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THE BOTTOM LINE

Residential buildings account for most of the energy used in buildings overall and thus offer significant potential for energy efficiency. Over the next decade, energy consumption in the residential subsector is expected to grow faster than in the rest of the building sector owing to expected increases in both the number of households and in per capita energy use as incomes rise. Improvements in residential energy efficiency would provide multiple benefits to individual households and society at large but are often blocked by a number of barriers.

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Residential Energy Efficiency

Why does energy efficiency in the residential sector matter?

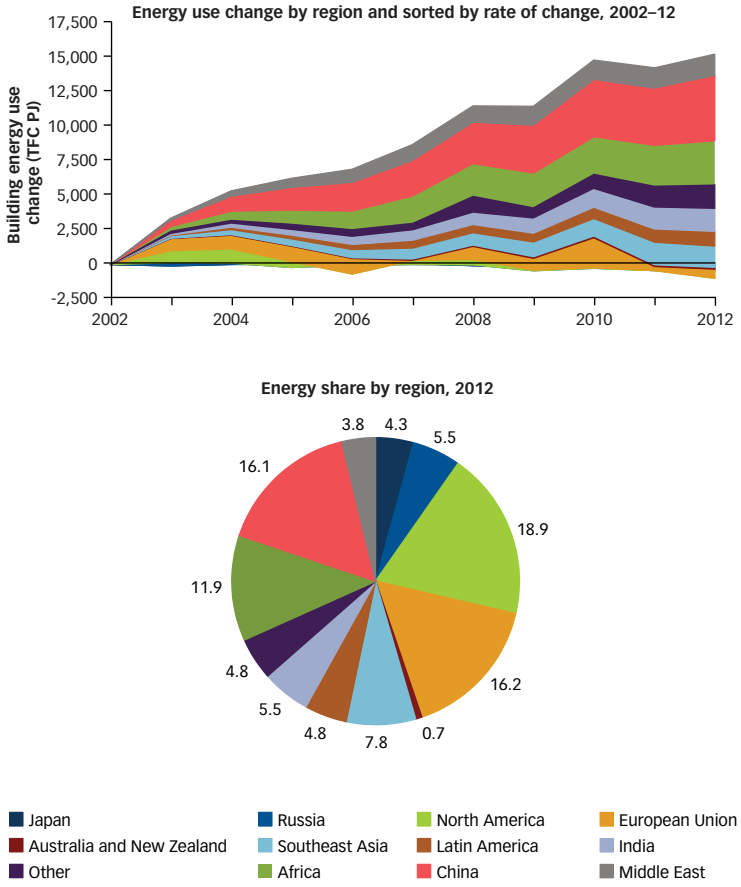
Residential buildings are responsible for a large share of global energy consumption

Buildings are responsible for nearly 40 percent of primary energy consumption globally, half of electricity consumption, and about a third of greenhouse gas emissions. The residential sector—housing—makes up about 70 percent of building energy use and thus offers the majority of the energy efficiency (EE) potential in buildings. The increase in building energy use between 2002 and 2012 is shown by region in figure 1. Rapid growth rates can be seen in the Middle East (55 percent), China (35 percent), and Africa (30 percent). Over the next decade, energy consumption in residential buildings is expected to grow faster than in the rest of the building sector owing to expected increases in both the number of households and in per capita energy use as incomes rise. Such growth will place a strain on energy infrastructure and resources.

Better residential EE provides multiple benefits to individual households and society at large. Reduction in demand can ease energy infrastructure bottlenecks and delay the need for new investments in capacity expansion; at the same time, it can enhance energy security by reducing imports and increasing exports, reduce global and local emissions, offset the impact on households of energy pricing reforms, and make access to energy more affordable. Other local and social benefits accrued by residential EE include:

- **Increased local economic activity and job opportunities.** Investing in residential EE supports local businesses and can create job opportunities in construction, renovation, and other areas. Similarly, local manufacturing companies see increased

Figure 1. Change in building energy use by region



Source: IEA (2015).

demand for their energy-efficient products. And service companies see more demand for their energy audits, EE designs, and prefeasibility studies.

- **Reduced energy costs for households.** Residential EE reduces energy costs, which can impose a significant burden on poor households. Lower costs for energy thus help to mitigate the impact of high energy prices or planned reforms of energy tariffs. Most energy-efficient appliances also have longer operating lives, further reducing households' costs.
- **Improved comfort levels and health.** Modern heating and cooling systems allow users to adjust room temperatures to suit their personal needs and to control their energy consumption. Better lighting enhances nighttime studies and reading for children. More efficient cookstoves lessen indoor air pollution.
- **Improved building stock.** Renovated, energy-efficient buildings improve the value and appearance of buildings, often leading to higher property values and property taxes in addition to more sustainable urban renewal. As the public becomes more aware of their lower operating costs, interest in renovated buildings can grow.

The residential sector is particularly challenging because homeownership is so disaggregated, because owners and tenants have split incentives, and because of the small size of individual investments and returns.

So why is most of the EE potential in housing still untapped?

An assortment of surmountable barriers has blocked progress

More than 80 percent of the global economic EE potential in buildings remains untapped, equivalent to the final energy consumption of Japan (IEA 2015). Although most EE measures for residential buildings are economically viable and have reasonable payback periods, they still face a number of barriers. The residential sector is particularly challenging because homeownership is so disaggregated, because owners and tenants have split incentives, and because of the small size of individual investments and returns. Decentralized ownership of apartments complicates the implementation of EE measures in multi-unit buildings. And many individual EE projects create high transaction costs. Prevailing low comfort levels (for example underheating and undercooling) may lower the potential for cost savings if the energy savings from an efficiency measure are offset by additional energy use to increase comfort levels. Other key barriers to realizing residential EE are listed below.

- **Lack of awareness and information.** Lack of information about energy efficiency means that residential consumers are often unaware of the performance of various building materials (windows, insulation) and appliances (air conditioners, refrigerators, lighting). Lack of knowledge keeps consumers from making informed investment decisions.
- **High upfront costs.** The higher initial investment cost, either for more efficient homes or appliances, is another constraint to widespread market development. This is particularly true for less creditworthy or low-income households that have little access to affordable financing.
- **Lack of access to affordable financing.** Access to financing is often restricted or costly where households are perceived to pose risks of nonpayment and have limited collateral, where they are offered short loan terms, where project sizes are small, where uncertainty about actual savings persists, and where financial institutions have not yet learned to offer specialized EE products or assess and structure EE deals.
- **Competing priorities and low incomes.** Residential customers have many priorities other than upgrading their homes or appliances, particularly when energy prices are low. Higher-income consumers often make investment choices based on safety, health, comfort, aesthetics, reliability, convenience, and status; the priority for low-income households is usually to meet basic needs.
- **Lack of incentives.** When energy prices are low and buildings do not practice consumption-based billing or metering (as in the case of district heating), consumers have weak incentives to invest in EE and are prone to overconsumption. Split incentives may exist when a building owner is responsible for capital upgrades, while tenants pay for energy costs.

One of the largest recent projects introduced efficient lighting, refrigerators, and air conditioners in Mexican residential buildings. More than $700 million in financing was deployed, including $308 million from international organizations and $406 million in local cofinancing.

- **Collective decision-making.** Multifamily apartment buildings, which are common in densely populated urban areas, require consensus around decisions to upgrade buildings. Consensus can be hard to reach. Also, condominiums and homeowners' associations (HOAs) may be obligated to sign contracts, take loans, and oversee contractors, all of which pose risks and require certain skills.

How have countries addressed these challenges?

Governments have developed a range of policies, programs, and approaches to help overcome these barriers

Policy measures include programs to spread information, raise awareness, and offer incentives. These include performance labels for appliances and buildings; minimum energy performance standards for appliances; mandatory energy codes for residential buildings; incentive schemes (for example, tax incentives) to speed uptake of energy-efficient appliances and building materials; and establishment of HOA legislation to facilitate collective decision-making and implementation of EE upgrades to multifamily apartment buildings. Of course, policies must be accompanied by appropriate secondary legislation and regulations and stringent enforcement. And getting energy prices at cost-recovery levels and requiring full collection will help strengthen incentives. Many countries have made participation in EE programs mandatory for low-income consumers eligible for energy bill subsidies.

Awareness, information, and capacity-building programs have been implemented to complement policy measures. Examples include campaigns to promote energy efficient appliances and inform consumers about their benefits; initiatives to provide homeowners and HOAs with legal, financial, and engineering advice regarding EE rehabilitations; the development of tools and guides (e.g., EE calculators and product lists, endorsement labels, appliance guides) for appliance and building upgrades; and efforts to build capacity in implementing agencies through training, awareness campaigns, consultancies, and new equipment. A recent approach has been to motivate households to become energy efficient by comparing their energy usage to that of their peers and neighbors.

One of the most difficult issues is the development of **financing and delivery mechanisms** for reaching residential customers. Individual investments are usually small, so projects need to be bundled into attractive investment propositions for financial institutions and others. Successful delivery mechanisms have included utility demand-side management programs, commercial bank financing, green mortgages, credit guarantees, EE funds, and market transformation programs.[1] Table 1 provides an overview. These delivery mechanisms need to be tailored to conditions in each country.

What has the World Bank done to promote residential EE?

Bank programs have promoted building retrofits and energy efficient appliances

Working in Europe and Central Asia, the Bank has assisted in numerous renovations of multifamily apartment buildings, most of them linked to tariff reforms and upgrades of district heating. In recent years, however, most of the Bank's residential programs focused on appliances. One of the largest recent projects introduced efficient lighting, refrigerators, and air conditioners in Mexican residential buildings. More than $700 million in financing was deployed, including $308 million from international organizations and $406 million in local cofinancing; the project closed in July 2015. It is notable that many other residential appliance programs are part of larger projects that themselves have complementary components—for example, distribution reform and upgrading, grid extension and distributed renewable energy, tariff reforms, and broader energy planning. Many of the efficient lighting programs in Sub-Saharan Africa address power shortages and peak demand. In addition to investment programs, the Bank has also completed two Development Policy Loans in Mexico and Morocco that included policy actions on residential EE. Although the programs have had varying results and are difficult to aggregate, reporting shows consistent and substantial energy savings in the

[1] Market transformation programs are interventions designed to remove barriers or exploit opportunities to accelerate the adoption of cost-effective EE measures.

Many residential appliance programs are part of larger projects that themselves have complementary components—for example, distribution reform and upgrading, grid extension and distributed renewable energy, tariff reforms, and broader energy planning.

residential sector. Table 2 reports results from some recently closed World Bank programs.

The current Bank portfolio for residential EE focuses mostly on lighting and appliances, which have shorter payback times and are easier to implement than building retrofits. Most of the total financing volume of about $154 million for residential EE targets lighting or simple appliances such as ceiling fans; only a few projects include water heaters, air conditioners, or heating since these generally require higher investment costs and tend to be used by higher-income households. One ongoing project (Metropolitan Buenos Aires Urban Transformation Project, P159843) includes energy-efficient design of social housing units.

Table 1. Delivery mechanisms in the residential sector

Delivery mechanism	Description	Key success factors	Country examples
Utility demand-side management programs	Regulatory mechanisms to oblige utilities to implement EE measures in their customers' premises. To meet these obligations, utilities may (i) directly implement EE measures in residential buildings, (ii) engage contractors for implementation, (iii) purchase energy savings achieved by others,[a] or (iv) establish a (revolving) fund for implementation of the measures. Utility programs may include demand response programs which encourage end-users to make short-term changes in energy use in response to price signals (e.g., to reduce peak demand).	Proper incentives for utilities (e.g., utility obligations) and measures to address conflicts with utilities' core energy sales business (e.g., decoupling energy sales and profits)	Belgium, Canada, Denmark, France, Ireland, Italy, Netherlands, UK, USA
Commercial financing	Government or donor credit lines to commercial banks (or specialized lending windows) for on-lending to residential consumers. Schemes include direct loans to homeowners and HOAs for building renovations or credit schemes for qualifying energy-efficient appliances carried out through vendors or retailers.	Technical assistance to help strengthen banks' capacity to assess projects, standardized project appraisal procedures.	Lithuania, Mexico, Poland, Serbia, Thailand
Green mortgages	Subsidized or preferential mortgages to promote energy efficient building construction and retrofits based on predefined green measures.	Constant and predictable funding for green mortgages to allow investors to make long-term plans.	Australia, Germany, Mexico, Netherlands, USA
Credit guarantees	A public or private agency (e.g., development or commercial bank, insurance or guarantee company) guarantees a portion of loan losses from defaults to encourage banks to lend for EE and defray perceived risks.	Sufficiently large project pipelines, proper assessment and pricing of risks.	Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Slovakia
EE funds	National or state governments provide concessional loans or incentives for EE projects. In the residential sector, EE funds include some portion of grant funds (usually 20–30 percent) from government budgets or special taxes.	Funds to provide other services (e.g., audit templates, guidebooks, online EE calculators)	Armenia, Bulgaria, Romania, Slovenia
Market transformation	*Bulk procurement and distribution:* Energy-efficient appliances are procured in bulk and distributed to customers by a utility or government agency.	Measures to ensure that efficient appliances are available in the market after the end of program.	Bangladesh, Ethiopia, Philippines, Rwanda, Uganda, Vietnam
	Channel marketing: Existing market channels distribute energy-efficient appliances through coupons, branding, and promotion programs and rebates.	Marketing and awareness-building campaign to ensure high consumer participation.	India, Mexico, Sri Lanka
	Standards and labeling: Efficiency standards and/or labels that assist customer decision-making are established. For lighting, many countries use phase-out policies to eliminate incandescent bulbs from the market through legislation or regulation.	Strong market monitoring, verification and enforcement schemes to protect consumers from noncompliant products.	Australia, Canada, Cuba, EU, UK, USA

Source: Author's compilation.

a. A utility may purchase energy savings from end users, energy service companies, equipment suppliers, or other entities for a predetermined rate after verification of energy savings.

Table 2. Results from recently closed World Bank residential EE programs

Project name [Implementation period]	Project cost and financing, US$ million [residential EE component]	Description	Reported results
Mexico Efficiency Lighting and Appliances (P106424, P120654) [Nov 2010–Jun 2014]	Cost: $974 [$974] Financing: IBRD $250.6 CTF $50.0 GEF $7.1	Replacement of incandescent bulbs with CFLs and incentives to replace old inefficient appliances in the residential sector	• 9,242 GWh in energy savings (92.42 percent of target) • 5.074 million tons of CO_2 emissions eliminated (98.72 percent of target) • 45.8 million incandescent bulbs replaced (102 percent of target) • 1.88 million appliances replaced (111 percent of target)
Burundi EE Project (P117225) [Mar 2012–Dec 2015]	Cost: $2.8 [$0.9] Financing: IDA $1.0 GEF $1.8	Distribution and promotion of CFLs, promotion of EE to large consumers	• 56 GWh in energy savings (76 percent of target due to delay in distribution of CFLs) • 71,138 tons in CO_2 emissions eliminated (51 percent of target) • Distributed 400,000 CFLs
Vietnam Demand-Side Management & EE Project (P071019) [Jun 2003–Jun 2010]	Cost: $26.0 [$8.2] Financing: IDA $2.5 GEF $4.8	Bulk procurement and distribution of CFLs, promotion of thin fluorescent tube lamps	• 2,859 GWh energy savings (576 percent of target) • 310.1 MW peak load reduction (258 percent of target) • 3,430,000 tons CO_2 emissions reductions (361 percent of target) • 1 million CFLs and 25 million thin fluorescent tube lamps sold
Bangladesh Rural Electrification and Renewable Energy Development (P071794) [Jun 2002–Dec 2012]	Cost: $759.0 [$14.0] Financing: IDA $462.9 GEF $8.2 GBOPA $14.2	Distribution of CFLs	• 10.5 million incandescent bulbs replaced with CFLs (105 percent of target) • 4.14 million tons of CO_2 emissions eliminated as a result of project interventions, including the renewable energy component
Uruguay EE Project (P068124) [May 2004–Dec 2011]	Cost: $15.6 [$15.6] Financing: GEF $6.8	EE market development and utility based EE services, e.g., provision of efficient lighting, water heaters	• 225 ktpe (thousands of tons of petroleum equivalent) in energy savings (40 percent of target) • 499,000 tons of CO_2 emissions eliminated (36 percent of target)
Togo Efficient Lighting Program (P115066) [Jun 2009–Jun 2016]	Cost: $4.1 [$4.1] Financing: GEF $1.8	Installation of CFLs and public information and awareness campaign	• 132.5 GWh in energy savings (133 percent of target) • 12.5 MW peak load reduction from CFLs installed (116 percent of target)
Czech Republic Green Investment Scheme (P114304) [May 2010–Apr 2015]	Cost: $46.0 [$46.0] Financing: Carbon Fund $46.0	Purchase of emission allowances by the project to support subsidies for EE in residential buildings	• 581,745 tons of CO_2 emissions eliminated
Mexico Low-Carbon Development Policy Loan (P121800) [Nov 2010–Jun 2012]	Cost: $400.0 Financing: IBRD $400.0	Prior action on establishment of a sustainable housing program	• 351,444 green mortgages granted by National Housing Commission (251 percent of target) • 375,956 EE subsidies issued (187 percent of target)
Morocco Inclusive Green Growth Development Policy Loan 1 and 2 (P127956) [Dec 2013–Dec 2014]	Cost: $602.0 Financing: IBRD $602.0	Prior action on adoption of decree on EE in the building sector	• 3,403,165 m^2 of new buildings integrating energy efficiency requirements and respecting thermal regulations for new buildings (850 percent of target)

Source: Author's compilation.

Note: CFL = compact fluorescent lamp; GPOBA = Global Partnership on Output-Based Aid; IBRD = International Bank for Reconstruction and Development; CTF = Clean Technology Fund; GEF = Global Environment Facility; IDA = International Development Association.

Energy efficient lighting programs offer one of the most cost-effective solutions to demand reductions.

Table 3 provides an overview of ongoing World Bank projects that support residential EE. The India Energy Efficiency Scale-up Program (P162849), which supports delivery of energy efficient LED lightbulbs, tube lights, and ceiling fans through ongoing government programs implemented by Energy Efficiency Services Limited, accounts for more than half the current financing volume for residential EE because many of the other projects are in smaller countries. Much of the portfolio has been in the Africa Region, where projects are often driven by the urgent need to close the gap between supply and demand: Energy efficient lighting programs offer one of the most cost-effective solutions to demand reductions. Most of these programs replace energy-intensive incandescent bulbs with more efficient compact fluorescent lamps (CFLs) that provide savings of more than 80 percent for the equivalent lighting output and last five to ten times longer. Bulk purchase of CFLs helps to lower prices. Bulk purchase of 5 million CFLs can achieve prices of less than $0.90 per CFL and peak-demand savings of more than 150 MW. With the introduction of LEDs, even further demand reductions are possible.

Table 3. Overview of ongoing World Bank financing for residential EE

Project	Country	Financing, US$ million [residential EE component]	Approval date	Closing date
Efficient Lighting Projects: Distribution of CFLs to reduce electricity consumption, in particular peak loads	Rwanda (P111331)	Carbon Fund $2.3 [$2.3]	6 Jul 2009	30 Jun 2019
	Bangladesh (P118605)	Carbon Fund $15.0 [$15.0]	28 Jun 2010	31 Dec 2019
	Bangladesh (P131263)	IDA $155.0 [$17.0]	20 Sep 2012	31 Dec 2018
	Senegal (P107167)	Carbon Fund $1.8 [$1.8]	3 Sep 2008	31 Dec 2019
Electricity Sector Support Project: Installation of energy efficient equipment, e.g., appliances and lamps (P128768)	Burkina Faso	IDA $165.0 [$4.7]	30 Jul 2013	30 Jun 2021
Benin GEF EE Program: Distribution of CFLs and enhancing standards and labels for energy efficient lamps and air conditioners (P115064)	Benin	IDA $54.5 GEF $1.8 ESMAP $2.0 [$1.8]	23 Jun 2009	31 Dec 2018
Energy Sector Support Project: EE activities focusing on water heaters (P099626)	Malawi	IDA $84.7 [$6.8]	28 Jun 2011	31 Jul 2018
Energy Sector Development Project: EE investments such as enhanced insulation, replacement of inefficient lighting and appliances (P144573)	Tuvalu	IDA $7.0 ESMAP $2.1 [$1.2]	26 Jan 2015	31 Mar 2019
Heat Supply Improvement Project: Pilot efficient and clean heating solutions for households without district heating (P157079)	Kyrgyz Republic	IDA $46.0 [$5.0]	27 Oct 2017	31 Dec 2023
Metropolitan Buenos Aires Urban Transformation Project: Energy efficiency measures in new social housing units (P159843)	Argentina	IBRD $200.0 [$10.3]	27 Feb 2017	30 Jun 2023
India Energy Efficiency Scaleup Program: Providing the financing needed to scale up EE delivery in the residential sector focusing on LED lightbulbs, tube lights, and ceiling fans (P162849)	India	IBRD $200.0 [$88.0]	17 May 2018	30 Sep 2022

Source: Author's compilation.

Note: CFL = compact fluorescent lamp; ESMAP = Energy Sector Management Assistance Program; IBRD = International Bank for Reconstruction and Development; GEF = Global Environment Facility; IDA = International Development Association.

Many countries are in the process of deepening sector reforms, including removing energy subsidies. Residential EE programs can mitigate impacts by offsetting higher bills through increased efficiencies.

What have we learned?

International experience shows that implementing residential EE programs at scale is resource intensive and requires sector reforms that create a favorable enabling environment

Countries have chosen different approaches to promote EE. There is no single, optimal model. But valuable lessons can be derived from these experiences.

Residential EE programs should be designed for implementation at scale. Instead of one-off pilots, emphasis should be placed on national-level programs that can create economies of scale, which will help lower transaction costs and increase the pace of implementation. In a World Bank–financed project to upgrade lighting and appliances in Mexico, for example, the awarded contractor was responsible not only for supplying more than 22 million CFLs but also for distributing them through major retail stores, collecting and disposing of the replaced bulbs, and conducting a dissemination campaign. For building retrofits, in particular, public funds may need to be leveraged with commercial financing for scaleup—for example, through credit guarantees, interest rate buydowns, or other mechanisms.

Residential EE programs can complement energy sector reforms and renewable energy access programs. Many countries are in the process of deepening sector reforms, including removing energy subsidies. Residential EE programs can mitigate impacts by offsetting higher bills through increased efficiencies. Higher prices also reinforce further EE improvements. Bundling of residential EE with decentralized renewable energy systems, such as solar, can also reduce investment costs by reducing the size of the systems required.

Effective awareness campaigns are essential. Disseminating information about the costs and benefits of EE measures helps consumers make informed purchasing decisions. Information about promotional programs, incentives, qualified products and suppliers, and so on are also necessary, as are education programs about good behaviors and practices, including operations and maintenance, to sustain the energy savings benefits over the life of the appliances. Awareness campaigns can make use of a range of media including radio, television, newspapers, billboards, leaflets, bill inserts, branding, and displays at utility offices and retail outlets. Communication channels can also be customized to the target group. For example, many countries have had success at targeting students through collaboration with schools.

Mandatory standards and voluntary labels help address split incentives. The imposition of minimum standards for manufacturers and developers helps to address the issue of split incentives. Labels and certificates, which go beyond the mandatory requirements, can provide critical information to the consumer about the energy consumption and operating costs of appliances or buildings. Building codes and certificates incentivize building developers and real estate owners to consider EE in their designs and renovations and can also inform occupants about the energy performance of buildings and thus their relative energy cost.

Financial incentives are often required to overcome the higher upfront costs. Grants, subsidies, preferential loans, and credit lines are typically used to increase the pace of adoption. Alternatively, channel marketing achieves more sustained market shifts with the use of coupons, branding, and rebates. Several examples show that even countries with lower financial means can offer incentives by working with the private sector. In Bangalore, India, the utility negotiated with CFL manufacturers to offer a 10 percent discount through coupons. While the utility marketed and distributed the coupons, the manufacturers funded the discounts. In Vietnam, retailers introduced a lottery to promote efficient tube lamps (thin tubes)—every purchase of a thin tube resulted in a weekly lottery ticket to win a five-pack of CFLs.

Monitoring and evaluation (M&E) of residential EE programs tracks the progress of program implementation and energy savings, provides feedback for periodic adjustments, informs the design of future programs, and demonstrates results. M&E should include a baseline study, conducted before the EE measures; such studies determine the energy consumption in "business-as-usual" conditions. In addition to measuring savings from more efficient appliances and designs, an effective M&E framework will capture

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consumers' behavioral changes and changes in well-being—for example, longer periods of nighttime illumination in homes and more comfortable indoor temperatures. The design phase should consider household quality-of-life issues in order to estimate savings and other socioeconomic benefits. Consumers will offset expected energy savings when their households had been undercooled or overheated, sometimes referred to as the "rebound effect."

Reference

IEA (International Energy Agency). 2015. *Energy Efficiency Market Report*. Paris: OECD/IEA.

The internal World Bank briefing note on which this Live Wire is based was prepared in July 2016 and reviewed by Gevorg Sargsyan, Jas Singh, and Martina Bosi. The Live Wire was reviewed by Jas Singh.