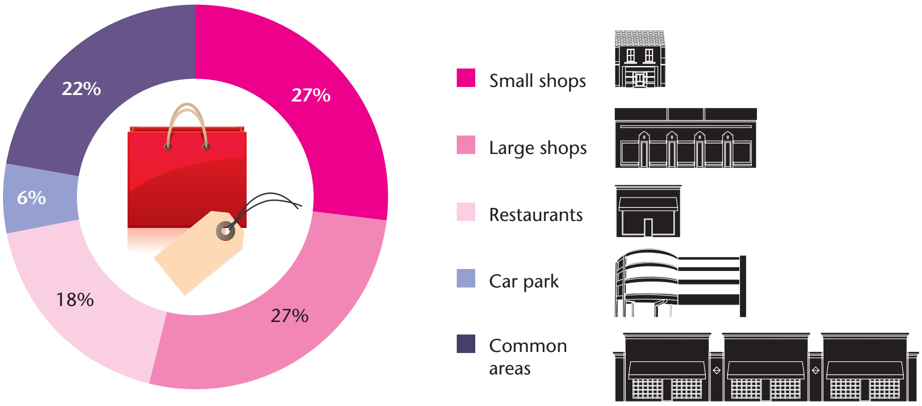


Figure 41

Energy use in malls

one level to the next in an official labeling hierarchy (such as the A-G European model), but the energy savings could be less than 1% of the mall's energy consumption.

A full package of the measures described above costing more than US$ 4 million per mall on average can achieve more substantial energy savings with financial paybacks in less than four years.

In one example, a mall operator used a package of measures to cut energy consumption by 37% with an investment of less than US$ 3 million. But the payback on the financial savings was more than five years for the whole package. The payback on individual actions ranged from 0.2 years (using external air to provide "free cooling") to nearly 18 years (for changing external lighting).

The most significant savings in this example came from installing photovoltaic panels followed by smart metering. These two measures provided 75% of the total energy savings for 68% of the total investment. The average payback was 4.8 years.

Cutting energy in supermarkets

Leading supermarkets such as Wal-Mart and Tesco are saving energy through radical store design. Wal-Mart is experimenting with low-energy stores that will eventually use 100% renewable energy. In January 2008, the company opened the first of four next-generation, high-efficiency stores that are 25% more energy efficient than the 2005 base, reducing refrigerant use by 90%. (See also the Tesco case study.)

Case study: Tesco

Tesco has halved energy per square foot in its UK stores since 2000. In 2009 it opened a new store in Manchester, UK, which has a carbon footprint 70% smaller than an equivalent store built in 2006. Foot print reductions come from a mix of design, materials and technologies, including a timber frame instead of steel, roof lights to cut down on artificial lighting, and a refrigeration system using CO_2 as a coolant. Of the 70% carbon savings, 31% has been achieved through energy-efficiency measures.

The store has special windows in the roof, allowing natural daylight to filter down to the sales floor. The lightweight panels are filled with a gel that allows light through without over-heating the store. In the offices, mirrored tubes reflect daylight into areas that would otherwise be dark. The lighting system automatically dims individual lights when natural light increases.

Transformation recommendations for Retail

1. Audit energy performance of retail buildings; introduce labeling systems to provide transparency, and enforce increasingly strict building energy codes
2. Introduce heavy subsidies for achieving high performance in existing and new buildings
3. Regulate to phase-out low-performing buildings
4. Introduce maximum Watts/m² for lighting and HVAC
5. Retailers to participate in an energy-awareness campaign, promoting their energy credentials and raising consciousness of energy use
6. Create an improved technical offer, using R&D to drive down first cost and increase energy savings
7. Require smart sub-metering for retail units within malls
8. Introduce process incentives for developers to adopt integrated design approaches achieving high energy efficiency
9. Promote onsite renewable generation for all new retail developments

3. Action for change

Our modeling and analysis emphasize the need to transform the whole building sector. Without fast and effective action, the energy used in buildings will be as much as transport and industry combined by 2050. Our research demonstrates that we can cut that dramatically, saving as much energy as the entire transport sector currently uses.

These enormous savings are possible even with the anticipated huge increase in building numbers. But current policies, financial arrangements and behaviors will not provoke the necessary decisions by businesses and individuals. Businesses in the building sector will make progress, but not the necessary transformation without stronger market signals and regulatory change.

There are common themes across subsectors. The first cost and short-term investment horizons are major barriers in both residential and commercial buildings. We find widespread ignorance about energy consumption and how to reduce it. Energy is not a priority for many building users, and raising energy prices (within levels that seem economically and politically acceptable) is unlikely to change this substantially because energy costs are usually relatively insignificant for most users. Even if the knowledge gap is overcome, building owners and users will not make the necessary investment under current conditions. Non-financial (or behavioral) barriers also mean that investments may not be made by businesses and consumers even when they are economically rational.[38] In short, most building owners and users don't know enough and don't care enough about energy consumption, and inertia is reinforced because first costs are too high and savings too low.

Overcoming these barriers will not only achieve the energy objective but will also create jobs and business opportunities that can support economic growth. However, transformation will not occur solely through market forces as the financial, organizational and behavioral barriers are too significant. Transformation will only happen when:

- Political will and business leadership make building energy a top priority, so that behaviors change, and energy-efficient design and technologies become the norm
- Favorable and reliable financial returns are available from investments in energy efficiency because
  - Energy prices are consistently high enough (including a price on carbon) to produce significant savings
  - Innovative financial models provide funding and share risks
  - Design and technology innovations reduce first costs to viable levels
- Business, government authorities and others work together to implement energy-efficient building solutions in developing economies, allowing for improvements in living standards while limiting absolute energy growth

"Governments and businesses have to do the right things as well. Otherwise it gives people excuses for not doing anything."

Participant at the EEB Behavior workshop
July 2008

"Energy is invisible. We need to make it visible."

Participant at the EEB Behavior workshop
August 2008

"Carbon tax is not a way to motivate downstream behavior. US$ 30/tonne tax doesn't have much financial impact."

Participant at EEB Finance workshop
October 2008

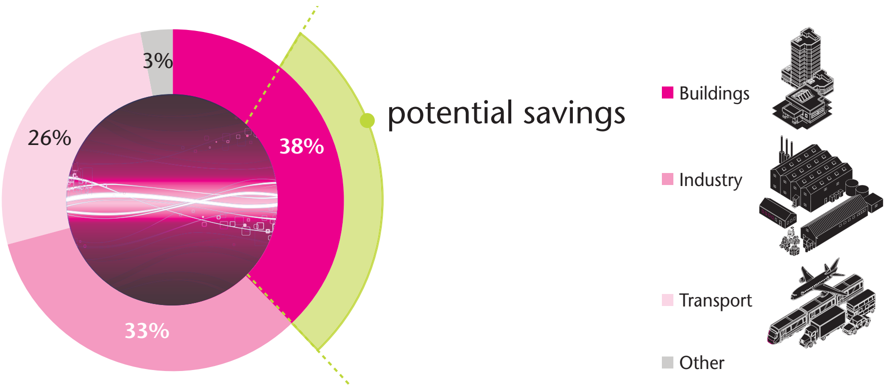


Figure 43

Building energy savings as much as transport today

Recommendations for action

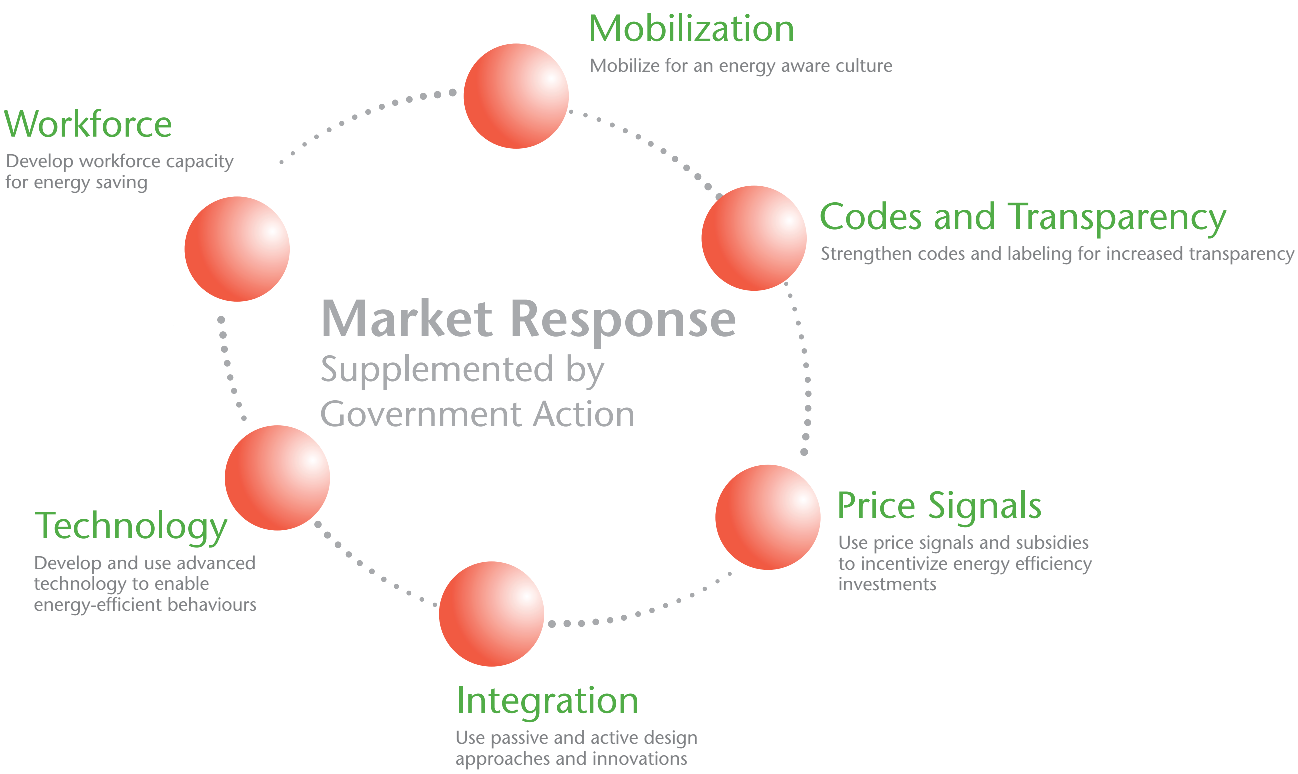
The necessary transformation of the building sector requires immediate and substantive action by business, individuals and governments. Policies and promises are not enough. *Action* is required by all those involved in determining building energy use. Developing the specific subsector recommendations in the previous chapter, we now propose six broad recommendations to stimulate both supply of and demand for energy efficiency in buildings.

This project concentrates on the building sector rather than the broader environment, but we acknowledge that building energy is just one aspect of sustainability, along with elements such as transport, water and food. We also recognize the importance of the energy mix in the electricity grid, but that is also beyond our project scope.

Our recommendations need to be applied appropriately to each building subsector but represent a comprehensive package that must be seen in totality, rather than a set of options that can be implemented separately or sequentially. They overlap and interrelate and are mutually reinforcing *(see figure 43)*. They are relevant globally, although the emphasis may be different from country to country. They assume a post-Kyoto agreement on combating climate change with a long-term commitment to substantially cutting carbon dioxide emissions, based on the fundamental principle of "common but differentiated responsibilities" between countries.

Figure 43

Mutually supportive recommendations



Strengthen codes and labeling for increased transparency

Our modeling work demonstrates that market forces will not achieve the necessary transformation fast enough without external stimuli. For example, energy consumption for single family homes in France rises by 24% in our simulation even with current levels of incentives.

Because of the urgency of the challenge, policy intervention is essential. The right policy packages will support the market to work more effectively towards low energy use, and will stimulate behavior change. A wide range of policies are available to support energy saving action.[39] They include fiscal and financial measures as well as regulations. Policies need to be considered as mutually reinforcing packages rather than assessed individually and narrowly. For example, effective energy performance certification is essential for many fiscal/financial measures. Governments also need to cooperate on policies and coordinate action, providing consistency from market to market, which allows economies of scale that will support energy investment.

> **We recommend** that building codes be enforced with strong energy efficiency requirements, tightened over time and appropriate to local climate conditions.

Government authorities must set and enforce high building energy standards and make clear that those standards will become tougher over time. This will underpin a more energy-conscious market. Strict building codes and equipment efficiency requirements should define maximum acceptable energy consumption (based on appropriate indicators) for each building subsector, relevant to the climate conditions of each region. They should apply to the actual performance of the building rather than designed levels, because many well-designed buildings do not achieve the intended energy efficiency levels. This requires common measurement and data reporting schemes but also an adequate code compliance mechanisms including trained compliance teams.

Energy components of building codes are most effective in defining standards for new buildings. But their impact is limited in developing countries that have a large informal building sector out of the reach of government policy and enforcement. In developed countries the priority is to improve the energy performance of existing building stock, using building energy codes to stimulate energy efficiency investments when buildings change hands or are refurbished.

Energy efficiency standards in building codes are useful but tighter standards do not necessarily reduce total energy consumption. For example, someone living in a very large energy-efficient house will still use large amounts of energy.

This is the “two-fridge syndrome”. Families in developed countries now often have two large refrigerators, each highly efficient, but which use more energy than the single, inefficient refrigerator they used to own. Similarly, retailers increase lighting specifications so that total energy use increases even though the systems are more efficient. This loss of potential energy savings is sometimes described as the “rebound effect,” the syndrome by which savings are dissipated as behavior changes to use the savings in other ways. Studies have found that people who install efficient lights lose up to 12% of the expected energy savings by leaving them on longer, and people who buy an efficient furnace lose up to 30% because they raise the thermostat.[40]

Because of the rebound effect and the “two-fridge” syndrome, it is important to use a range of energy indicators. Energy efficiency achieves reductions but it is not enough on its own. Other indicators are needed covering both energy and CO_2:

- Absolute figures (total usage)
- Per person per year
- Per square meter per year.

Developing such indicators would allow regulators to explore comprehensive policy packages responsive to local energy demands and local cultures.

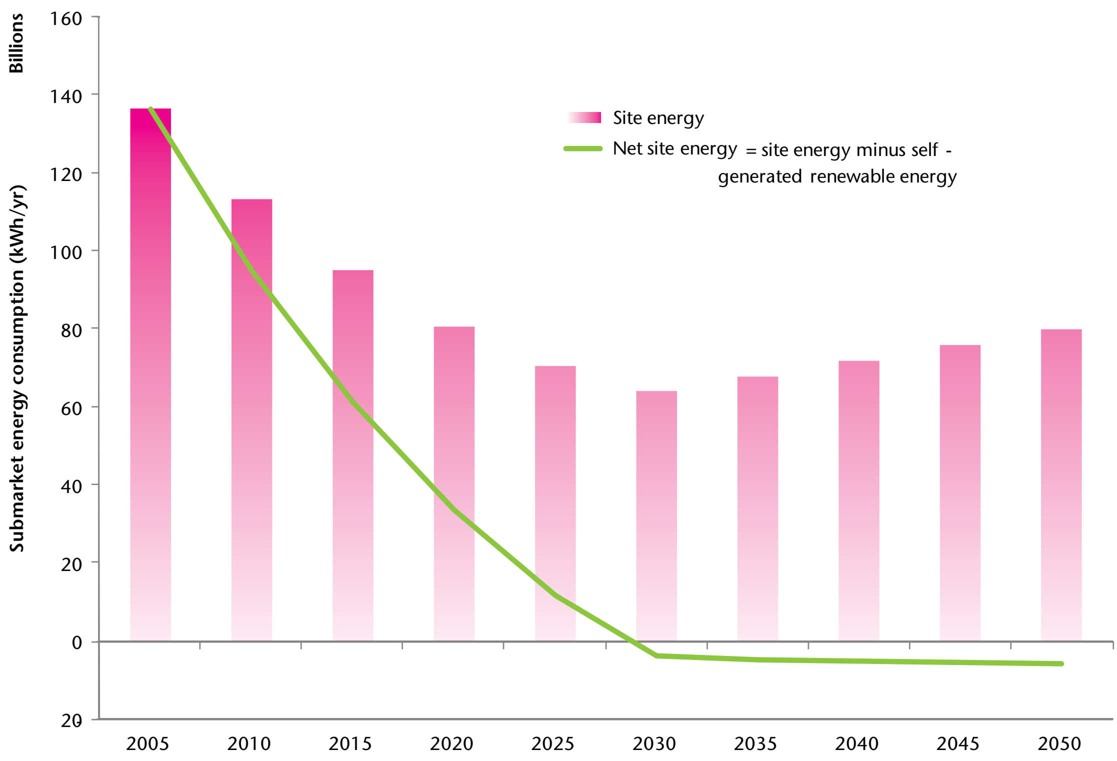
We recommend a building energy measurement and labeling standard be developed, adapted to regional climate conditions, with an obligation for all non-residential buildings to display the energy performance level.

Information on energy performance must be made public if it is to influence the market. The EU has introduced a mandatory labeling system (through Energy Performance of Buildings Directive – EPBD) that will raise the profile of energy, especially in the residential sector. Voluntary labeling systems (such as BREEAM, CASBEE, Effinergie, LEED, Minergie and PassivHaus) are already raising awareness of building sustainability, though not all focus on energy use. They are increasingly adopted to support regulation and are beginning to influence market prices. A study of 9,000 home sales in Switzerland found that those with the Minergie label achieved a sales price 7% higher than comparable homes without the label.[41]

This kind of labeling provides transparency, stimulates market adoption and provides a basis for regulation. Our modeling demonstrates that labeling schemes with imposed minimum standards can transform energy use, achieving zero net energy outcomes in residential buildings, if effectively enforced.

Figure 44

Net zero energy consumption achieved in US Southeast single-family residential submarket under Transformation policies



Labeling supports market forces, making it easier for people to include energy in their building choices. Standardized labeling systems provide a measurement basis for rigorous performance-based building standards.

We recommend that building energy audits be introduced to identify energy performance and establish priorities for improvement.

Transparency is crucial. Unless people know about the energy consumption of the services they use in buildings they cannot make energy-related choices and cannot measure progress. Similarly, government authorities cannot plan major retrofitting programs unless they have information about the energy performance of buildings. Inadequate knowledge and data inhibit energy investment.

We recommend regular inspections be required to check performance of the building envelope and key systems such as heating and cooling equipment.

Actual performance often differs from design, with degradation over time unless installation is correct, maintenance is carried out and people are trained to use equipment properly. For example, windows may cease to be airtight due to building movement. In the US, the Environmental Protection Agency estimates that air leakage typically wastes between 25% and 40% of the energy used for heating and cooling.

We recommend that energy controls be required for each unit in multi-occupied buildings and energy be charged according to use.

Split incentives are a major issue in leased apartments and office buildings (as described in chapter 2). Tenants often have no control over heating in multi-occupied buildings and are not charged according to the energy they use. This means they have no incentive to change behavior or use low-energy equipment to cut consumption. Providing control and charging according to use would overcome this barrier. Building owners get no financial benefit from lower energy use, but our other recommendations encourage such investment, especially when energy efficiency is reflected in building rental values.

We recommend that building codes enforcement for commercial buildings be incorporated in health and safety, fire and other inspections.

Code enforcement is often inadequate, in developed as well as developing countries where much building takes place beyond the scope of formal approvals and standards in commercial buildings. This is often due to a lack of effective inspection resources, but also because building standards inspectors lack the level of authority of other compliance teams, such as health and safety inspectors. Enforcement of codes could be improved by incorporating building standards in health and safety and other regular audits such as fire inspections in commercial buildings. Some sectors have inspection processes that could include building energy, for example food safety inspections for restaurants *(See figure 44)*.

Use subsidies and price signals to incentivize energy-efficient investments

Investors need to consider risks such as impacts of future regulation and energy prices. But energy issues remain a low priority for most building owners and occupiers because energy is a relatively small part of total costs in commercial and residential sectors, and the cost is rarely highly visible.

Some energy investments are not financially attractive without subsidies or other incentives. Even when they do make financial sense, returns tend to be long-term. The first cost of the investment is a significant deterrent for individuals, and long payback periods deter corporate decision-makers. Our other recommendations raise the profile of building energy efficiency so that energy performance will be increasingly reflected in property prices and rental yields. But incentives are needed to help price signals stimulate the market.

> **We recommend** that governments introduce tax packages and subsidies high enough to stimulate the market in building energy efficiency.

Taxation can be adapted to have a more significant impact on building energy investment than a broad carbon tax:

- Use the revenues raised from a price on carbon to finance subsidies that would reduce the first cost of investments
- Apply a specific building tax, thus avoiding the potential economic impact of an indiscriminate energy or carbon tax. This tax could be in the form of an adapted property tax, or could be additional, relating to the energy labels described previously. It could be neutral across the economy, adding to the energy efficiency incentive by distributing taxes raised from lower-rated properties as subsidies to those with high-performing buildings.

Subsidies paid under programs such as these must be considered carefully to avoid unintended consequences. For example, Japan's desire in the 1970s to spread energy sources resulted in incentives to use gas absorption chillers for building air-conditioning. This resulted in higher CO_2 emissions because of the higher efficiency of electric alternatives and the low CO_2 content of the electricity supply. Incentives must avoid encouraging isolated retrofitting of individual building components such as windows or boilers. Instead, these items should be included in integrated energy-efficient designs – for both new and existing houses.

> **We recommend** charging structures to encourage lower energy consumption and on-site renewable generation

There are two other ways to shift the financial equation in favor of energy-efficient investment – reduce the first cost or increase the savings in the early years. One widely recognized way of increasing potential savings is to increase the cost of energy, which would happen if post-Kyoto agreements result in higher carbon prices. These are useful mechanisms across the broader economy, but our modeling shows that they are likely to have a limited impact on energy investment decisions if set at a level that is acceptable politically and economically. Even a relatively high carbon price does not add enough to the energy cost to make energy savings sufficiently attractive (although rising prices may influence behavior by highlighting the need for energy saving).

Potential savings can be increased through commercial means. In some countries, utility charging practices may encourage waste because of discounts for higher use –

the unit rate typically declines above specified consumption levels. Reversing this practice would increase the cost of energy at higher consumption levels. This is already the case in Japan, where the first 120 kWh are charged at Yen 17.87/kWh (18 cents), increasing to Yen 22.86 (23 cents) up to 300 kWh and Yen 24.13 (24 cents) above that level.

A high feed-in tariff for renewable energy supplied to the grid may encourage investment in on-site renewable generation as is already the case in countries like Germany and France.

We recommend that energy utilities, businesses and financial institutions develop creative business models that overcome the first-cost hurdle

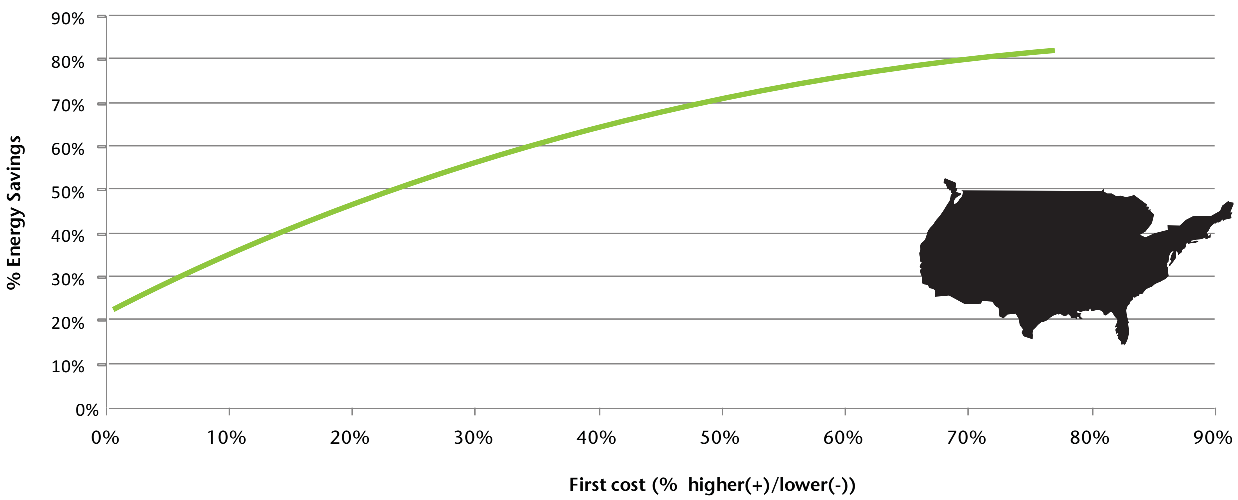
EEB modeling has clearly shown that many potentially attractive energy investments do not meet the short-term financial return criteria of businesses, investors and individuals. While significant savings are possible with relatively modest investment premiums, a first cost sensitive buyer will never adopt transformative solutions. *(See figure 45.)*

One solution is to attract new sources of funding, learning from best practice and experience with business models such as ESCOs. Several opportunities are available to open up finance for energy investment:

- Pay as You Save – the first cost is financed in full or in part by an energy utility, which recoups the outlay through regular surcharges on the monthly bill; these surcharges attach to the house, not the specific customer
- Energy service companies (ESCOs) utilities or other providers contract to achieve specified energy performance for a commercial building and share the savings with the owner
- Energy performance contracting schemes enabling energy services companies or other players to offer innovative contracts guaranteeing the level of services and the energy savings to the customer
- Local authorities provide loans to finance the energy investment, and repayments are made through an addition to the property tax charge
- Energy-efficiency investment funds capitalizing on the lower risk of mortgage lending on low-energy housing; funds to provide such investment could be attractive to socially responsible investment funds.

Figure 45

Energy savings vs. first cost for the most cost-effective efficiency options, based on US southeast single-family residential analysis.



Encourage integrated design approaches and innovations

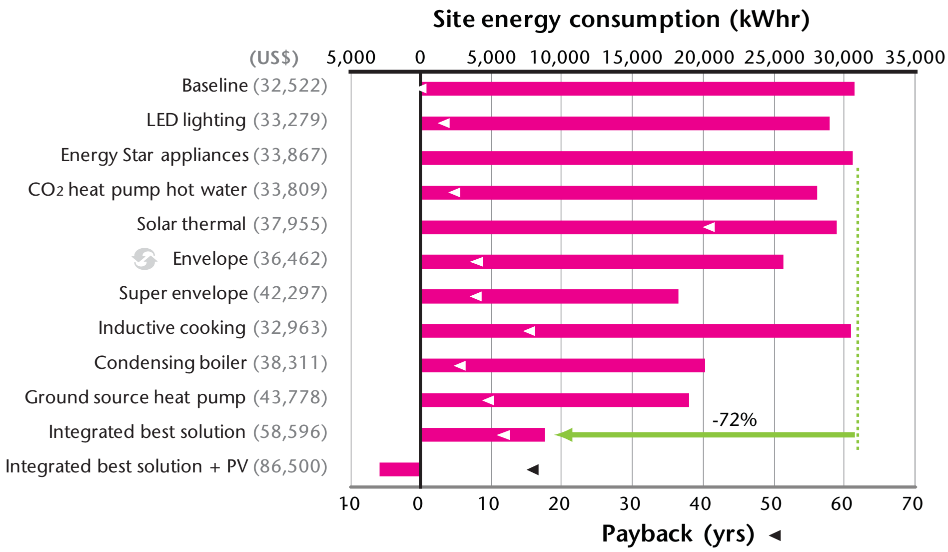
Attention to individual design or technical solutions, such as natural ventilation or insulation, can lead to sub-optimal solutions. While each component may be valuable in saving energy, the greatest energy efficiency is achieved by taking a whole-system, integrated approach, considering all the relevant factors. For example, our modeling of options for a house in the southeast US found that integrating the best solutions achieved a 72% reduction in energy consumption. The best individual solution achieved less than half this *(see figure 46)*.

An integrated design process involves all relevant participants from the start. This helps to avoid expensive revisions and disruptions later if new considerations have to be incorporated.

Integration of both passive and active measures is crucial to effective building design and construction because the individual elements work together to create an energy-efficient building. The building envelope is the starting point, beginning with the orientation of the building and the use of shade. Other passive measures include thermal mass, the use of natural ventilation and daylight. Active measures save energy in services such as lighting and HVAC by using compact fluorescent lamps (CFLs) and heat pumps.

Figure 46

Integrated solutions achieve the best performance



An integrated approach is just as important in retrofitting. For example, installing more efficient boilers and heat pumps saves more energy if it is part of an integrated refurbishment that includes building insulation and attention to other energy elements. But carrying out a package of works will be more expensive than a single investment, so the work program may need to be carried out in stages and/or supported with financial measures.

We recommend that government authorities introduce process incentives for developers to submit applications for energy-efficient buildings based on a holistic approach.

Whole-system design approaches including both passive and active measures can reduce energy use by as much as 70%. Yet the segmented structure of the building industry hampers attempts to bring together the different players in an integrated project team. The role of agents can be a brake on innovation, as they are typically preoccupied with financial criteria, which can reinforce a conservative approach to building design.

Measures are needed to incentivize property developers in particular. The bidding process hampers integrated approaches. The key issue for a developer is the significant risk of not winning approval for a project; some 90% of commercial projects never get off the drawing board. This encourages developers to minimize costs during the early phase of a project. Bringing together the different specialists in an integrated team would add costs at this stage, increasing losses if the project is not approved. But early integration significantly reduces rework and construction costs.

Reducing the risk of failure would be a significant incentive for developers. This could be achieved by giving fast-track and preferred status to development submissions that demonstrate they use an integrated team to create a holistic design to reduce energy use. Relaxing some regulations would also provide an incentive – for example, allowing higher occupancy densities than usual for high-performing buildings.

The corollary of this is that as building energy codes and standards are tightened, developers are only likely to meet the requirements at reasonable cost by adopting a whole system approach.

We recommend that property developers restructure business and contractual terms to encourage early contractor involvement as part of an integrated team.

Engineers and other project participants may be reluctant to join a project earlier than usual because of the potential additional cost, and especially cash flow, implications. This could be remedied if developers adopt new business models that transform the typical fee structure for engineers and architects to share risk and accommodate early participation by a broad-based team, including material and equipment suppliers, which could be financially viable for the developer if the project received preferential status for approval.

We recommend that utility companies and other stakeholders work with property developers to improve the energy efficiency of building projects, especially by helping to create integrated design teams.

Regulators in some cases require utilities to achieve energy savings – sometimes based on energy-saving obligations schemes such as “energy-efficient credits” that oblige energy suppliers to reach a specified level of energy savings by supporting customers’ efforts and working through partnerships with the building industry. If utilities could count demonstrable improvements in the energy-efficient design of new buildings they would have an incentive to become involved in such projects and work with developers to create integrated design teams including the whole building chain.

We recommend that subsidies and other incentives for domestic energy-efficiency improvements be provided in priority for holistic improvement programs with proper sequences and defined timescales.

Retrofitting domestic properties presents a different challenge. A holistic approach is just as important here because carrying out piecemeal improvements is more expensive and less efficient. Putting highly efficient windows in a poorly insulated building will have only a minimal impact on overall efficiency gains. Homeowners need a one-stop shop so they can easily find information on how to upgrade their property in the most energy- and cost-effective manner using integrated approaches. Financial incentives can help if they are provided only for a whole building approach to the retrofit, which may be carried out in stages.

Develop and use advanced technology to enable energy-saving behaviors

We recommend that government authorities provide initial support for research and development of effective energy-efficient technology for buildings.

Research and development is essential to bring improved energy efficiency technology to market and to drive down the first cost and increase the savings. Improved performance at lower cost is necessary for on-site renewable energy generation, the efficiency of passive measures and of equipment. Initial financial support from governments will accelerate such development and stimulate the market. This would be an efficient public investment because a larger market means that higher volumes will be produced, leading to lower prices. This process will eventually eliminate other subsidies that are necessary to overcome the first cost and investment barriers.

We recommend that new and refurbished buildings be designed to use information and communication technology that minimizes energy use and is easily updated with technological advances.

ICT can be used to reduce energy consumption in design, commissioning and operation. A building management system (BMS) automates building services such as lighting, heating and cooling. Examples include:

- Sensors for remote monitoring and measurement
- Building automation such as shade control systems
- Maintenance of energy generation services such as solar PV.

Technology can help to raise awareness of energy waste and reduce the level of waste, especially in commercial buildings and in residential buildings in developed countries. Decision-makers are often unaware of their energy consumption, and technology can provide useful information to trigger action so long as it is used appropriately and not as a substitute for substantial energy-saving measures. For example, smart meters that indicate individual appliance consumption can alert users to waste. Simple feedback has been found to cut energy use by up to 15%.[42] Future technological advances will help automate building operation to provide further energy reductions.

We recommend that energy utilities develop or improve energy information relevant to each customer, alerting users to potential energy savings.

Expanding on the smart meters theme, utility companies can stimulate energy conservation by analyzing plug load performance and informing users of potential savings as part of demand-side management. Utilities could also alert users to excessive consumption by providing comparative information about energy use on the bill, as already happens with some consumers in the UK. This can show whether the bill payer uses more energy than other buildings of a similar size and style. Utilities could benefit from these measures if they resulted in lower peak loads, especially with the development of smart grids for improved management of demand.

Develop workforce capacity for energy saving

The huge program of energy-efficiency investment we envisage will need a large, skilled workforce skilled enough to carry out high-quality work at relatively low cost. The workforce capacity must be expanded to meet the demand, which could include retraining workers to support economic growth. It requires a major effort, well beyond the current level of activity.

In some cases the existing skills of workers are neglected. In commercial buildings, facilities engineers have an important role in ensuring that technology is operated effectively but they have relatively low status, may not be provided with energy consumption data, and have little opportunity, authority or incentive to improve energy performance. As one participant in our behavior workshop put it, this is about “getting the guys out of the basement” to identify and implement best practices.

> **We recommend** that professional bodies, educational institutions and others introduce training on energy efficiency for all building stakeholders and vocational programs for building workers.

Our research identified a lack of knowledge of effective energy measures among building professionals and decision makers. This must be overcome if available design and technology expertise is to be applied in transforming building energy efficiency.

Education and training on energy efficiency is necessary for all those involved in financing, designing, constructing and operating buildings. It must be included in professional training but is also necessary for those who do not acquire professional qualifications. This could be particularly important in reaching the informal building sector in developing countries. Vocational programs are necessary to expand the supply of skilled building workers.

Energy efficiency certification could not only improve the skills of those involved but are necessary to support our other recommendations. For example, local authorities could require certification for members of certain development projects and could offer fast-track incentives to developers including such people in project teams.

> **We recommend** developing a ”system integrator” profession to support retrofitting in residential properties.

Shortages of skilled workers could limit the capacity to carry out wide-scale retrofitting, especially integrating the different aspects of energy-efficient renovation. Retrofitting is specified and carried out by specialists, usually skilled in only one aspect of the work. As we want to see integrated retrofits, it will be necessary to develop workers with the skills necessary to manage and integrate the process. They would be able to assess energy-efficiency requirements and develop a whole-house plan, select appropriate contractors and manage the retrofit process.

Mobilize for an energy-aware culture

We recommend that businesses and government authorities mount sustained campaigns to develop an energy-aware culture.

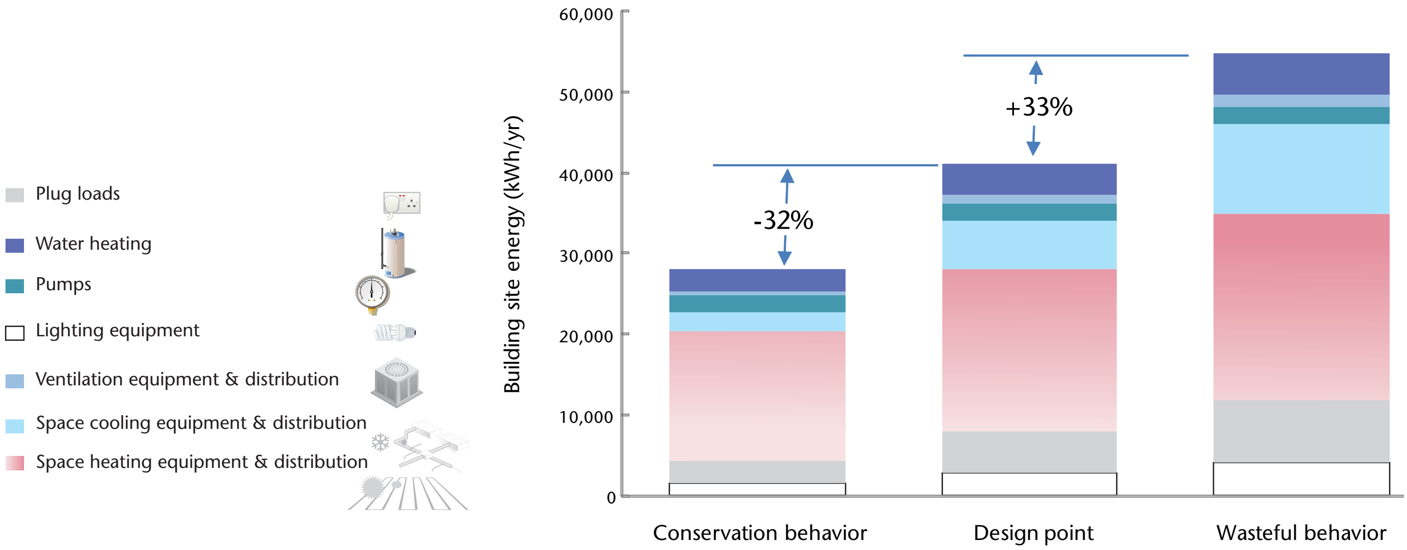
Significant behavioral changes and improved knowledge are needed to create an energy-aware culture to deliver our ambitious energy targets. The most significant step in transforming the building sector will be to raise the profile of energy throughout the sector, the business world and wider society. This underpins our other recommendations.

It is essential to build awareness of, interest in and enthusiasm for energy efficiency among all building stakeholders. Decision-makers must better understand energy efficiency opportunities. This applies to decision-makers in residential and commercial sectors, to new buildings and retrofitting, to developed and developing markets.

User behavior (positive and negative) can make a substantial difference. Our analysis concludes that wasteful behavior can add one-third to a building's designed energy performance, while conservation behavior can save a third *(see figure 47)*. Wasteful behavior uses twice as much energy as the minimum that can be achieved.

Figure 47

The impact of user behavior on residential site energy consumption



Improved transparency to provide clear information about energy use and cost will raise awareness. But information alone is often not enough to change behaviors. Other obstacles include:

- Lack of understanding and knowledge – including a belief that energy and climate change are too big for any individual to affect
- Lack of motivation – alarming talk about energy security and the threat of climate change can demotivate; people may disengage from the challenge, especially if they feel it is someone else's problem; they may distrust new approaches and prefer sticking with traditional methods and old habits; this is especially true if the benefits of action for the decision-maker are not clear.

A variety of approaches are needed to overcome these obstacles. It is necessary to motivate people by targeting the values that matter to them (which can include financial incentives. It means appealing to people through public and private sector marketing campaigns, making an emotional connection as well as providing information.

A wide-ranging and sustained mobilization campaign will create a new mindset. Campaigns might range from formal advertising to viral marketing and indirect routes such as motivating children to persuade their parents ("pester power"). Attitudes will change so that the apparently impossible or impractical becomes achievable. Such cultural change campaigns have achieved major attitude shifts in public health, safety and the environment. Many companies have created a safety culture by changing assumptions, norms and beliefs *(See figure 48)*.[43] The importance of safety is now taken for granted in business. Energy efficiency needs to be seen as similarly important.

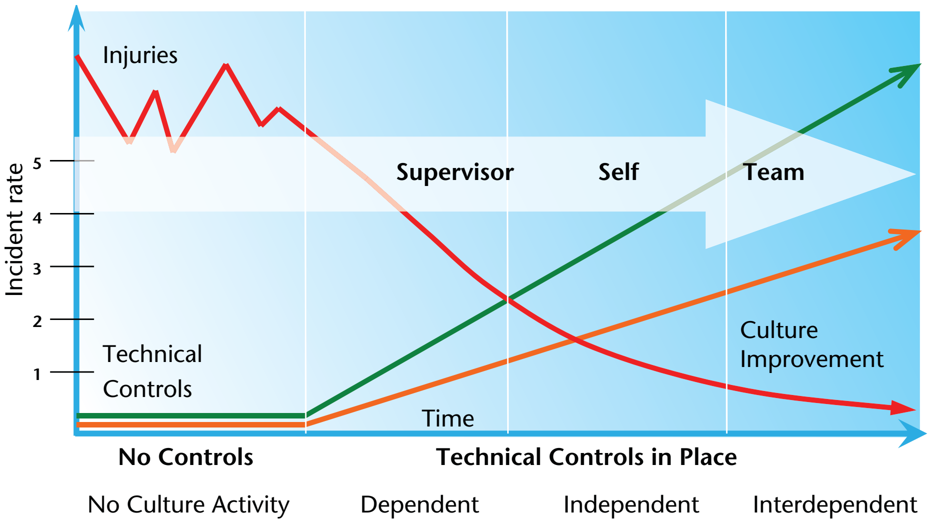


Figure 48

Bradley Curve, Environment Health & Safety Culture Model

We recommend that business and governments demonstrate leadership and show commitment to building energy efficiency by urgent action to cut the energy consumption of their own buildings.

Leadership is essential to change a culture. Efforts to stimulate action on energy waste would be undermined if major building users failed to heed their own messages. It is important for governments and businesses – especially those in the building sector – to avoid hypocrisy and manage energy in their own buildings. As well as showing leadership and commitment, this can provide important support for emerging technology.

How much will it cost?

The cost of transforming the building sector will be substantial, reflecting real transaction costs and market responses rather than theoretical analyses based on life cycle costs. But the costs of inaction are far greater and represent enormous risks for business and for market stability. Building energy efficiency is one of the most cost-effective ways to achieve the needed energy reductions.

The costs of transformation will fall on society as a whole: business, individuals and governments. Sharing the burden is appropriate and aligns with the benefits that the spending will deliver. Businesses will develop attractive markets and improved buildings. Households will get better homes with lower energy costs. Governments will improve energy security, protect the environment, meet their carbon emissions targets faster and stimulate their economies.

As we have noted, market-based measures alone cannot achieve the energy objectives. Our findings support the view that regulation can be the most cost-effective means of cutting energy waste in buildings[44]. But it is important not to impose excessively rigid regulations, because they are likely to lead to inefficiencies.

Many energy efficiency projects are feasible with today's energy costs. At today's energy prices and for the six regions studied in the EEB project, building energy efficiency investments of US$ 150 billion annually (on average) will reduce related energy use and corresponding carbon footprints by 40% with discounted paybacks of five years or less. A further US$150 billion annual investment with paybacks between five and 10 years will add 12 percentage points and bring the total reduction to slightly more than half. Additional investments to achieve the 77% target will not be justifiable on economic return grounds at today's energy prices and will require the additional steps outlined in this report.

The incremental costs of transformation can be partly offset through energy cost savings, and the remaining societal costs will be significantly below other carbon emissions abatement opportunities.[45] Our simulations suggest that the net costs to energy users in the six EEB regions could be approximately US$ 250 billion a year. This represents the additional cost of achieving transformation above existing spending, after deducting energy savings and energy payments from comparable feed in tariffs at today's costs of energy amounting to some US$ 700 billion a year. This figure is extrapolated from our detailed submarket analyses. The scale of this net cost demonstrates the need for both public subsidies and for businesses to develop products that achieve energy efficiency at lower cost to meet decision-makers' return criteria.

It is expected that higher carbon costs would increase the amount of financially justified efficiency investments and therefore provide carbon footprint reductions. However, the EEB's modeling concludes that only a marginal increase in reductions would result, from 52% at today's energy prices to 55%, with an incremental carbon cost of US$40/ton. At market acceptable prices of energy, these costs cannot be recovered simply by energy prices alone, including higher costs of carbon from proposed carbon mechanisms such as cap and trade, carbon tax, or cap and tax. It will take a broad mix of measures, consistent with those outlined in the recommendations provided in this report to fully transform the sector, and it is clear that market response alone will not achieve the necessary results and that. Supplemental government action is will be fundamentally necessary.

This level of investment, shared between private and public sectors, is essential to achieve the cuts in energy use and CO_2 emissions necessary to stabilize climate change. Piecemeal actions, as in our Too Little, Too Late scenario, will not be enough to address the necessary energy reductions.

Transformation of the building sector, working in partnership with government authorities, is critically important because:

- The net abatement cost of building efficiency measures are lower than the costs for similar abatement in alternative sectors
- Building efficiency improvements help households and businesses adjust to higher energy prices and volatility, while freeing up available income for other uses linked to greater economic growth
- Energy efficiency measures can be implemented immediately while other sector actions will take longer to develop and implement
- Investments in energy efficiency are net job creators, offering a 2:1 relationship between job creation in the service sector versus the utility sector.

In conclusion, transformative action to cut energy use is essential for economic, social and environmental reasons. The building sector provides an important component of such action. We must begin immediately to create the transformation that will deliver sustainable business success as well as cut energy consumption to curb climate change.

Notes and references

1 See IPCC 4th Assessment Report, Residential and commercial buildings.

2 "Final energy" refers to the end use. "Primary energy" refers to generation.

3 We use "subsector" to describe a global building type such as office or single family. We use "submarket" to describe that subsector in a specific geographic market.

4 For example, McKinsey (2009) *Pathways to a Low-Carbon Economy;* Lend Lease Lincolne Scott Advanced Environmental (2008) *Emissions Reduction in the Building Sector.*

5 Consumers' implicit discount rates in the range of 25% to 75% are described in Fuller, M. (2008), "Enabling Investments in Energy Efficiency - A study of energy efficiency programs that reduce first-cost barriers in the residential sector", UC Berkeley, for California Institute for Energy and Environment.

6 See our first report WBCSD (2008), *Energy Efficiency in Buildings: Business realities and opportunities.*

7 Ademe study in France in 2008.

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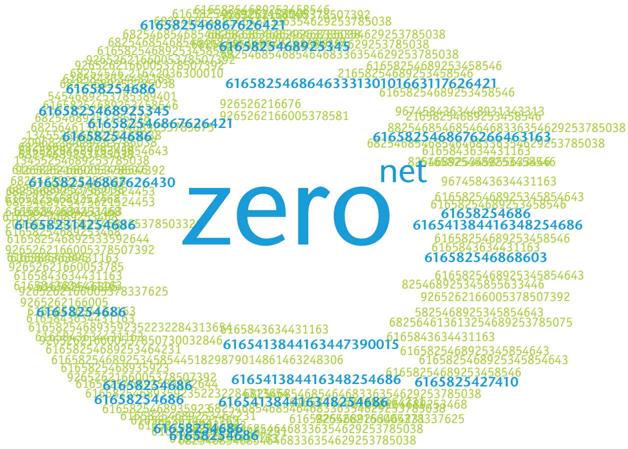

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