Written testimony
Hearing of the U.S. Senate Committee on Energy and Natural Resources
Dr Brian Motherway
Head of Energy Efficiency
International Energy Agency

October 22, 2019

Introduction

I wish to thank the Senate Committee on Energy and Natural Resources for the kind invitation to present my testimony and to exchange views on the important topic of energy efficiency.

This discussion on energy efficiency is very timely as many governments consider the issue in the context of wider energy policy goals, and a growing recognition of the need for stronger progress on energy efficiency. This is also the context for the recently established Global Commission for Urgent Action on Energy Efficiency. This Global Commission represents a very important global process of high-level engagement to examine opportunities to accelerate progress on energy efficiency through policy. It comprises heads of state, energy ministers, CEOs and thought leaders, and we are very pleased and honoured that Committee Chairman Lisa Murkowski is an honorary member. We believe that the work of the Global Commission will be very significant for energy efficiency's future progress globally.

This statement provides background information on energy efficiency and demand trends, and highlights some successful policies from around the world. The information contained in this statement is based primarily on analysis and research conducted by the International Energy Agency.

In this statement, I will first set out an overview of the global dynamics of energy efficiency – how and where energy is used, and how efficiently is it being used. Last year, global energy demand saw its largest increase since 2010, driven primarily by increased levels of economic activity. Energy efficiency can play a key role in making sure this kind of growth is sustainable, not only from an environmental point of view, but also in terms of ensuring the resilience of electricity grids, reducing import dependency, and lowering energy costs for all.

Efficiency has already made major contributions to a range of energy goals, including energy security, cost reduction and environmental protection. However, we are observing a noticeable slowdown in the rate of improvement, as measured by global energy intensity (the energy required to produce one unit of GDP). This is driven by wider trends putting pressure on energy use that efficiency policies are not keeping up with.

The second part of this statement considers how this trend could be reversed through readily available and cost-effective technology options. According to IEA analysis, maximising the available energy efficiency opportunities could allow the global economy to double by 2040, with essentially the same energy demand as today. These efficiency measures would also allow the global industrial sector to save about USD 600 billion on energy spending, and households about USD 550 billion.

Much more policy ambition and investment are needed, however, to achieve these kind of outcomes. The final part of this statement looks at what such policy ambition might involve, by setting out examples of global best practice in energy efficiency policy making. Numerous compelling examples from across the world show how efficiency policies can be deployed by governments to achieve a range of both energy and non-energy benefits. It also explores how rapid and far-reaching innovations in digitalisation have the potential to take efficiency policies to the next level, by transforming the way that energy is used across the entire energy system.

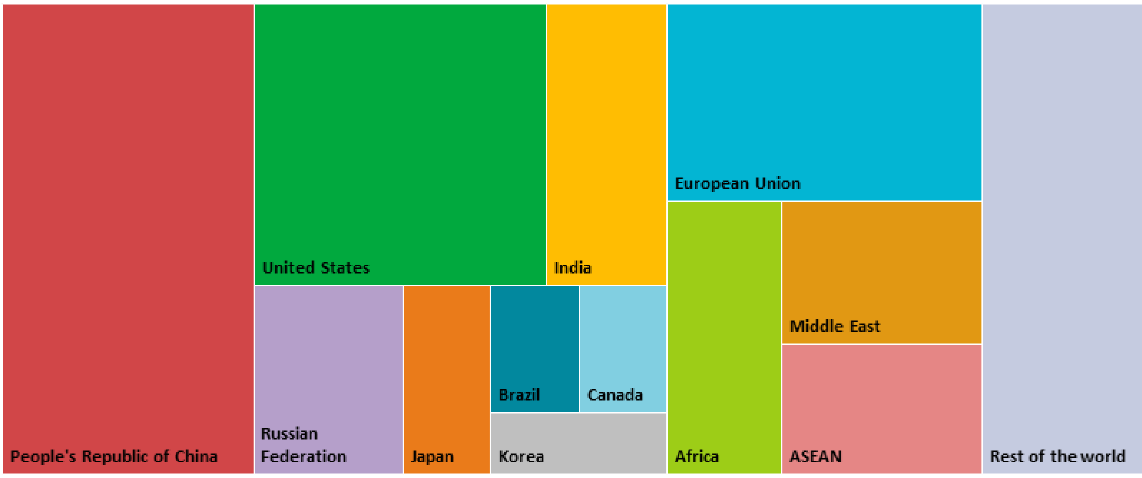
Since its foundation in 1974, the IEA has worked closely with the United States and all its member governments on energy issues of global importance. The IEA looks at all fuels and all technologies, and is now the world's leading policy advisor across the entire energy mix. Energy efficiency is seen by the IEA as a high priority, and we have greatly expanded our work on the topic in the past few years. We undertake global analysis of energy efficiency trends and monitor their impacts as part of our wider analysis of the global energy system. We also support governments through research and dissemination of policy best practice, exchange and collaboration. We work directly with many governments, including the United States, to support their understanding of energy efficiency issues and their development and implementation of appropriate policies. We appreciate this opportunity to discuss this topic further and I hope the information contained in this statement is of value to the Committee.

1 – The global dynamics of energy efficiency

Where and how is energy used

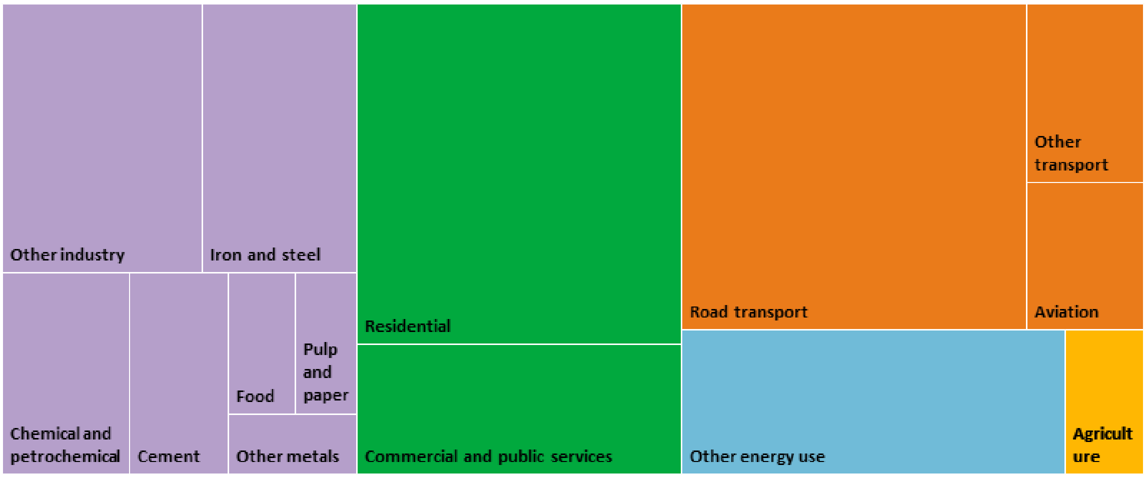
The following charts provide an overview of the world's main energy consuming countries and sectors.

Figure 1. Largest energy consuming countries or regions, 2017



Source: IEA (2019), *World Energy Balances* (database).

Figure 2. Distribution of global final energy use, by sector, 2017

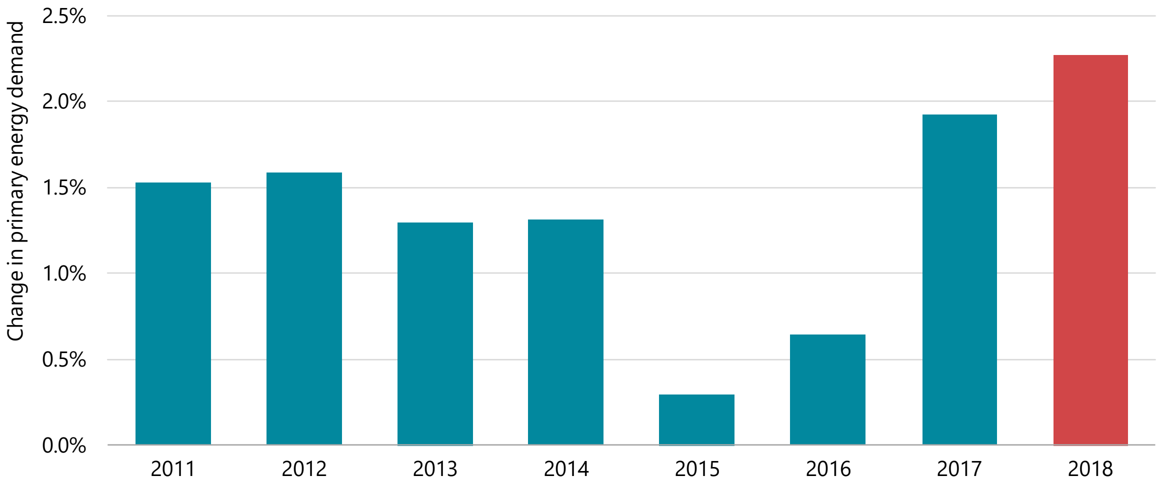


Source: IEA (2019), *World Energy Balances* (database).

Global energy use and intensity trends

In 2018, global energy demand grew by over 2.3% – its highest level since 2010. This followed similarly strong demand growth in 2017, after markedly lower growth in 2015 and 2016 (Figure 3). As the largest economies, the United States and China accounted for over 60% of this growth between them.

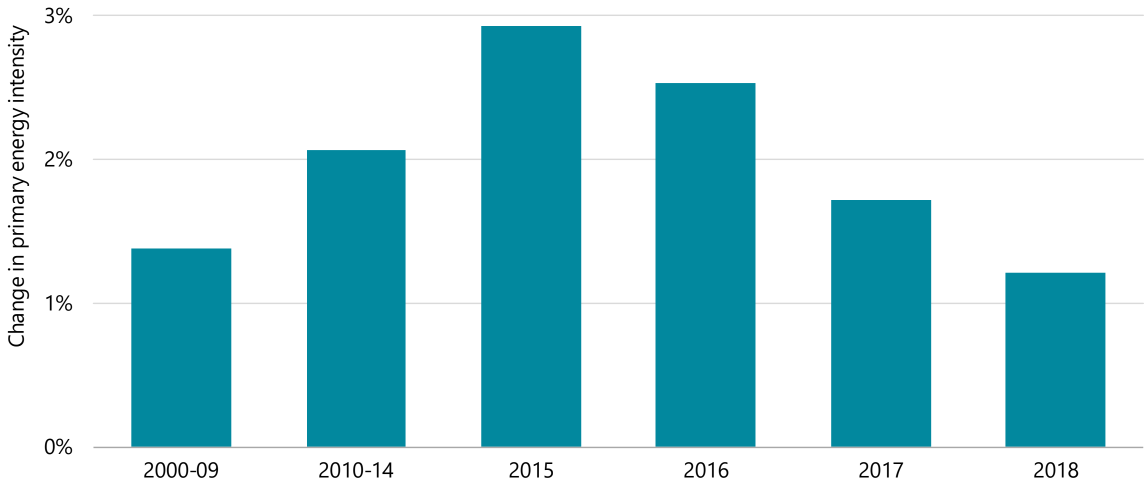
Figure 3. Changes in global primary energy demand, 2011-18



Source: IEA (2019) *World Energy Balances 2019* (database) and IEA (forthcoming) *World Energy Outlook 2019*.

Global energy intensity – energy demand per unit of gross domestic product (GDP) – is a commonly used global indicator to track annual changes in energy efficiency. In 2018, this indicator showed that global energy intensity had improved by 1.2%; in other words, 1.2% more value was extracted from each unit of energy than in the previous year. However, this rate of improvement has been slowing since 2015 (Figure 4). Had the world stayed on track with the 2015 rate of improvement, the equivalent additional value extracted from global energy use would have been $8 trillion in 2018.

Figure 4. **Annual improvement in global energy intensity, 2000-18**



Sources: IEA (2019), *World Energy Balances 2019* (database) and IEA (forthcoming), *World Energy Outlook 2019*.

Why are we experiencing slowing energy intensity improvements?

The recent slowdown in global energy intensity improvement rates is explained by a number of key factors, the most important of which are:

1. **Short-term phenomena** were important in effecting a slowdown in efficiency gains. These include recent strong growth in industrial output from energy-intensive heavy manufacturing. For example, Chinese steel output has grown strongly (8% in 2017 and 6% in 2018) after contracting in 2015 and remaining essentially flat in 2016. A second short term phenomenon is exceptional weather, which in 2018 increased demand for heating and cooling at different times of the year in several major economies. A relatively cold winter in parts of the US led to an increase in gas demand for home heating.

2. **Longer-term trends** have also played a role in influencing year-on-year changes in energy intensity improvement. While technologies and processes are becoming more efficient, structural and behavioural factors are dampening the impact of these technical efficiency gains on demand, and slowing global energy intensity improvements. In transport, for example, consumer preferences for larger cars combined with lower vehicle occupancy are driving up the energy intensity of transport, offsetting improvements in vehicle efficiency. In residential buildings, while building technologies are becoming more efficient, homes across the world are becoming larger, with more appliances being used more often. Many of these trends enhance quality of life, but their energy demand implications are outweighing the gains made though technical efficiency improvements.

3. Another major cause of the efficiency slowdown is the ongoing **slow rate of action on policy**, and the consequent flat progress in the level of energy efficiency investments. The coverage of mandatory efficiency policies, for example, increased only slightly in 2018, and almost exclusively due to existing policies rather than new ones. Similarly, overall total investment in energy efficiency has remained flat for the past few years, and well below the levels required to harness the cost-effective opportunities available.

2 – The opportunity for energy efficiency gains

The global potential of energy efficiency

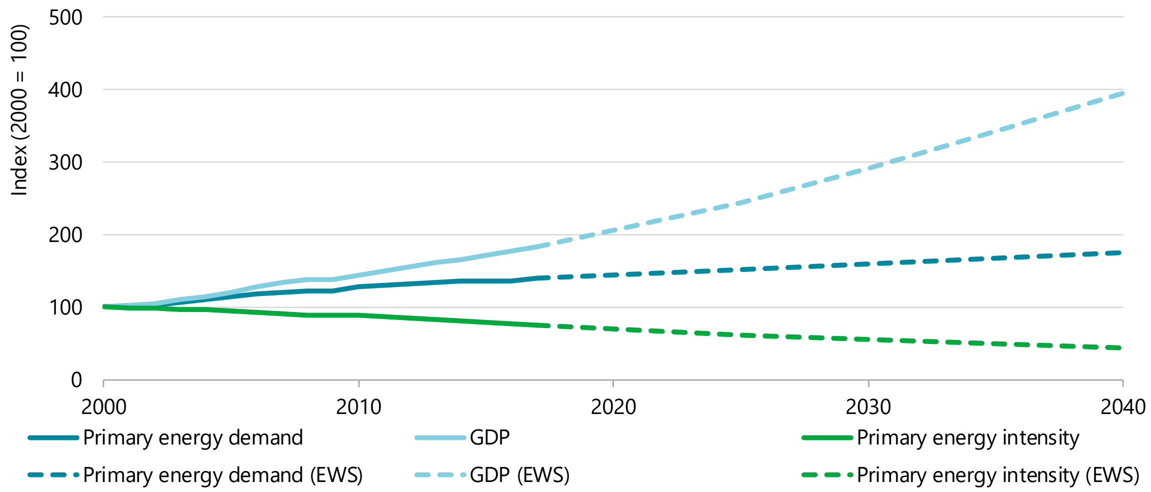
What can we hope to obtain from improvements in energy efficiency if all cost-effective and technically available opportunities were deployed by 2040? What would be the economic, social and environmental benefits?

To address these questions, the IEA has undertaken modelling to determine what would happen if global policy makers deployed all available, cost-effective efficiency measures. The results of the modelling provide the basis for the IEA's Efficient World Strategy, which outlines the potential of energy efficiency for economies and societies, and the measures required to achieve it.

Global energy intensity could be halved by 2040

Stepping up action on energy efficiency could see global energy intensity improve by an average annual rate of 3%. With this kind of improvement, the size of the global economy could double by 2040 for only a marginal increase in energy demand (Figure 55). Greenhouse gas emissions could be substantially lower, consumer bills reduced, and global energy security greatly enhanced.

Figure 5. Global primary energy demand, GDP and intensity, 2000-40



Source: IEA (2018), Energy Efficiency 2018.

Energy use could be avoided and emissions could fall

Capturing these efficiency opportunities could mean 20% less energy use in 2040 than otherwise would be the case. Energy efficiency alone could achieve an immediate peak in global energy-related carbon dioxide (CO_2) emissions, and then see levels fall 12% lower than today by 2040. This represents over 40% of the emissions abatement required under the goals of the Paris Agreement; demonstrating the key role played by energy efficiency in achieving global climate targets.

Financial benefits could flow to economies, sectors and households

At a national level, efficiency gains could reduce the need for energy imports and associated expenditure, as well as improve trade balances and energy security. By 2040:

- China, India and the European Union could avoid expenditures of about USD 700 billion in fossil fuel imports;
- Global industry could avoid about USD 600 billion in energy spending; and
- Household savings could amount to about USD 550 billion in energy spending.

Opportunities for efficiency gains

Developing an understanding of the technologies and energy-uses which could yield the largest energy savings provides a clearer view as to which policies and measures can unlock the potential of energy efficiency. The opportunities for efficiency gains in transport, buildings and industry are summarised in the following sections.

Transport energy demand could stay flat despite doubling activity levels

Global transport energy demand could stay flat between now and 2040, despite a doubling in activity levels. Efficiency measures in the transport sector offer the largest energy savings, with road transport, particularly cars and trucks, having the greatest potential. In 2040, today's most efficient hybrid cars could be the norm, and as much as 40% of the global car fleet could be composed of electric vehicles. Between now and 2040 the efficiency of trucks could improve by 2.5% annually, much higher than historical rates, and aviation and shipping could improve by 3% annually.

Behaviour change to shift existing transport patterns could yield significant additional benefits. Examples include encouraging people to use public transport instead of cars, which in many countries has been incentivised in various ways. Introduced in 2003, the London congestion tax levied a daily charge for driving or parking on congested roads, and resulted in noticeable behaviour change and other impacts. This included a 20% reduction in traffic; a 16% reduction in vehicle emissions; and over 40 million litres of avoided fuel consumption (C40, 2011).

Building space could increase by 60%, with no additional energy use

The deployment of the most efficient technologies could mean that global buildings energy use could remain flat between now and 2040, despite an increase of 60% in total building space. Heating and cooling could provide the majority of potential savings, and global heating energy use could be cut in half, despite the growth in building stock.

Industry could produce twice as much value for each unit of energy

Recent improvements in overal global industrial energy efficiency have been linked to new, highly efficient factories that have been built in emerging economies. Technological changes and automated control have also made it possible for current equipment to make efficiency gains. There remains considerable opportunity for further gains, such that by 2040, cost-effective efficiency potential could result in industry producing twice as much gross value added for each unit of energy.

While energy efficiency has improved in the largest, most energy-intensive sectors, less intensive sectors, such as food and beverage manufacturing, have not seen the same level of improvement and therefore hold the most potential for efficiency gains. Significant potential can be unlocked through the widespread adoption of more efficient technologies, and improving the efficiency of electric motors and the systems they drive.

An important opportunity for industry is the increased adoption of energy management systems, which provide ways for industry to manage and optimise energy use. Incentives are often used to promote the adoption of energy management systems. In Germany, tax reductions are provided to eligible industrial firms implementing an energy management system and contributing to sector-wide efficiency gains. This has led to Germany having the highest adoption rate of such systems in the world (IEA, 2018).

Investment must rise to unlock potential efficiency gains

A substantial scale-up in investment will be needed to unlock the potential benefits of energy efficiency between now and 2040. Average annual energy efficiency investment will need to double from the current investment level of about USD 240 billion (unchanged since 2014) to about USD 600 billion between now and 2025, and then double again to 2040.

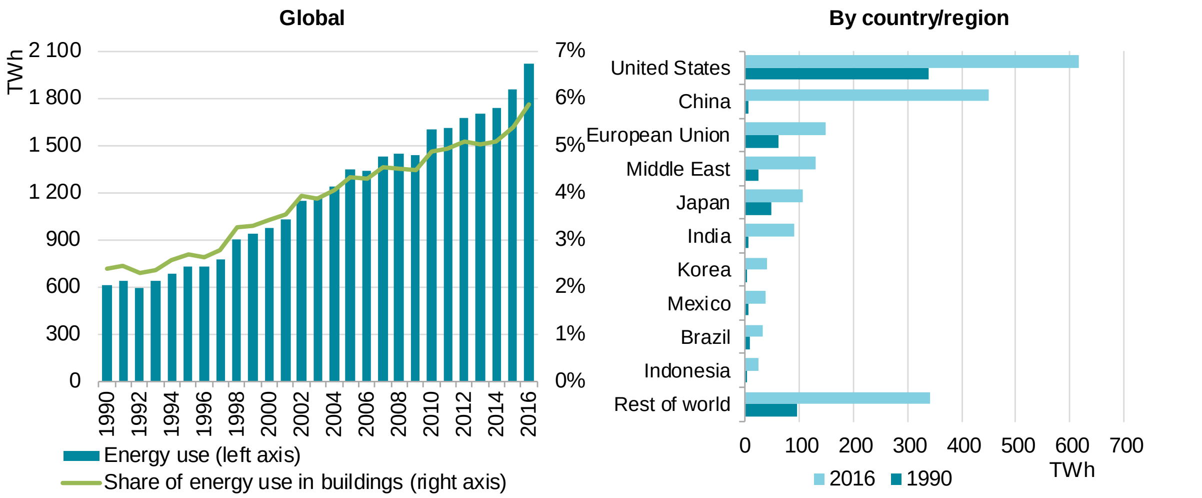
It is important to emphasise that all the efficiency measures included in the IEA's Efficient World Strategy will achieve a positive return on investment. Across all sectors, each dollar spent on improving energy efficiency will, on average, pay back by a factor of three. This is only based on energy savings, and does not include some of the other benefits of energy efficiency, many of which deliver additional financial returns.

While efficiency investments are financially attractive, there are important barriers to increased spending, including the complexity and variety of energy efficiency projects. Energy efficiency investment is highly varied, and ranges from individual appliance replacement to major retrofits of commercial buildings. These larger projects are also complex, involving multiple technologies and systems, and may deter major investors as many of these efficiency investments are either too small or too complex to be appealing. The implication is that there is no 'one size fits all' approach to increasing investments in efficiency.

The importance of cooling energy use

The fastest growing source of energy demand in buildings, globally, is space cooling. This reflects both the increased ownership of air conditioners across major economies and warmer weather conditions. Global space cooling energy use more than tripled between 1990 and 2016, with its share in total building energy use also rising from 2.5% to 6%. While the largest overall increase has been in China, air conditioner energy use is remains highest in the United States (Figure 66).

Figure 6. **Growth in air conditioner energy use**



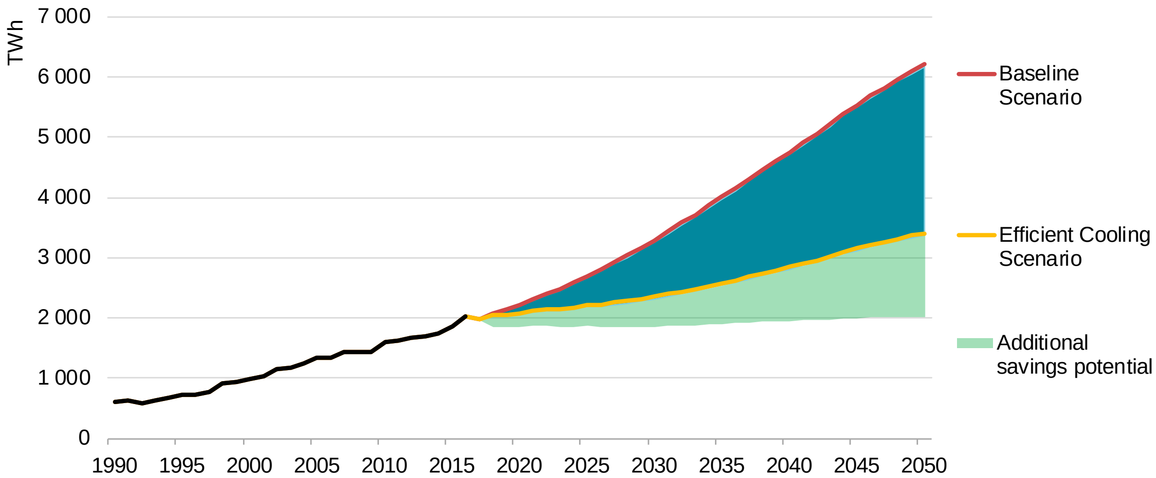
Source: IEA (2018), The Future of Space Cooling, OECD/IEA, Paris

Growing demand for space cooling is most apparent when considering its impact on peak electricity demand. In countries where there is demand for space cooling throughout the entire year, such as Singapore, Australia or countries in the Middle East, the share of air conditioning in peak electricity load can exceed 50%.

Without greater policy action to improve both the efficiency of space cooling equipment and the performance of buildings, the impact on the global energy system could be significant. IEA projects a potential threefold increase in space cooling energy demand between 2016 and 2050, which would result in a doubling of associated emissions. This increase is linked to greater air conditioner ownership in large emerging economies, particularly India and Indonesia, where space cooling could represent nearly half of total peak electricity demand by 2050.

However, the IEA estimates that greater efforts on efficiency could see the average energy efficiency of the global stock of air conditioners could more than double between 2019 and 2050. This would result in energy demand growing at a much slower rate, to be 45% lower in 2050 than would otherwise be the case, with additional savings also possible from improving building performance to minimise the need for space cooling. The savings on investment in electricity infrastructure required to meet peak demand would be particularly significant. These efficiency gains, combined with increased penetration of renewable power generation, could see emissions from space cooling fall to levels below that estimated in 2016.

Figure 7. Contribution to global energy savings from energy efficient air conditioners and additional potential energy savings



Source: IEA (2018a), *The Future of Cooling*

While the use of air conditioners in buildings will underpin future demand for space cooling, its impact also extends to the transport sector. Air conditioners in cars, buses and trucks currently consume the equivalent of 1.5% of global oil consumption, representing around 420 million tonnes of greenhouse gas emissions. Without further policy action, this energy consumption could nearly triple due to increased vehicle uptake in countries with warm climates. However, efficiency gains limit this impact. IEA estimates that improved technology and vehicle design could limit the increase in energy demand to be half what is currently projected (IEA, 2019b).

Digitalisation has the potential to unlock greater efficiency gains

Digitalisation will undoubtedly change the future landscape of energy efficiency. The following sections highlight three digitalisation trends that have the potential to lead to dramatic efficiency gains in buildings, transport and industry.

Smart buildings

Digital technologies and enhanced connectivity have led to the concept of a 'smart' building. A smart building is one in which devices are connected through a building (or home) energy management system, which gathers data from these devices, as well as external data, such as weather conditions and local grid requirements, to control and optimise building energy use.

The benefits of smart buildings will vary depending on the type of building, the appliances used and the market structures incentivising action. Some studies indicate that home energy management and automation technologies can reduce energy use by up to 30% (IEA 4E EDNA, 2018). For the global building stock, forecasts indicate that greater levels of digitalisation between now and 2040 could lead to average annual savings of around 10% of current global buildings energy use (IEA, 2017a).

Shared mobility

Digitalisation has the potential to significantly influence the global transport sector. Among its benefits and potential applications are vehicle automation; optimisation of freight logistics; and enhanced route planning. Another application, shared mobility, has also gained significant attention.

Shared mobility – the shared use of a vehicle, motorcycle, scooter, bicycle, or other means of travel – has been greatly enabled by the considerable growth in digital technologies, particularly smartphones. The extent to which shared mobility will enable additional efficiency gains will depend on several factors, most importantly whether it moves people away from single-occupancy car journeys. Greater penetration of electric vehicles in shared mobility could limit energy and emissions impacts.

Smart manufacturing

Digital technology has long been used within industry to improve process control, safety and overall productivity. The concept of smart manufacturing – characterised by greater levels of connectivity and the use of advanced software to carry out analysis and improve performance and productivity – is being enabled through recent technology advances. Energy and material cost savings of 3-5%, along with reduced maintenance costs and production downtime, have been estimated as potential benefits across various industry sectors (Schneider Electric, personal communication).

Artificial intelligence (AI) algorithms are also being used to optimise complex industrial processes; analyse data collected from a wide variety of sources; 'learn' and predict the future performance of industrial equipment; as well as alert operators to potential faults before they disrupt production. While still in early stages of deployment, AI algorithms are reported to be yielding energy savings of up to 10% in energy-intensive industry sectors (IBM, 2019).

Additive manufacturing (3-D printing) is also becoming more common within industry. As a technology, 3-D printing has the potential to significantly reduce material waste, and facilitate the production of more complex parts and components. This, in turn, could improve the efficiency of appliances and equipment using these parts and components.

From end-use efficiency to systems efficiency

Digital technologies are opening up greater potential for energy efficiency and shifting attention away from the use of energy in specific appliances or equipment towards the entire energy system. This is of particular interest in electricity systems, where electrification of energy loads combined with greater levels of renewable energy deployment is seen as an important strategy for decarbonisation in many countries. In this context, system balancing and optimising the use of renewable resources is enhanced when the demand-side can play a more active role in modern energy systems.

Digital technology can improve the flexibility of energy demand, and ensure that energy-using equipment can respond in real time to changes in supply and market conditions. Such actions, referred to collectively as demand-side management, can enhance energy security and affordability by reducing the need for additional sources of energy supply. The challenge for policy makers is to ensure that markets are established and structured in ways that recognise and capture the benefits that demand-side actions can bring to modern energy systems. This is a fast-emerging dimension of energy efficiency and energy transition thinking that could profoundly transform approaches to energy efficiency in a systems' context.

3 – Efficiency Policies in Action

Introduction

Decades of accumulated global experience demonstrate that well-designed and well-implemented policies to enhance energy efficiency can bring huge social and economic benefits.

The following examples illustrate how forward-looking efficiency policies and private sector engagement can enhance competitiveness, enable job creation and energy access, and improve energy security. They are only a glimpse into the huge potential offered by energy efficiency policies. Emerging trends in digitalisation offer even greater potential: connected devices, data and analytics are transforming traditional efficiency value propositions, with tremendous untapped opportunities for policy makers and market actors alike.

Lowering costs and enhancing competitiveness by making technology more efficient

Minimum energy performance standards (MEPS) are a well-known instrument in efficiency policymaking. They regulate the amount of energy consumed by technologies, such as air conditioners or motors. To date, over 80 countries have adopted MEPS covering more than 50 different types of technologies. MEPS have been proven to be cost effective, with evaluations showing that benefits typically outweigh any additional costs by a factor of 3 to 1 (IEA 4E, 2015).

MEPS have been used effectively by policy makers in the **United States** to allow consumers to obtain more value from refrigerators. Since the introduction of the first MEPS for refrigerators in 1978, consumers spend on average two-thirds less (based on 2010 USD values) for refrigerators than they did forty years ago. In addition, due to MEPS, refrigerators sold in the United States today have larger volumes but use over 75% less energy (ACEEE, 2014).

Well-designed MEPS can also be used to drive innovation among equipment manufacturers to improve the competitiveness of industries and economies, especially if they form part of a wider economic policy agenda.

Japan, for example, encourages companies to compete with one another to obtain the official 'Top Runner' label, which is widely recognised by consumers to denote that a product performs best in its class in terms of energy efficiency. The programme covers a range of products, from passenger cars to refrigerators. Performance standards are dynamic, so that every few years the most efficient devices are set as the new standard for everyone to meet. In operation since 1999, Top Runner has increased the international competitiveness of Japanese companies, and given consumers access to efficient highly cost-effective equipment.

Deploying efficient technologies quickly

There are many efficient technologies that are ready to be scaled up and could have a strong impact, but which are unable to reach the necessary scale of use. This may be due to their cost, or they are not familiar to consumers or installers. Equally, some very good efficiency standards are in place but will take many years to have a full impact due the time required to fully phase out inefficient equipment.

Efforts to rapidly get efficient technologies into the hands of millions of consumers can accelerate their benefits. One effective means of achieving this is through the **bulk procurement** of efficiency services or products to accelerate their deployment. Bulk procurement creates economies of scale, decreasing the costs of services and products, and in some cases encouraging the development of new or spin-off markets.

India, for example, is procuring millions of efficient lights through a national programme called UJALA, which has already delivered more than 330 million lamps across India in the past four years. While the programme receives no public subsidy, consumers are able to pay for the lamps partly upfront and partly out of the ongoing savings. The purchasing power of the large programme means that consumers pay only 70 rupees (1 USD) for an energy efficient LED light bulb (EESL, 2019).

Creating an efficiency culture

Countries often deploy a range of information and awareness-raising measures to build support and encourage consumers to make more energy efficient purchasing decisions.

China, for example, introduced the **China Energy Label** in 2005 to improve energy efficiency and meet a target of a 20% decrease in energy consumption per unit GDP by 2010. According to surveys, the China Energy Label has been seen and recognised by 97% of China's urban population, and 75% of them understand how the label helps them compare the efficiencies of competing products. In 2016, the Chinese government improved its labelling approach by introducing a QR code on the labels. The QR code allows consumers to easily access relevant information using their phones, including comparisons of difference appliance prices and running costs, manuals, repair options and end-of-life recycling options (CLASP, 2017).

In **Japan**, social norms influencing energy use have been tackled through the multi-year **Cool Biz Campaign**. The campaign encourages raising temperature settings on air conditioners, while allowing office workers to wear lighter and less formal clothing. Launched in 2005, the campaign took on urgency following the Fukushima Daiichi nuclear disaster of 2011. National leaders sought to encourage new behaviours by being pictured wearing more casual clothes. Significant energy and carbon savings were achieved and have been sustained (Japan Times, 2019).

Information measures can also be used to encourage a shift in established market practices, such as the sale or lease of commercial real estate. **Australia's** Commercial Buildings Disclosure (CBD) programme, for example, requires energy efficiency information to be provided when commercial buildings are sold or leased. Before offering their office space for sale or lease, buildings owners must obtain a mandatory building energy efficiency certificate with an efficiency star rating (CBD, 2019). Since the implementation of the CBD programme, the energy efficiency of Australia's commercial buildings has increased consistently. The CBD programme has also ensured that efficiency is a selling point in commercial real estate, and it has encouraged owners of poorly performing buildings to make energy efficiency improvements.

Incentives can promote efficiency in industry and beyond

Given the high energy costs for many manufacturing sectors, energy use in industry has been a focus of attention for many years. The range of policies that have been applied include voluntary agreements, financial incentives, and legally binding targets.

Germany uses a combination of information and incentives to encourage industries to adopt the globally recognised **ISO 50001** standard for industrial energy management. Companies that achieve ISO 50001 certification and specific energy performance improvement rates are eligible for a tax exemption. Using an independently verified certification makes the programme much easier to administer. As a result of the scheme, Germany has the largest number of ISO 50001 certifications of any country. Energy management systems also unlock additional energy and cost savings, such as improvements in staff awareness and staff accountability (IEA, 2018).

Financial incentives are also deployed in other sectors. More sophisticated policies seek to establish the right incentive structure while minimising the burden on the state. In **France**, government incentivise consumers to purchase more efficient cars, while stabilising tax revenues from changing patterns in vehicle sales. This is done through a policy called Bonus-Malus, which reduces taxation on more efficient cars and raises them on less efficient ones. To adjust to shifting consumer preferences, the Bonus-Malus policy is updated every year to ensure that revenue from the scheme is neutral relative to previous vehicle taxation schemes (ICCT, 2018).

Transforming inefficient buildings

For many countries, energy and climate targets will not be met without addressing inefficiencies in their existing building stock. However, retrofitting existing buildings, even if financially viable, is beset by many practical challenges. Although insulation, double-glazed windows, or more efficient heating systems are readily available, a number of barriers prevent these technologies from being more widely installed, especially in residential buildings. Homeowners may be unwilling or unable to pay large sums upfront to make long term energy savings. They may have to vacate their homes during building projects, or they may not know which solutions are right for them.

Governments frequently use grants to overcome these barriers and to incentivise homeowners to adopt efficiency technologies. However, grants can prove expensive and, rather than stimulating the development of a retrofit market, they may simply make homeowners dependent on grants. All this has meant that many efforts to encourage large-scale efficiency retrofits of homes have often proven unsuccessful.

A pioneering approach launched in the **Netherlands** addresses some of these persistent barriers through a different kind of residential retrofit business model. Known as Energiesprong, the model is based on a one-week efficiency intervention featuring pre-fabricated facades, rooftop solar and new heating installations. Energiesprong focusses on entire neighbourhoods rather than individual homes, and no upfront payments are required. Instead, the service is guaranteed and paid over time through energy and maintenance charges (Energiesprong, 2019).

Energiesprong has provided a trove of important learnings on the use of prefabricated building facades for residential retrofits. Because local companies are involved in manufacturing and installing facades and other technologies, the model has the potential to create jobs and spur innovation in building materials supply chains. Energiesprong has also shown promising potential in terms of scalability and replicability, with spinoffs being created in numerous other jurisdictions across the globe. A number of US States are also implementing innovative ways to finance home upgrades to try to stimulate the market.

Another initiative that is advancing residential energy efficiency in neighbourhoods, with important implications for energy system resilience, is Alabama Power's Smart Neighborhood™, with support from the **United States** Department of Energy (US DoE, 2018). The initiative involves a range of public and private sector actors to develop a community-scale micro-grid. It relies on efficient homes, to reduce the overall demand for energy and support the resilience of the system, and on digital technologies that enable energy using equipment in homes to 'interact' with one another as well as with energy providers.

Digitalisation is taking energy efficiency to the next level

The previous example from United States is only one of a rapidly growing number of cases that illustrate how digital technologies, supported by energy efficiency, offer a potential step-change in how energy is used, and how government can play an enabling role in market development. Indeed, the **United States** has been a pioneer in this area. A number of states have led the way in terms of developing **demand response** programmes, which reduce stresses on grids by incentivising consumers to reduce their electricity consumption at peak times (SEPA, 2019).

While demand response has been used for some time, digital technologies – such as smart meters, which monitor energy use remotely and in real time, appliances that can be remotely controlled, and electric vehicles that can store excess grid electricity – allow energy efficiency to be better integrated within a wider range of demand-side measures. In an age of fast-growing deployment of clean, affordable renewable energy sources, particularly on electricity grids, a vital goal is not just to maximise efficiency of specific energy end-uses, but rather to optimise the efficiency of the whole system. In modern electricity grids, the value of end-use efficiency is fundamentally different at times when solar and wind power is plentiful and essentially free, as opposed to times when the grid is operating at maximum capacity and deploying expensive, often carbon-intensive electricity generation to meet demand.

City governments are also exploring the powerful combination of energy efficiency and the use of digital technologies to achieve both energy and non-energy related outcomes. **Barcelona** leveraged its conversion to LED street lighting as an opportunity to test 'smart city' functionality. Instead of merely rolling out new street lights, the city is using some of its lighting infrastructure to deploy pollution and noise sensors, and enable the expansion of Wi-Fi networks and electric vehicle charging stations (CityOS, 2019).

Numerous other cities across the globe have been developing and testing similar approaches. These city governments are realising that digitalisation presents an opportunity to transform a 'pure' efficiency intervention, i.e. converting to a more efficient street lighting technology, into an opportunity for large-scale digital technology deployment that provides a wide range of benefits to citizens (IEA, 2017a).

Digital technologies are also enabling new approaches to providing energy access to communities where the electricity grid does not reach. In **Rwanda and Kenya,** the company BBOXX has deployed solar home systems since 2014, providing first-time clean electricity access for over 77 000 rural households. BBOXX offers a range of packages, including mobile charging accessories, televisions and LED lights, combined with a solar panel and a battery. The service is made possible through ultra-efficient devices and digital technologies to control monitoring, maintenance and payment via mobile phone networks (BBOXX, 2019). This is one of many examples showing how the private sector is at the forefront of leveraging digitalisation trends in energy efficiency.

Many companies are now in the process of transforming their energy and energy efficiency business models, and moving away from focussing on technology sales to selling software as a service; customer value and commercial profits are increasingly being based on data-based analytics and insights.

Policy makers can draw on a wealth of global experience to best leverage effective efficiency policies and digital tools to meet a range of objectives. Now is the time to open a new chapter in the story of a more sustainable energy future. Efficiency can take a leading role in this story, supported by smart and effective policies.

References

Alliance to Save Energy (ASE). (2018). Alliance to Save Energy CAFE Standards. Retrieved from https://www.ase.org/resources/corporate-average-fuel-economy-cafe-standards#targetText=The%20CAFE%20standards%20were%20passed,a%20specific%20average%20ofuel%20economy.&targetText=Fuel%20economy%20roughly%20doubled%20from,27.5%20mpg%20oten%20years%20laterChina Electricity Council (2019), *Data/Statistics: Monthly Statistics of China Power Industry*, China Electricity Council, english.cec.org.cn/No.110.index.htm

Australian Government. (2019). Commercial Building Disclosure. Retrieved from http://cbd.gov.au/

BBOXX. (2019). Retrieved from https://www.bboxx.co.uk/

C40 (2011), *London's Congestion Charge Cuts CO2 Emissions by 16%*, C40, https://www.c40.org/case_studies/londons-congestion-charge-cuts-co2-emissions-by-16Cisco (2019),

California Independent System Operator (CAISO). (2019). Retrieved from Demand response and energy efficiency roadmap: http://www.caiso.com/informed/Pages/CleanGrid/Demand_Response.aspx

Cisco Visual Networking Index: Forecast and Trends, 2017-2022, https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white-paper-c11-741490.html

Cisco (2016), *The Zettabyte Era: Trends and Analysis, July 2016*, https://webobjects.cdw.com/webobjects/media/pdf/Solutions/Networking/White-Paper-Cisco-The-Zettabyte-Era-Trends-and-Analysis.pdf

CityOS Foundation (2019, *Smart City Barcelona*. https://cityos.io/view.competitor/28428/Smart-City-Barcelona

CLASP. (2017). China Launches Digital Energy Label & App. Retrieved from https://clasp.ngo/updates/2017/china-launches-digital-energy-label-app

Clewlow, R., and G. Mishra (2017), *Disruptive Transportation: The Adoption, Utilization and Impacts of Ride-Hailing in the United States*, University of California Davis, Institute of Transportation Studies, Research Report UCD-ITS-RR-17-07, https://itspubs.ucdavis.edu/wp-content/themes/ucdavis/pubs/download_pdf.php?id=2752ENTSO-E (2019), *Monthly domestic values* (database), ENTSO-E, www.entsoe.eu/data/power-stats/monthly-domestic/

Energiesprong. (2019). Retrieved from https://energiesprong.org/

Energy Efficiency Services Limited (EESL) India. (2019). About Ujala. Retrieved from https://www.eeslindia.org/content/raj/eesl/en/Programmes/UJALA/About-UJALA.html

IBM (2019), *Cognitive Manufacturing: An Overview of Four Applications that are Transforming Manufacturing Today*, IBM, www.ibm.com/downloads/cas/VDNKMWM6

IEA 4E. (2015). Achievements of appliance energy efficiency, a global assessment. Retrieved from https://www.iea.org/publications/freepublications/publication/4E_S_L_Report_180915.pdfIEA (2019a), *Energy Technology Perspectives* (buildings model), OECD/IEA, Paris, www.iea.org/etp/etpmodel/buildings/

IEA. (2017). Energy Efficiency 2017. Retrieved from https://www.iea.org/publications/freepublications/publication/Energy_Efficiency_2017.pdfInternational Energy Agency (IEA) (2019), *World Energy Balances* (database), OECD/IEA, Paris, www.iea.org/statistics

IEA (2017a), *Digitalization and Energy*, OECD/IEA, Paris

IEA (2018), *Energy Efficiency 2018*, OECD/IEA, Paris

IEA (2018a), *The Future of Cooling: Opportunities for energy-efficient air conditioning*, OECD/IEA, Paris

IEA. (2019). Data centres and data transmission networks. Retrieved from Tracking Clean Energy Progress: https://www.iea.org/tcep/buildings/datacentres/

IEA (forthcoming), *World Energy Outlook 2019*, OECD/IEA, Paris

IEA (forthcoming), *Energy Efficiency 2019*, OECD/IEA, Paris

IEA 4E Electronic Devices and Networks Annex (EDNA) (2018), *Intelligent Efficiency: A Case Study of Barriers and Solutions – Smart Homes*, IEA 4E EDNA, www.iea-4e.org/document/413/intelligent-efficiency-a-case-study-of-barriers-and-solutions-smart-homes

International Council on Clean Transportation (ICCT). (2018). Practical lessons in vehicle efficiency policy: The 10-year evolution of France's CO2-based bonus-malus (feebate) system. Retrieved from https://theicct.org/blog/staff/practical-lessons-vehicle-efficiency-policy-10-year-evolution-frances-co2-based-bonus

Japan Times. (2019). Japan kicks off Reiwa Era's first energy-saving Cool Biz casual wear campaign. Retrieved from https://www.japantimes.co.jp/news/2019/05/07/business/japan-kicks-off-reiwa-eras-first-energy-saving-cool-biz-casual-wear-campaign/#.XX-hPSgzaUk

Malmodin, J., and D. Lundén (2018), "The energy and carbon footprint of the global ICT and E & M sectors 2010-2015", *Sustainability (Switzerland), 10(9), 3027*.

METI. (2015). Top Runner Program. Retrieved from https://www.enecho.meti.go.jp/category/saving_and_new/saving/data/toprunner2015e.pdf

Ministry of Economy, Trade and Industry (METI) of Japan. (2015). Top Runner presentation. Retrieved from https://www.kansai.meti.go.jp/3-9enetai/downloadfiles/shoenesympohaihusiryou/29fy/29fy_sesakusetsumei.pdf

National Oceanic and Atmospheric Administration (2019), *Climate at a Glance: Global Time Series* (database), NOAA, Silver Spring, Maryland, www.ncdc.noaa.gov/cag/global/time-series

Secretariat of Energy (SENER) of Mexico. (2018). Secretaría de Comunicaciones y Transportes, Programa de Trabajo para la Transición a la Televisión Digital Terrestre. Retrieved from https://www.gob.mx/sener/articulos/concluyo-el-programa-ahorrate-una-luz-con-la-entrega-de-39-799-447-lamparas-ahorradoras

Schaller, B. (2018), *The New Automobility: Lyft, Uber and the Future of American Cities*, Schaller Consulting, http://www.schallerconsult.com/rideservices/automobility.htm

U.S. Energy Information Agency (2019), *Natural Gas Consumption in the United States 2014-2019*, U.S. Energy Information Agency, www.eia.gov/naturalgas/monthly/

World Steel (2019), *Total production of crude steel*, World Steel, www.worldsteel.org/steel-by-topic/statistics.html