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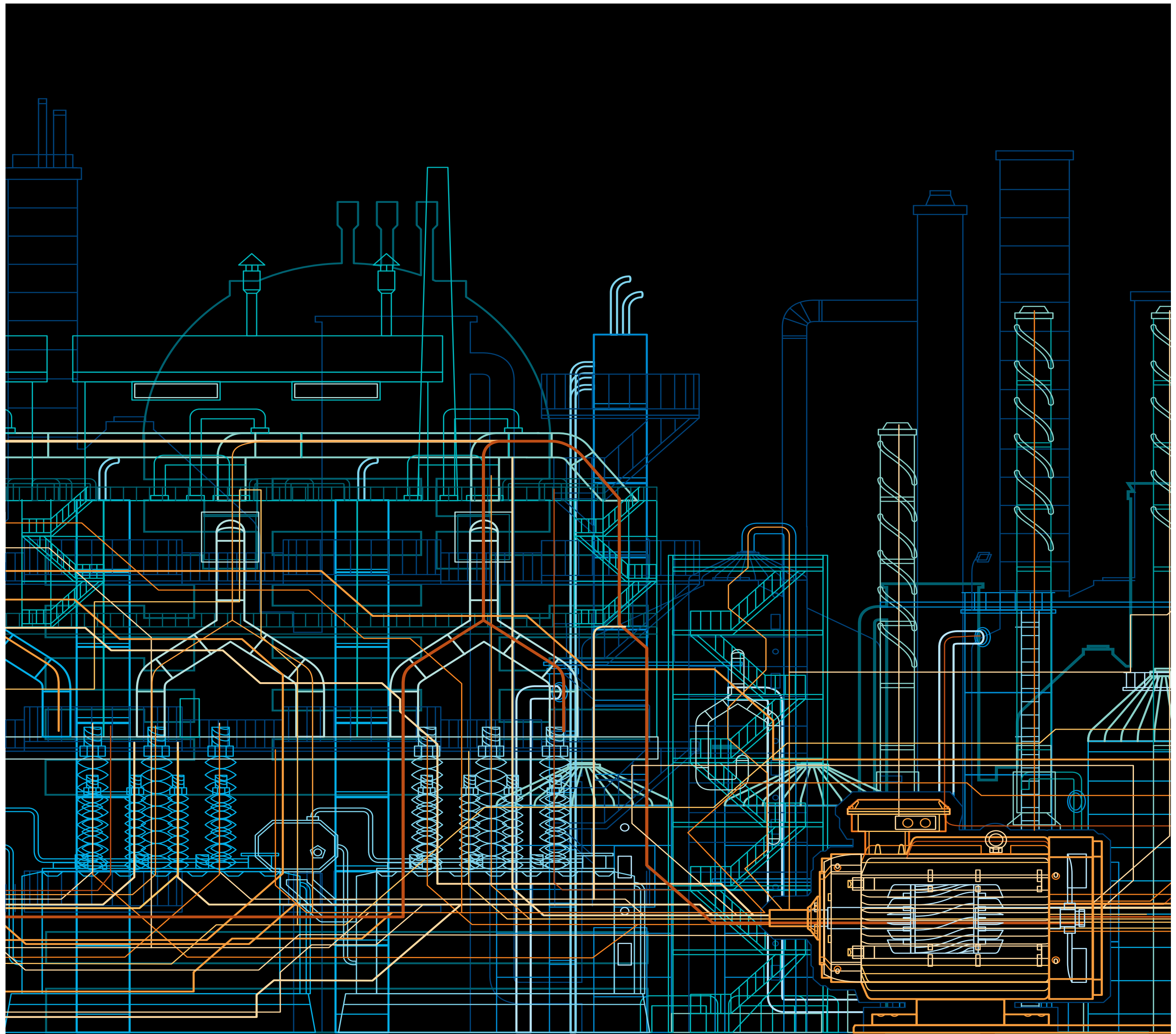
Power and productivity
for a better world™



Energy efficiency – the fast track to a sustainable energy future

Power and productivity
for a better world™

The most pressing global challenge

Without swift action to reduce CO_2 emissions, global warming is set to accelerate, with potentially catastrophic consequences.

To meet this challenge, the International Energy Agency (IEA) has proposed a so-called bridging strategy, which would make use of energy-efficient technologies that are already available today. Their consistent application, enforced by tighter regulation, would secure the long-term de-carbonization of the energy sector, and make a significant contribution to the target of limiting the rise in average global surface temperatures to 2°C compared with pre-industrial levels.

In view of megatrends such as urbanization and the industrialization of non-OECD countries, world electricity demand is expected to increase by more than 70 percent by 2040.[1] The power sector accounts for more than half of the increase in global primary energy use, equivalent to the total current energy demand of North America. Most of this demand will come from non-OECD countries, led by China (33 percent), India (15 percent), Southeast Asia (9 percent) and the Middle East (6 percent).[2]

To limit global warming, the increase in electricity demand needs to be accompanied by a significant reduction in the level of CO_2 emissions per unit of energy consumed.

Transforming the energy sector for a more sustainable future is a multi-generational project, but short-term actions, based on readily available, proven technologies, could provide a valuable short-cut in the effort to reach all-important climate goals. In 2014, energy efficiency measures were estimated to have saved more than 520 million tons of oil equivalent (Mtoe), corresponding to about 1.5 billion tons of CO_2 that would otherwise have been emitted.[3]

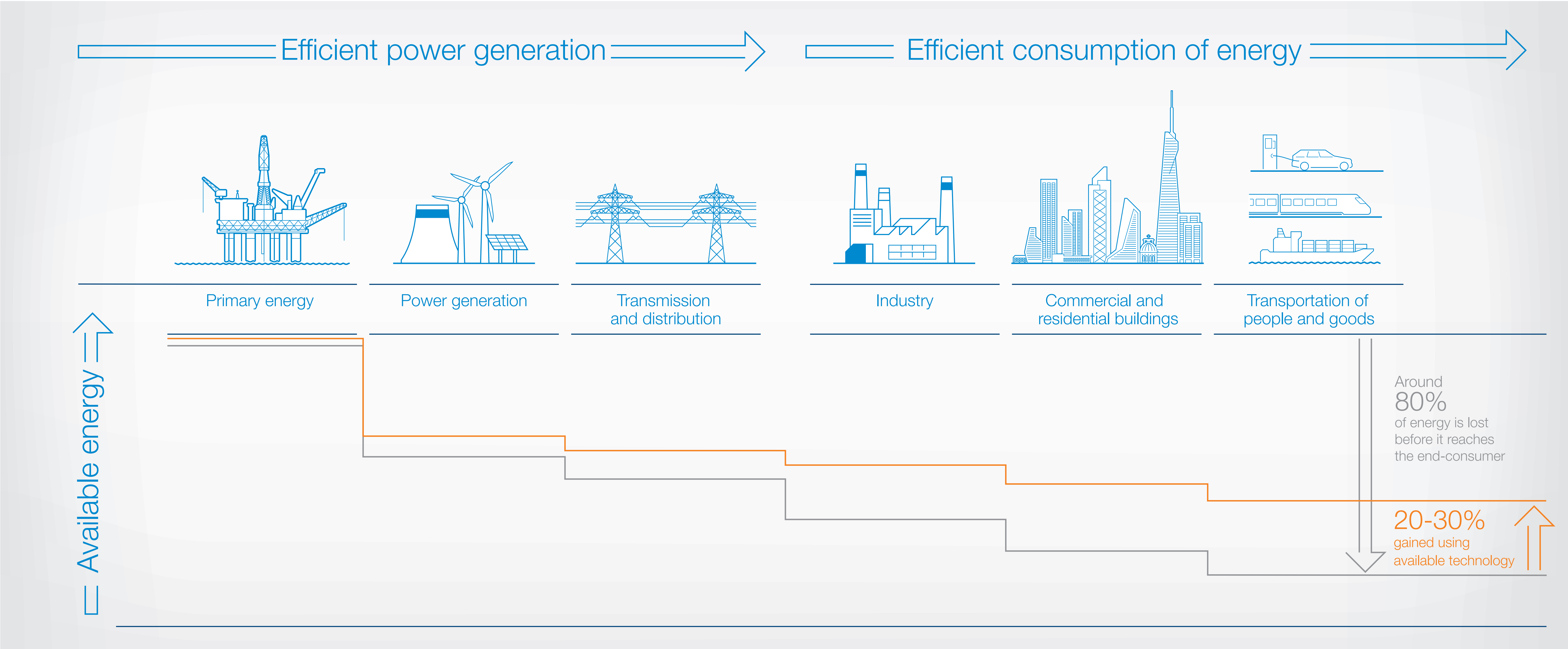
To mitigate climate change, we need to produce electricity with lower CO_2 emissions, and to optimize the efficiency of the energy value chain.

By deploying available technologies, it is estimated that almost 50 percent of the total emissions goal could be reached without compromising economic growth, because most investment in energy-efficient technologies quickly pays for itself in lower operating costs. In financial terms, the gains from energy efficiency measures are estimated to have lowered energy bills by over US$550 billion in 2014.[4]

A study, ordered by the European Commission,[5] analyzed how much energy would be saved worldwide, **if the most stringent energy efficiency requirements currently in force were applied globally. It concluded that the world's final energy consumption would be 9 percent lower.** The study calculated that the global saving potential of industrial motors alone by 2030 would be 13,286 terawatt-hours (TWh), equivalent to 1,140 Mtoe, second only to thermal heating applications.

Available technology can significantly increase energy efficiency

Enormous potential for reducing losses along the energy chain



Only 20 percent of energy generated by fossil fuels reaches the end-consumer.

The chart above shows the estimated savings potential along the major steps of the energy value chain of ABB.

Applying readily available technologies along the energy value chain would reduce energy losses and therefore CO_2 emissions, helping to mitigate climate change. Such technologies typically pay for themselves within a few years through lower energy costs.

Available technology could double energy efficiency levels.

This paper provides a brief overview of the savings potential across the energy value chain from technologies that are available today.

Power generation
Primary energy supply

Primary energy has historically come from fossil fuels and hydropower. Fossil fuels remain the most common sources of energy, with a value chain that extends from extraction activities to the generation of electricity. The IEA estimates that in 2014, **about 5 percent of energy obtained from fossil fuels was consumed in the extraction phase, while fully 65 percent was lost as combustion heat during the electricity generation process.** With available technologies, such as combined heat and power co-generation or district heating, heat losses can be reduced to 55 percent. A further 9 percent of electricity generated is lost in transmission and distribution from the power plant to the end consumer.

While renewable energy technology is advancing rapidly and renewable generation is the fastest growing power sector, the world's primary energy sources are still coal, oil and gas, and the use of these fossil fuels will continue to rise for many years. The exploitation of these primary energies must therefore be made as efficient as possible.

Electrification of offshore platforms makes it possible for fossil fuel extraction to be more energy efficient as electricity is brought from land to power the extraction equipment. A power-from-shore system has a higher efficiency than offshore generation and it enables power supply from multiple sources, including renewable power. A notable example is Europe's largest gas platform, Troll-A, located about 70 kilometers off the Norwegian coast. Instead of using gas turbines located offshore, Troll-A is completely electrified with approximately 200 megawatt (MW) of high-voltage AC (alternating current) and DC (direct current) power supplied via subsea cables connected to the Norwegian grid. The electrification has been carried out in two phases: it is estimated that phase one is resulting in avoidance of 230,000 tons of CO_2 and more than 230 tons of NO_x (nitrogen oxides) in emissions annually and this is expected to be much higher when phase 2 is in full operation.

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Power generation
Electrical power generation, transmission and transportation

There remain substantial opportunities to further improve energy efficiency in the power generation process.
In standard coal-fired plants, fully 5 percent of the energy generated is consumed by the operations of the plant itself. Even a small improvement in this process would lead to substantial energy savings since 40 percent of the electricity produced in 2012 came from coal.[6]

By optimizing combustion, for instance with new or upgraded boiler control systems, energy losses can be reduced; energy savings of 10-30 percent are possible by optimizing plant operations and electrical balance-of-plant auxiliary systems with advanced controls and energy-efficient equipment.

When it comes to solar energy, a key challenge is to improve the amount of energy obtained from solar cells. Thanks to advances in solar inverter technology, **conversion efficiency is continuously improving for all solar applications** through utilization of new switching devices and innovative topologies. Designing higher power inverters (4 megawatts for central and 50 kilowatts to 80kW for string inverters) helps to achieve better efficiency targets and improved economic performance. Overall, new solar inverters harvest more energy due to improved inverter designs.

Utilization of higher DC voltages in solar-power system designs helps to achieve higher system efficiency by reducing losses on DC cabling. Solar PV (photovoltaic) modules are becoming more efficient, which is also a contributor to the higher overall system efficiency. Lastly, controlling real and reactive power by the inverters in conjunction with other power factor correcting devices helps improve delivery of real power on large utility systems for energy production.

In wind power generation, drivetrain, overall design and voltage optimization of wind farms, use of high-voltage direct current (HVDC) and advanced control systems contribute to improving efficiency.

Bringing electrical power from the plant to the end user is typically done in two steps: long distance transmission, and more localized distribution.

In a network of interconnected transmission lines that can be hundreds or even thousands of kilometers long, about 9 percent of the electricity transmitted is lost in the process.[7]
If these systems operated with the best available technology, **about 800 TWh of electricity could be saved, the equivalent of the annual power consumption of 242 million Chinese or 60 million American consumers.[8]**

Sophisticated transmission technology such as FACTS (Flexible Alternating Current Transmission Systems) and high-efficiency power transformers can significantly reduce these power losses. In Bangladesh, a FACTS solution developed by ABB provides reactive power compensation in eight substations, and cuts electrical losses by 34 MW. This sophisticated technology has no greenhouse gas (GHG) emissions or operating costs, and paid for itself in less than 18 months.

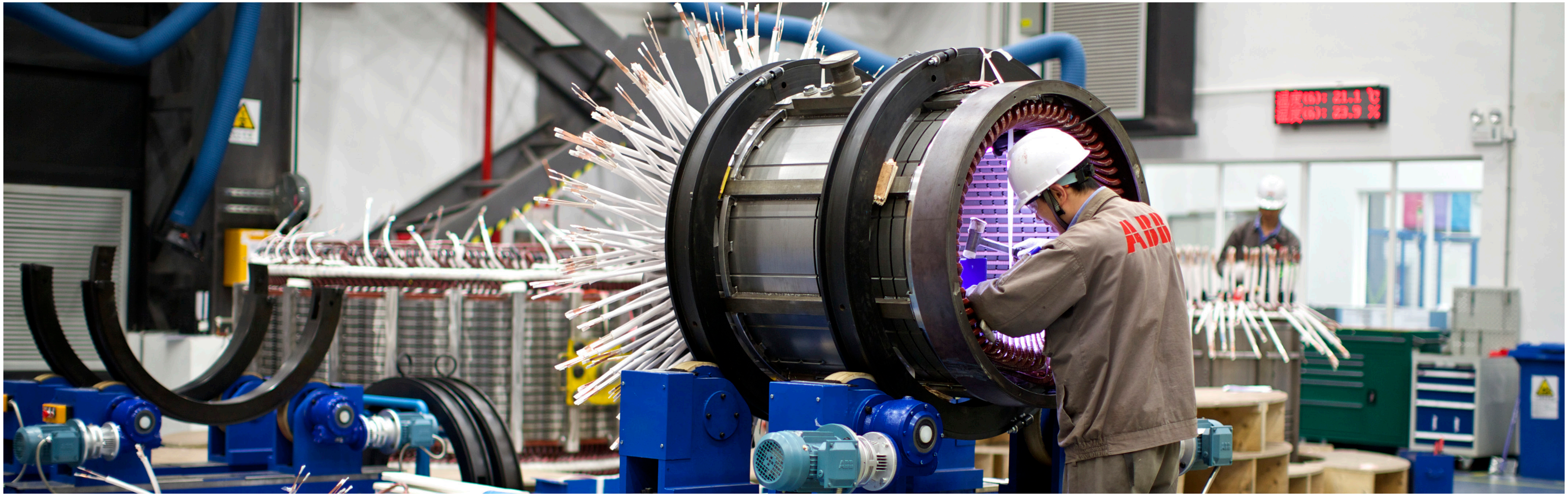
Long-distance HVDC transmission systems have lower power losses than conventional transmission lines, and minimal environmental impact. A key feature of this technology is its ability to interconnect different power systems, a basic requirement for renewable energy production. This technology was pioneered by ABB more than 60 years ago, and there are now around 100 HVDC systems in operation around the world. Notable recent projects are HVDC links between the grids of Norway and the United Kingdom and between Norway and Germany. Both will enable power trading and more renewable power to be transferred between grids.

ABB's latest high-voltage technology, **ultrahigh-voltage direct current (UHVDC), reduces transmission losses by around 30 percent compared with conventional power lines when used over distances of more than 1,500 kilometers.** This technology is ideal for transporting bulk power from distant renewable energy sources to consumption centers where the power is needed. ABB is currently installing three UHVDC transmission projects in China and India.

The expanding range of HVDC systems is supported by technological leaps in power cable capacity, enabling greater amounts of power to be transmitted over longer distances, with low losses. For example, an extruded HVDC cable system launched by ABB in 2014 set a world record for voltage capacity (525 kV) with losses under 5 percent. It can be deployed underwater or underground, and its expanded power and distance capacity and low-loss operation makes it an ideal solution for countries and utilities that want to integrate more renewable power into their electrical grids from distant solar and wind generation sites.

When it comes to power distribution, substantial savings could be made by upgrading the world's existing base of low-rating power transformers. Most of these transformers were efficient at the time of installation, but **newer high-efficiency transformers and dry-type transformers developed for specific applications can reduce unit losses by up to 80 percent.** The savings potential of highly efficient transformers is 1,508 TWh by 2030.

Advances in transformer technology are also helping to drive the regulatory environment, which is increasingly setting minimum efficiency standards and regulations for transformers. In Europe alone, more than one million transformers will be installed over the next decade.



Industry accounts for more than 40 percent of global electricity use,[9] and technologies that improve productivity, safeguard quality and save energy are available in almost every industry. These products and systems include controls, enterprise software, instrumentation, low- and medium-voltage products, drives, motors and robots.

Around 70 percent of energy consumed by industry is used to power electric motors, of which tens of millions are in operation worldwide, running machines, fans, pumps, compressors, conveyor belts, etc. **These motors account for about 28 percent of global electricity consumption,**[10] and every year millions more are added to the world's factories, offices and other workspaces.

By switching to electric motors with variable-speed drives, which adjust the speed of motors to match the actual demand of an application, energy consumption of such motors is typically reduced by 20-50 percent. If drives were mandatory for all pump and fan applications total global energy savings would be 3'338 TWh, equivalent to the entire electrical energy production of all 28 European Union (EU) countries in 2013.[11]

If all fans and pumps were equipped with energy-efficient drives, the savings would equal the entire power generation capacity of the EU.

As the world's largest manufacturer of electric **motors and drives, ABB's installed base of motors and drives saved an estimated 850 TWh in 2013 and 2014, equivalent to the power consumed annually by all households in the EU.** If that power had been generated by fossil fuels, an extra 700 million tons of CO_2 would have been emitted, equivalent to the yearly emissions of about 200 million cars.

The energy savings potential of efficient motors and drives is enormous: **more than 90 percent of industrial motors either cannot adjust their power consumption, or use only very crude methods to do so.** Many simply run at full speed all the time, regardless of the actual output requirement. In many applications, energy use can be reduced by almost 90 percent simply by adjusting motor speed to 50 percent.

Many end users seek higher motor efficiency than the minimum level set by the Minimum Energy Performance Standards (MEPS), in order to maximize the efficiency of their machines. ABB meets their demands by offering a range of super-efficient IE4 motors, and is paving the way for IE5-rated motors and higher. Recent motor technology advances, including new motor concepts connected to the internet and new topologies, provide the means for further improving energy efficiency. And because drives and motors are used in all manner of equipment and machinery, they offer opportunities for energy efficiency not only in industry but in buildings and transportation as well.

Key products for energy efficiency pay for themselves in 1-2 years.

Automated systems for smart factories and utilities that improve productivity, and provide more environmentally friendly processes, provide yet more possibilities for increasing energy efficiency.

A new era of industrial innovation is **combining the digital world of the internet and the machine world of production**. This is causing a **profound transformation of global industry,** as advances in mobile technology and cloud services create new opportunities for industrial internet solutions that interconnect things, services and people.

The next big step in this transformation will be the availability of measurement data from outside a facility, either through cloud services or standardized secure interfaces and remote access. By combining factory-level measurement data with the availability and price data of raw materials and energy, decision-making can be much more precise, increasing value-chain efficiency and leading to new, service-based offerings, such as pre-emptive maintenance.

Efficient consumption of energy
Commercial and residential buildings

Commercial and residential buildings account for about 40 percent of primary energy consumption in most IEA countries, including the EU member states and the US. This energy is used mainly for heating, cooling and powering electric appliances.[12] The fastest growing commercial buildings are data centers which use at least 30 times more power per square meter than other building types – 3 percent of total energy consumption.

In this area, significant energy efficiency gains can be realized with intelligent building solutions that precisely manage temperature, lighting and electrical appliances. A study by the German Electrical Industry Association (ZVEI) found that **energy consumption and costs** for lighting in buildings of all kinds **can be reduced by up to 80 percent by using intelligent building systems.**

These systems typically enable customers to reduce their combined energy consumption by around 50 percent, with a payback period of 1-5 years. For example, a new low-voltage circuit breaker from ABB, Emax2, acts as an intelligent power manager, protecting electrical circuits and managing energy consumption based on need. The global savings potential of this energy manager alone is estimated to be 5.8 TWh, equivalent to the electricity consumption of 1.4 million EU-28 households per year.

Energy management systems for buildings integrate lighting, heating, ventilation, air conditioning, window shading, security and comfort controls with energy measurement processes, improving energy efficiency by up to 30 percent. For example, ABB drives that were installed to control the indoor climate system of the State Library of Victoria, Australia, led to energy savings of 30-60 percent, depending on the application, in the two-hectare, 150-year-old building. The building's total annual energy usage was cut by 1,800 MWh, saving about US$160,000. The investment paid for itself within 13 months.

With 2.5 quintillion (30 zeroes) of bytes of data used every day and growing, reliable and efficient energy supply and management has never been more important in the data center market. **ABB provides control systems and expertise to help data center developers save energy.**

Intelligent building systems typically cut energy consumption by half.

Efficient consumption of energy
More efficient transportation of people and goods

When it comes to the transportation of people and goods, all types of engines can be made more energy efficient. Moreover, vehicles powered by electrical motors offer substantial energy efficiency gains over vehicles with combustion engines because they do not experience significant heat losses.

ABB's high-performance diesel engine **turbochargers,** applied to ships, power stations, locomotives and off-road mining vehicles, **help to increase engine power output by as much as 300 percent, delivering fuel economy and reducing NOx emissions.**

Marine applications, in particular, offer substantial energy efficiency opportunities because 90 percent of the world's traded goods are transported by sea. High-efficiency **Azipod propulsion systems which combine diesel reduce fuel consumption on large open-water vessels by up to 25 percent.** In addition, software-based solutions that take account of sea and weather conditions as well as loading times enable ships to take the most energy efficient routes and can reduce fuel consumption by a further 10 percent.

ABB also provides technology for both rail infrastructure and rolling stock, including efficient power transfers from grid to railway, transformers, frequency converters, switchgear, and FACTS devices as well as energy efficient traction drives and motors. ABB also offers technologies to recover braking energy and to capture and store energy which can then be used during a train's acceleration phase.

Electric vehicles (EV) of the latest generation have a significantly higher energy efficiency than cars with combustion engines. With increased electrical power generation from renewable sources, electric vehicles can be driven virtually emission free. One reason EV adoption has been slower than originally expected is the lack of a suitable charging infrastructure on roads and motorways. ABB is a leading provider of Internet-based EV charging infrastructure, supporting all EV charging standards and **delivering specific charging solutions and connected services for any location,** a technology that has been successfully deployed already in Europe, North America, Africa and Asia.
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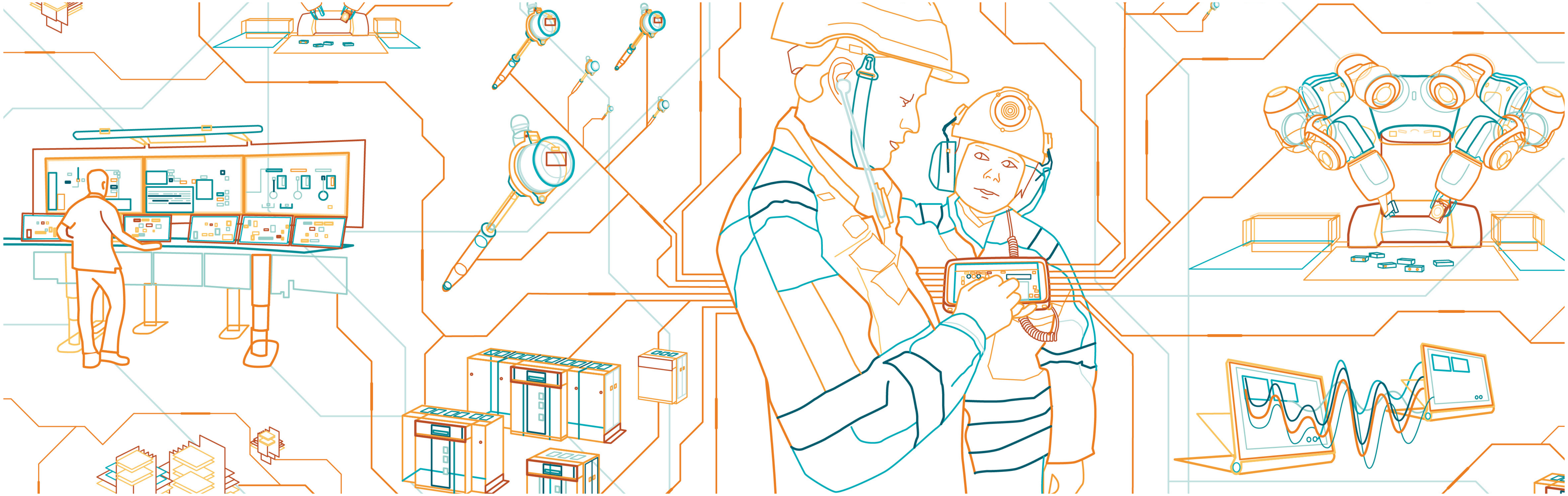
Paving the way to manage future challenges
Technology shifts provide further energy savings



Big technology shifts in power and automation will further support the mitigation of climate change. **A central element will be the use of ICT-based solutions (information and communication technology) to drive substantial additional efficiency gains and to allow the large scale use of renewable power.**

The rise of renewables is adding new challenges to our power sector, as centralized power generation and delivery models gradually turn into distributed models, characterized by multi-directional power flows and interconnections, and the ever-present need to ensure the delivery of quality power.

Among the key challenges of the evolving power grid is the need to integrate and balance intermittent power sources like wind and solar energy, and to maximize efficiency of power conversion to obtain as much electricity as possible from the energy captured.

For remote locations that are not connected to the main grid, such as rural communities and islands, microgrids are an ideal solution. Powered by a few wind turbines or a small-scale solar farm, they are quick to build and can therefore be used to power communities which would otherwise have had to wait years or even decades for a grid connection. At the moment, such grids usually have to rely on diesel generators to provide power when the wind stops blowing or the sun goes down. But advances in battery storage technology are limiting the use of such generators and the expectation is that such technology will evolve to the point where enough energy can be stored so that grids can be run entirely on renewables.

ABB is also at the forefront of the ever-tighter integration of sophisticated information technology and hard-wired infrastructure, the so-called "smart grid". **Smart grids offer further potential for efficient use of electrical energy by interlocking the requirements of energy producers and consumers, while coping with fluctuating renewable energy sources.**

As mentioned above, we are entering a new industrial age where the internet meets production, and this has the potential to profoundly transform global industry in ways that support efficiency improvements.

An impressive example and a powerful demonstration of how the Internet of Things, Services and People is changing industry is ABB´s power and automation solutions for grinding mills and mine hoists, including hundreds of motors and energy-saving drives, at Boliden ABB's **Garpenberg** mine in Sweden. These technologies have transformed the mine into the **most efficient and productive** zinc, lead and silver **mine in the world.**

The "Industrie 4.0" initiative in Germany is one of several projects set up to bring this fourth industrial revolution into being. ABB is collaborating with the Industrie 4.0 initiative group, the Industrial Internet Consortium and other working groups of related industrial associations to make this new and highly anticipated chapter of industrial history happen.

Concerted actions of all stakeholders make the difference

Improving energy efficiency is the most effective way to mitigate climate change while building a more sustainable energy future.

From the point of view of climate goals, **the most compelling aspect of energy efficiency technology is that it already exists and can therefore be applied immediately.** Technology leaders like ABB have a wide array of products, systems and services that can significantly boost energy efficiency in virtually any application. But the **speed of implementation needs to be enhanced dramatically.** Reaching long-term goals for climate change mitigation requires immediate action.

That is why energy efficiency has become a central feature of energy policy in a number of countries in recent years. Measures already implemented have reduced energy demand and curbed greenhouse gas emissions. In fact, energy efficiency regulation is crucial to boost implementation which in turn offers economic benefits.

Political leaders have already taken important steps to support the more efficient handling of energy resources, mandating for example, Minimum Energy Performance Standards (MEPS) for motors. National policy goals in Canada, Mexico and the US target the premium motor efficiency standard IE3, and now that the EU, Japan and China have started to introduce this standard, more than 50 million units are expected to be installed worldwide in the next three years.[13]

In the EU, variable-speed drives will be more strictly regulated from 2017 onwards. Given that electric motors consume more energy than any other group of products, **stricter regulation could reduce the energy consumption of motors and drives by 30 percent globally.**

A new study commissioned by the European Commission estimates that the global saving potential of industrial motors by 2030 is calculated at 13,286 TWh. In the US, the National Electrical Manufacturers Association estimated that the NEMA Premium efficiency motor program would save 5,800 GW of electricity from 2010 to 2020; this translates to preventing nearly 80 million metric tons of CO_2 into the atmosphere, equivalent to keeping 16 million cars off the road.

However, the **speed of implementation needs to be enhanced dramatically**, and regulation will need to go beyond current standards, if long-term goals for climate change mitigation are to be met. The biggest gains would come from mandating the adoption of variable-speed drives for the world's installed base of electric motors. With tens of millions of these motors in service, and millions more being added every year, this would reduce energy consumption of such motors by 20-50 percent. And because such technologies typically pay for themselves within a few years through lower energy costs, financing models should be practicable.

Regulation works – minimum energy performance standards have delivered massive energy savings in the US, the EU and China.

A spectrum of measures, taking account of customer needs and market demands, is needed to limit CO_2 emissions and drive the shift towards a low-carbon future. These include a solid regulatory framework to give investors more security; higher standards for energy efficient products; and public promotion to solidify the need for change.

Leadership actions to initiate the change could include:

- implementation of the best available energy efficient technology through appropriate laws and standards;
- organizations consistently applying life cycle cost assessments in their own procurement activities;
- targeted tax incentives to encourage energy-efficient investments;
- risk-sharing programs or loan guarantees to encourage financial investments in energy efficiency.

Regulation to drive the rapid deployment of proven energy-efficient technologies is needed to fight climate change.

Notes

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2 IEA, World Energy Outlook 2014 Factsheet, Power and renewables

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5 Savings and benefits of global regulations of energy efficient products, European Union, September 2015

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7 Enerdata, The state of global energy efficiency, Global and sectorial energy efficiency trends

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10 IEA, Energy Efficiency Policy Opportunities for Electric Motor Driven Systems, 2011

11 Eurostat, Electricity production, consumption and market overview

12 www.iea.org/aboutus/faqs/energyefficiency/

13 IHS 2014: The world market for low voltage motors