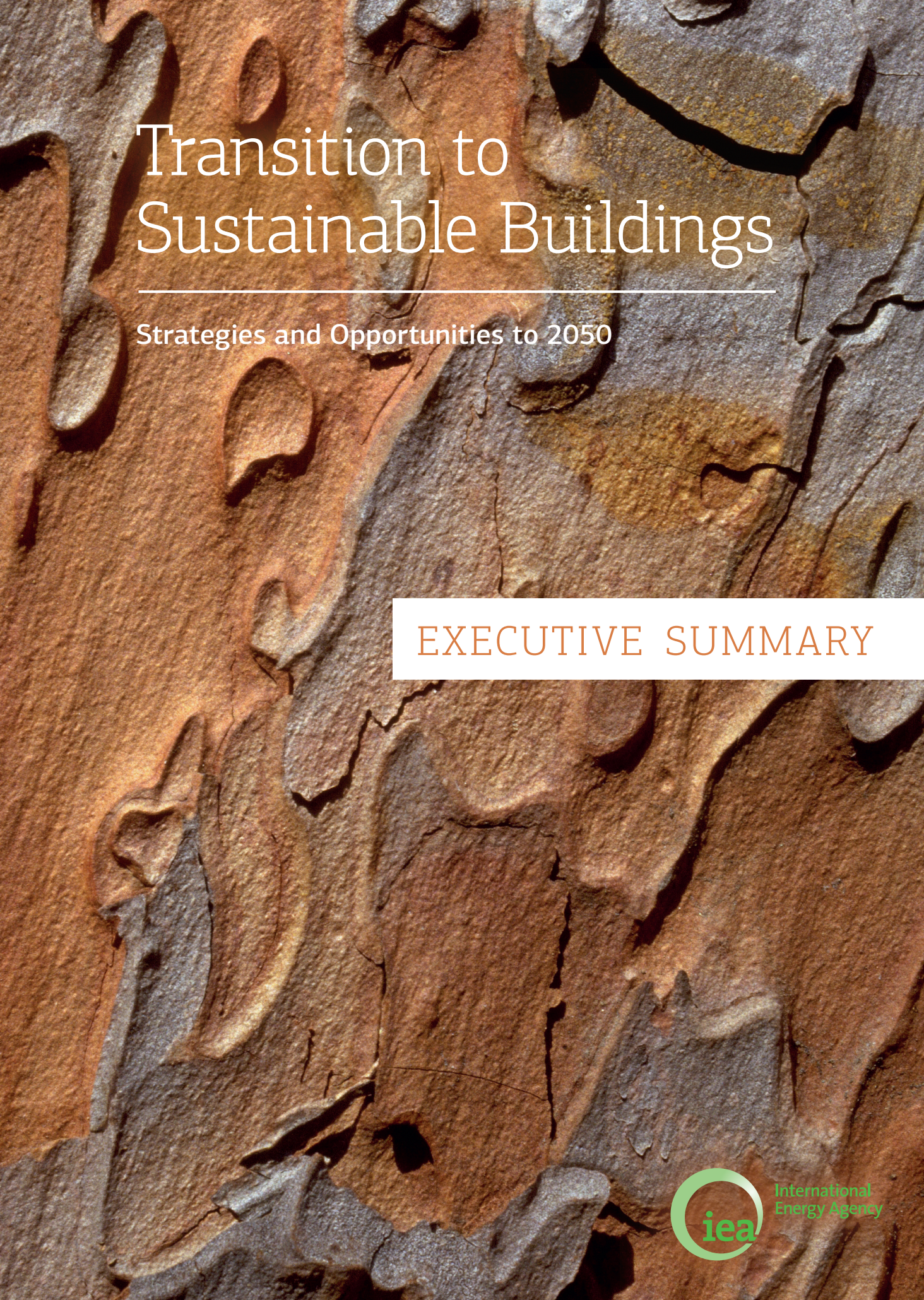

Transition to Sustainable Buildings

Strategies and Opportunities to 2050

EXECUTIVE SUMMARY

International Energy Agency

INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 28 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

- Secure member countries' access to reliable and ample supplies of all forms of energy; in particular, through maintaining effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context – particularly in terms of reducing greenhouse-gas emissions that contribute to climate change.
- Improve transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, including through improved energy efficiency and development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with non-member countries, industry, international organisations and other stakeholders.

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The European Commission also participates in the work of the IEA.

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Executive Summary

Overview

The rationale for changing our current energy and climate path is compelling. Energy efficient and low-carbon technologies will play a crucial role in the energy revolution needed to make this change happen. The buildings sector is the largest energy-consuming sector, accounting for over one-third of final energy consumption globally and an equally important source of carbon dioxide (CO_2) emissions. In certain regions highly dependent on traditional biomass, energy use in buildings represents as much as 80% of total final energy use.

The buildings sector, including the residential and services sub-sectors, uses a wide array of technologies. They are used in the building envelope and its insulation, in space heating and cooling systems, in water heating, in lighting, in appliances and consumer products, and in business equipment. The long lifetime of buildings and related equipment presents both challenges and opportunities for the sector.

Some of the technologies needed to transform the buildings sector are already commercially available and cost effective, with payback periods of less than five years. Others are more costly and will require government intervention if they are to achieve wide market uptake. Unlike many of the technologies needed in the transport and industry sectors, only a small proportion require major research and development (R&D) breakthroughs. Many could, however, benefit from a combination of additional R&D and economies of scale to reduce costs, enhance performance and improve their affordability.

Market barriers in the buildings sector are complex and can be difficult to overcome, so successful implementation of public policy will be essential to achieving high levels of market diffusion. There is a need for integrated and comprehensive policies to help overcome a range of barriers, such as higher initial costs, lack of consumer awareness of technologies and their potential, split incentives and the fact that the true costs of CO_2 emissions are not reflected in market prices.

The transformation of the buildings sector will have positive benefits for other sectors, most notably the power sector, as over half of all electricity consumed today is used in buildings. Electricity savings in buildings will have far-reaching benefits for the power sector and will translate into avoided electrical capacity additions, as well as reduced distribution and transmission network expansion, with potentially huge savings for utilities.

Achieving significant energy and CO_2 emissions reduction is a challenging policy goal, but this publication demonstrates that it is possible with a combination of best available technology and intelligent public policy. Ensuring that all available options are tapped will require unprecedented effort and co-ordination among a diverse set of stakeholders, including policy makers, builders, technology developers, manufacturers, equipment installers, financial institutions, businesses and household consumers.

How to get on track for saving energy in the buildings sector

The International Energy Agency (IEA) annual report to the Clean Energy Ministerial categorised buildings as being in serious trouble for meeting energy savings and carbon

emissions reduction (IEA, 2013). While there has been significant technological progress, implementation has been delayed. Examples of best available building technologies combined with renewable energy sources in advanced buildings, such as zero-energy buildings, only represent a small niche market today.

In most cases, this trend can be changed with assertive policy action. However, it still may not be easy from a political perspective. With the world economy struggling, policy makers need to realise that promoting building energy efficiency can increase jobs, support economic development and lead to reduced energy consumption. For example, when a high performance value-added building material or equipment is installed instead of a typical product, that results in an immediate investment today, rather than continued purchasing of often imported fossil fuel for years to come.

This publication makes specific recommendations for policy actions, and is supported with the pertinent technological background to initiate the immediate implementation process. A whole-building approach is critical to get the buildings sector on track. A key action to curtail the energy consumption of fast-growing developing markets is the adoption of enforceable building codes. This publication and the forthcoming *Policy Pathway on Building Energy Codes* and *Technology Roadmap on Energy Efficient Building Envelopes* will significantly improve the knowledge base on how to do this. The IEA is calling on major economies in collaboration with leading product manufacturers to have greater focus on implementing building codes globally.

Constructing a sustainable buildings sector

If no action is taken to improve energy efficiency in the buildings sector, energy demand is expected to rise by 50% by 2050. This increase is driven by rapid growth in the number of households, residential and services floor area, higher ownership rates for existing electricity-consuming devices and increasing demand for new products. However this growth could be limited to just over 10% without changing comfort levels or requiring households to reduce their purchases of appliances and other electronic equipment.

An estimated 40 exajoules (EJ), equivalent to current energy use in Russia and India combined, could be saved in the buildings sector in 2050 through the wide deployment of best available technologies. Examples include high-performance windows, optimal levels of insulation, reflective surfaces, sealants, heat pumps, solar thermal heating, co-generation, energy efficient appliances and equipment, efficient cook stoves and solid-state lighting (SSL), among others.

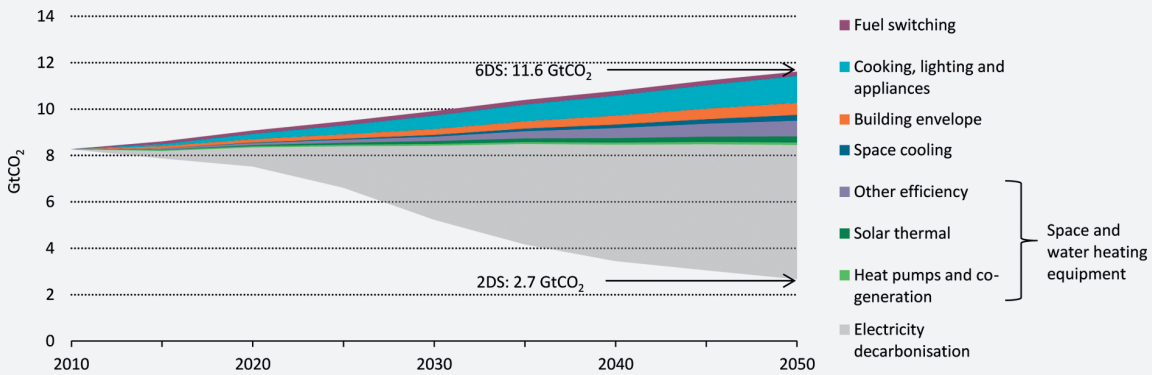
Achieving the goal of limiting global temperature rise to 2°C (*Energy Technology Perspectives 2012* [*ETP 2012*] 2°C Scenario [2DS]) would require an estimated 77% reduction in total CO_2 emissions in the buildings sector by 2050 compared to today's level. Energy demand reduction, increased use of renewables and, most importantly, a decarbonised power sector will be the main drivers of this decarbonisation in buildings (Figure ES.1).

A combination of efficiency standards, greater use of heat pumps, solar thermal and co-generation with waste heat and renewables could reduce growth in electricity demand by 2 000 terawatt-hours (TWh) in 2050. This is equivalent to half the final electricity consumption of the United States in 2010, or the final electricity consumption of South America, Africa and the Middle East combined in 2010. These savings would represent avoided capacity expansion of roughly 330 gigawatts (GW) of coal-fired capacity or 460 GW of gas-fired capacity and savings of between USD[1] 70 billion and USD 150 billion in new generation capacity.[2] In

1 Unless otherwise noted, all costs and prices are in real 2010 USD. Other currencies have been converted into USD using purchasing power parity exchange rates.

2 This is based on an assumed load factor of 70% for coal-fired capacity and 50% for gas-fired capacity.

Figure ES.1 Contribution of CO_2 emissions reduction in the buildings sector



Key point *Enhanced energy efficiency options in all end-uses combined with a decarbonised power sector can reduce CO_2 emissions in the building sector to just one-quarter of current levels.*

addition, there would also be savings from reduced investments in expanding distribution and transmission networks.[3]

Regional priorities and recommendations

Energy trends in the buildings sector can vary significantly from country to country depending on a number of factors ranging from climate, population, income, economic development and household sizes. Immediate priorities and future goals will need to reflect a country's energy supply and consumer profile. Most of the technology options and policy recommendations discussed in this book could be applicable to all countries either immediately or in the future. However, given constraints on resources there is a need to prioritise those actions that have the largest impact in each country. Nine countries or regions have been examined in detail in this publication and recommendations for policy and technology priorities are summarised below (Table ES.1).

End-use contributions

More efficient building envelopes to keep energy use down

The building envelope determines the amount of energy needed to heat and cool a building, and hence needs to be optimised to keep heating and cooling loads to a minimum. A high-performance building envelope in a cold climate requires just 20% to 30% of the energy required to heat the current average building in the Organisation of Economic Co-operation and Development (OECD). In hot climates, the energy savings potential from reduced energy needs for cooling are estimated at between 10% and 40%.

3 Savings from the distribution and transmission network are regionally specific and have not been calculated for this present study.

Table ES.1 Regional priorities in the buildings sector

Technology	ASEAN[4]	Brazil	China	European Union	India	Mexico	Russia	South Africa	United States
Advanced envelope – cold climate (highly insulating windows, air sealing and insulation)			●	○			●		●
Reduced cooling loads – hot climates (reflective technologies and advanced cooling equipment)	○	○				○			
Heat pumps (water heating and/or space heating and/or space cooling)			○	●			○		○
Solar thermal (water heating and/or space heating)		●			○	●		●	
More efficient use of biomass (more efficient cooking and water heating, and leading to modern biogas)	●				●			○	
Policy									
Building codes with supporting infrastructure (education, product ratings, and implementation to pursue holistic approach with advanced envelopes)	○	○	○		●	○	○	○	
Appliance and equipment standard (promoting advanced appliances, lighting, heat pumps, heat pump water heater, gas condensing boilers, miscellaneous electrical loads, efficient cooling)	●	●	●		○	●		●	
Deep renovation of existing buildings (systems approach with advanced envelopes and high-performance equipment)				●			●		●
Zero-energy new buildings (advanced holistic building design with integrated renewable energy)				○					○

Notes: red indicates immediate priority, while gold indicates second priority. This is not intended to be an exhaustive list, but intentionally shows the immediate priority for technology and policy, along with a second goal, to help highlight which technologies and policies will have the largest impact in the country or region. Most of the technology and policy categories could be applicable to all countries.

Primary strategies and technologies needed for efficient building include high-performance envelopes optimised to harvest passive solar energy and daylight, combined with advanced windows, optimal insulation and proper sealing, along with reflective surfaces in hot climates.

An important first step in improving the global building stock is to establish and enforce stringent building codes that include minimum energy performance for new and refurbished buildings. With buildings in some countries lasting well over 100 years and expensive to retrofit, urgent action is needed to ensure that high-performance building envelopes rapidly gain market share and quickly become the standard for all new construction globally. Priority should also be given to refurbishing existing buildings, particularly in the European Union,

4 Association of Southeast Asian Nations.

Russia and the United States, where approximately 60% of current building stocks will still be in use in 2050.

More than 40% of the savings expected in heating and cooling energy demand under a low-carbon scenario can be directly attributable to improvements in the building envelope. This represents energy savings of about 6 EJ in 2050, equivalent to the current energy consumption of the United Kingdom. Lower heating and cooling requirements will also allow downsizing of the equipment needed to reach a desired indoor temperature.

Building comfort through efficient heating and cooling systems

Currently, space heating and cooling together with water heating are estimated to account for nearly 60% of global energy consumption in buildings. They therefore represent the largest opportunity to reduce buildings energy consumption, improve energy security and reduce CO_2 emissions, particularly due to the fact that space and water heating provision in some countries is dominated by fossil fuels. Meanwhile, cooling demand is growing rapidly in countries with highly carbon-intensive electricity systems such as ASEAN, China and the United States.

A systems approach, where equipment upgrades are co-ordinated in particular with improved building envelopes, will be key to achieving higher energy efficiencies and a low-carbon heating and cooling supply. The use of electric resistance heaters as the primary source of heating and for water heating in existing buildings needs to be avoided and should eventually be prevented for new installations and equipment replacements.

Instead, heat pumps, solar thermal and co-generation for space heating and cooling as well as hot water should be prioritised. The inefficient use of biomass for space and water heating is unsustainable. A major initiative is needed to promote modern biomass equipment that can reduce air pollution and improve human health, while allowing more of this scarce resource to be used in central systems.

With the demand for space cooling expected to triple between 2010 and 2050, the priority for countries with hot climates should be highly reflective external surfaces, to reduce the need for cooling, and the development and wide adoption of high-performance cost-effective air conditioners. The implementation of minimum efficiency standards will help to improve energy efficiency and control the growth in electricity demand from this end-use. This will be particularly beneficial in reducing peak loads, which often coincide with demand for space cooling.

Lighting more with less

Lighting has significant potential for energy efficiency improvements through the application of more efficient technologies, better matching of lighting intensity to need, and continued emphasis on technical and behavioural solutions that turn off or reduce lighting levels when no longer needed. Improved building design can also offer significant potential to reduce the demand for lighting in buildings, through building orientation and advanced fenestration technologies such as dynamic windows. With better use of natural lighting and adoption of highly efficient lamp technologies, buildings energy consumption for lighting could be reduced by 40% in 2050 compared to current levels.

In the 2DS, incandescent lighting in all regions of the world is progressively replaced with more efficient lighting technologies, including best available fluorescent lighting and SSL. Variable controls and sensors should be added to existing lighting systems via retrofit programmes. In the future, new solutions will be needed for problematic fixture types where current solutions are unacceptable to consumers or which are cost prohibitive to replace. In new buildings,

lighting power intensity requirements should be added to all buildings codes and deep retrofit programmes globally.

Moving from traditional biomass towards modern fuels for cooking

Cooking is currently one of the largest end-uses in the residential sub-sector, accounting for nearly one-quarter of global residential energy consumption and about 20% of total buildings energy use. In some regions, such as India, ASEAN countries and Africa, cooking can represent over half of residential energy use. The promotion of low-cost, efficient cook stoves is critical to reducing the use of traditional biomass in developing countries, with a co-benefit of reducing harmful emissions.

As economies mature, the move away from traditional biomass to modern fuels will help to improve household productivity and quality of life, reducing the social, environmental and economic impacts of traditional biomass cooking techniques. The transition away from traditional biomass to modern fuels could save 3.5 EJ of energy, equivalent to the current energy consumption of Australia or ASEAN countries. More efficient use of biomass in buildings will free up this resource for use in power, industry and transport.

Appliances and other electronics which save us time and electricity

In many countries, appliances and other electrical equipment represent the fastest-growing end-use for energy in buildings. This trend is expected to continue in the future, as household wealth rises in major economies such as China, India and South Africa, where current penetration of appliances and other equipment is well below that of OECD countries. This will place additional pressure on power systems that are already facing security of supply concerns.

Urgent action is needed to ensure that electricity demand from the buildings sector does not put undue pressure on the power sector. The deployment of best available technology and continued improvements in appliance and equipment efficiency will help to limit electricity demand growth from buildings and reduce peak demand for electricity. Growth in electricity demand could be reduced to 40% of current levels in a low-carbon scenario compared to a near doubling under a business-as-usual scenario.

Additional R&D is needed to develop smart electronics which can help curtail growing electricity loads. Some improvements have been realised, but additional effort is required to address on-idle power consumption and standby energy use. Innovative, low-cost sensors and controls for appliances and electronic equipment could reduce peak loads on average by about 15%.

Recommendations

Governments will need to work together and with key stakeholders to ensure that markets around the world send consistent signals to consumers and manufacturers, both to maximise efficiency and to limit the cost of future changes. Common medium- and long-term targets for implementing building codes and minimum energy performance standards for lighting, appliances, heating and cooling equipment would enable key market players to plan ahead. For those producing efficient products, knowing that a wide range of markets will be eager for their products will help them plan production and cut costs as their market expands.

In addition to setting and reaching efficiency targets, national governments need to collaborate with each other and with key stakeholders to develop and deploy energy efficient and low-carbon building technologies. New technology development strategies need to be supported by a carefully chosen selection of policies that will drive technology from concept to full market saturation. Successful advanced building programmes striving for zero-energy buildings need to continue; their standards should eventually become mandated.

It is recommended that integrated policies be implemented that can address technologies relative not just to individual components, but also the performance of whole buildings. These policies are equally applicable to the large array of highly effective yet under-utilised energy efficient building technologies and the introduction of existing technologies to new markets.

Rigorous building codes will need to be implemented in all countries. New buildings in cold climates should be subject to progressively tighter regulatory standards, to between 15 kilowatt-hours per square metre per year (kWh/m^2/year) and 30 kWh/m^2/year for heating purposes. In hot climates, the cooling energy demand intensity should be reduced by around one-third compared with current levels.

In OECD countries and non-OECD Europe and Eurasia, large-scale refurbishment of residential buildings should be the priority. Approximately three-quarters of all buildings in these countries will still be standing in 2050 and hence will need to be upgraded to a low-energy standard. In fast-growing economies with rapid new-build rates, the implementation of effective building codes should be the priority. Improved building envelopes in all regions will allow for the downsizing of heating and cooling equipment, and for a significant reduction in energy use.

Tougher regulation will be needed to reduce electricity demand for lighting, appliances and cooling. Support for R&D to reduce the cost of more efficient technologies should be provided, with tighter minimum energy performance standards implemented worldwide. Current best performing appliances should provide the minimum standard for efficiency by 2030 in most countries.

Efficient district heating systems can benefit from thermal energy storage coupled with waste heat and renewables, offering increased systems efficiency and flexibility. However, cross-sectoral policies will be needed among the industrial, power and building sectors to bring them to fruition. Accordingly, older inefficient district heating systems need to be upgraded. Opportunities to integrate building end-use equipment into smart grids and smart metering should be promoted, to help reduce peak load and bring other economic benefits.

Roadmaps that show what is needed to take technologies from their current status through to full commercialisation are a useful tool to help governments and the private sector take the right actions. The IEA is developing energy technology roadmaps with broad international participation and in consultation with industry. These roadmaps detail the technical, policy, legal, financial, market and organisational requirements necessary for an earlier uptake of more efficient low-carbon technologies.[5] In combination, this publication and the forthcoming roadmaps will give the public and private sectors the tools to change the course of the building sector, onto a low-carbon path.

5 The IEA has developed a roadmap on efficient heating and cooling technology, and will soon release a roadmap on energy efficient building envelopes.

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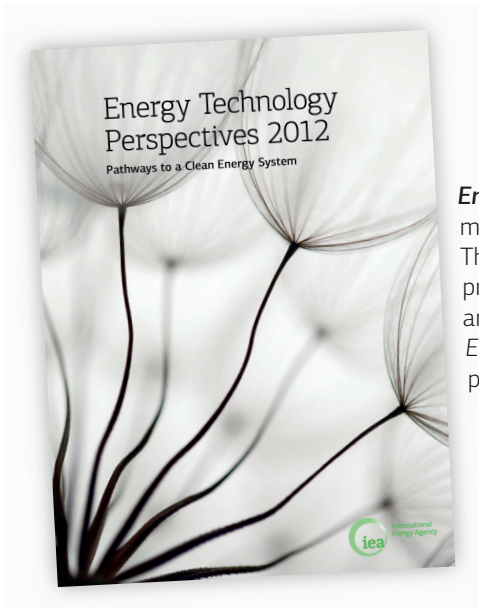

Energy Technology Perspectives is the International Energy Agency's most ambitious project on new developments in energy technology. The analysis and scenarios published in *Energy Technology Perspectives* provide the benchmarks used in *Tracking Clean Energy Progress 2013*, and also support other analysis in the ETP series. The next edition of *Energy Technology Perspectives* will be released in 2014 and can be pre-ordered starting in the second half of 2013.

Building Envelope Technology Roadmap (released late 2013). The *Technology Roadmaps* identify actions for governments, industry, financial partners and civil society that could advance technology developments described in the *ETP 2012 2DS*. As of June 2013, 18 global roadmaps have been published, covering a wide range of energy demand and supply technologies, including solar heating and cooling, geothermal heat and power, smart grids and energy efficient buildings: heating and cooling equipment.

The ***Policy Pathway on Building Energy Codes*** (released fall 2013) is an IEA-UNDP joint publication that provides policy makers the pathway to effective and successful implementation of building energy codes. The pathway includes four phases (plan, implement, monitor and evaluate) with a series of steps and actions for governments to follow. The choice and sequencing of those steps and actions will vary depending on current development of building energy codes in each country.

Tracking Clean Energy Progress 2013, released in April 2013, examines progress in the development and deployment of key clean energy technologies. Each technology and sector is tracked against interim 2020 targets in the *ETP 2012* 2DS, which lays out pathways to a sustainable energy system in 2050.

Nordic Energy Technology Perspectives, released in January 2013, assesses pathways and key challenges to a carbon-neutral energy system in the Nordic region. Other countries seeking to radically transform their energy system should take note.

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International Energy Agency

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Transition to Sustainable Buildings

Strategies and Opportunities to 2050

Buildings are the largest energy consuming sector in the world, and account for over one-third of total final energy consumption and an equally important source of carbon dioxide (CO_2) emissions. Achieving significant energy and emissions reduction in the buildings sector is a challenging but achievable policy goal.

Transition to Sustainable Buildings presents detailed scenarios and strategies to 2050, and demonstrates how to reach deep energy and emissions reduction through a combination of best available technologies and intelligent public policy. This IEA study is an indispensible guide for decision makers, providing informative insights on:

- cost-effective options, key technologies and opportunities in the buildings sector;
- solutions for reducing electricity demand growth and flattening peak demand;
- effective energy efficiency policies and lessons learned from different countries;
- future trends and priorities for ASEAN, Brazil, China, the European Union, India, Mexico, Russia, South Africa and the United States;
- implementing a systems approach using innovative products in a cost effective manner;
- pursuing whole-building (*e.g.* zero energy buildings) and advanced-component policies to initiate a fundamental shift in the way energy is consumed.

This publication is part of the *Energy Technology Perspectives* series and one of three end-use studies, together with industry and transport, which looks at the role of technologies and policies in transforming the way energy is used.

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