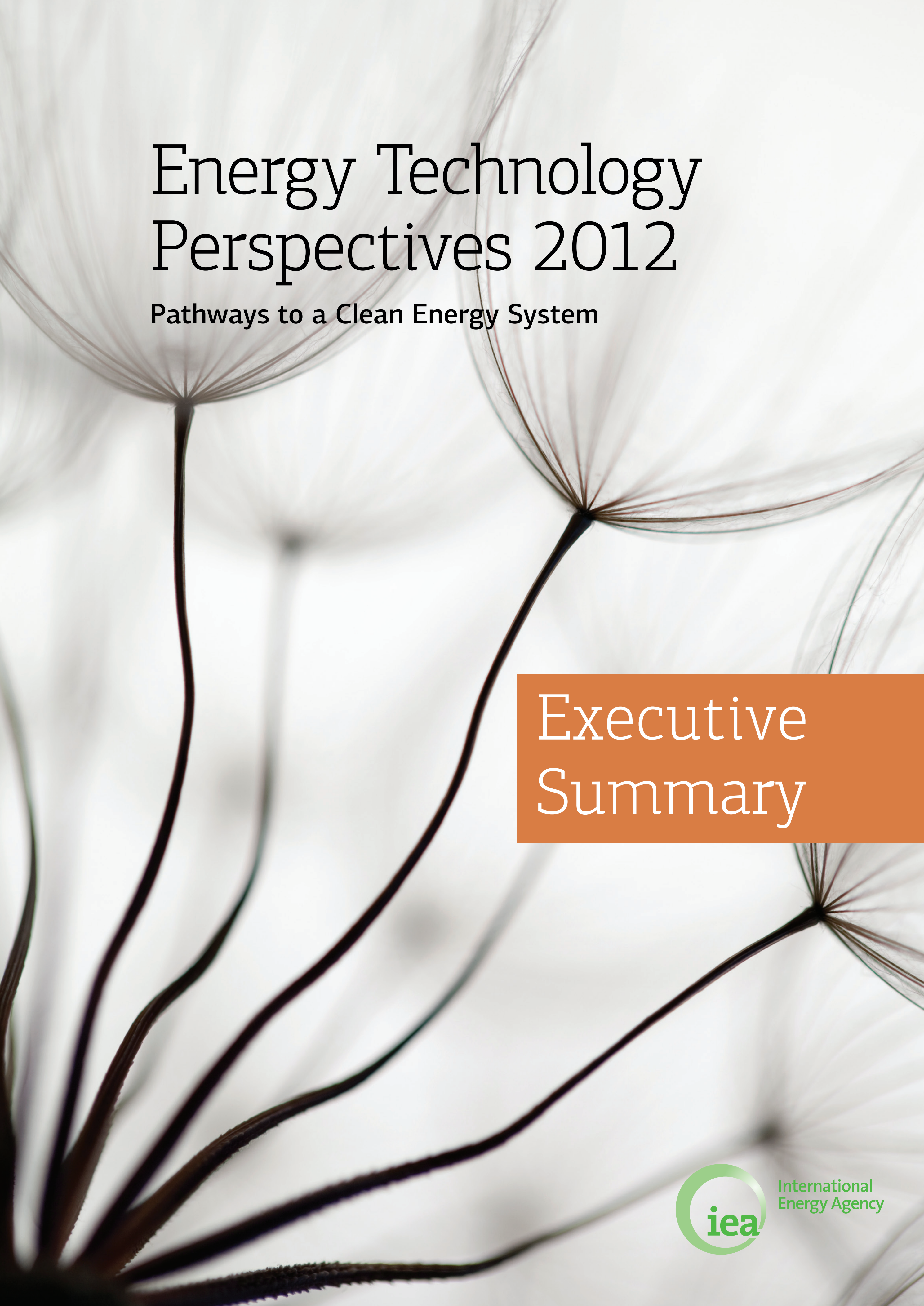
Energy Technology Perspectives 2012

Pathways to a Clean Energy System



Executive Summary

International Energy Agency

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A sustainable energy system is still within reach and can bring broad benefits

Technologies can and must play an integral role in transforming the energy system. The 2012 edition of *Energy Technology Perspectives* (*ETP 2012*) shows clearly that a technological transformation of the energy system is still possible, despite current trends. The integrated use of key existing technologies would make it possible to reduce dependency on imported fossil fuels or on limited domestic resources, decarbonise electricity, enhance energy efficiency and reduce emissions in the industry, transport and buildings sectors. This would dampen surging energy demand, reduce imports, strengthen domestic economies, and over time dramatically reduce greenhouse-gas (GHG) emissions. The *ETP 2012* 2°C Scenario (2DS) explores the technology options needed to realise a sustainable future based on greater energy efficiency and a more balanced energy system, featuring renewable energy sources and lower emissions. Its emissions trajectory is consistent with the IEA *World Energy Outlook's* 450 scenario through 2035. The 2DS identifies the technology options and policy pathways that ensure an 80% chance of limiting long-term global temperature increase to 2°C - provided that non-energy related CO_2 emissions, as well as other greenhouse gases, are also reduced.

Investing in clean energy makes economic sense – every additional dollar invested can generate three dollars in future fuel savings by 2050. Investments in clean energy need to double by 2020 (Chapter 4). Achieving the 2DS would require USD 36 trillion (35%) more in investments from today to 2050 than under a scenario in which controlling carbon emissions is not a priority. That is the equivalent of an extra USD 130 per person every year. However, investing is not the same as spending: by 2025, the fuel savings realised would outweigh the investments; by 2050, the fuel savings amount to more than USD 100 trillion. Even if these potential future savings are discounted at 10%, there would be a USD 5 trillion net saving between now and 2050. If cautious assumptions of how lower demand for fossil fuels can impact prices are applied, the projected fuel savings jump to USD 150 trillion.

Energy security and climate change mitigation are allies. The 2DS demonstrates how energy efficiency and accelerated deployment of low-carbon technologies can help cut government expenditure, reduce energy import dependency and lower emissions (Chapter 1). Renewable energy resources and significant potentials for energy efficiency exist virtually everywhere, in contrast to other energy sources, which are concentrated in a limited number of countries. Reduced energy intensity, as well as geographical and technological diversification of energy sources, would result in far-reaching energy security and economic benefits. In the 2DS, as a result of energy savings and the use of alternative energy sources, countries would save a total of 450 exajoules (EJ) in fossil fuel purchases by 2020. This equates to the last six years of total fossil fuel imports among OECD countries. By 2050, the cumulative fossil fuel savings in the 2DS are almost 9 000 EJ – the equivalent of more than 15 years of current world energy primary demand.

Despite technology's potential, progress in clean energy is too slow

Nine out of ten technologies that hold potential for energy and CO_2 emissions savings are failing to meet the deployment objectives needed to achieve the necessary transition to a low-carbon future. Some of the technologies with the largest potential are showing the least progress. The *ETP* analysis of current progress in clean energy (Chapter 2) produces a bleak picture. Only a portfolio of more mature renewable energy technologies – including hydro, biomass, onshore wind and solar photovoltaic (PV) – are making sufficient progress. Other key technologies for energy and CO_2 emission savings are lagging behind. Particularly worrisome is the slow uptake of energy efficiency technologies, the lack of progress in carbon capture and storage (CCS) and, to a lesser extent, of offshore wind and concentrated solar power (CSP). The scale-up of projects using these technologies over the next decade is critical. CCS could account for up to 20% of cumulative CO_2 reductions in the 2DS by 2050. This requires rapid deployment of CCS and is a significant challenge since there are no large-scale CCS demonstrations in electricity generation and few in industry. Committed government funds are inadequate and are not being allocated to projects at the rates required. In transport, government targets for electric vehicles are set at 20 million vehicles on the roads in 2020. These targets are encouraging, but are more than twice the current industry planned capacity so may be challenging to achieve, in particular given the relative short-term nature of current government support schemes.

The share of energy-related investment in public research, development and demonstration (RD&D) has fallen by two-thirds since the 1980s. Government support for technology RD&D is critical and offers opportunities to stimulate economic growth and reduce costs for low-carbon technologies. Promising renewable energy technologies (such as offshore wind and CSP) and capital-intensive technologies (such as CCS and integrated gasification combined cycle [IGCC]), have significant potential but still face technology and cost challenges, particularly in the demonstration phase. Renewable energy technology patents increased fourfold from 1999 to 2008, led by solar PV and wind (Chapter 3). While these two technologies have successfully taken off, patent development has failed to translate into sufficient commercial applications of other technologies (such as enhanced geothermal and marine energy production). Against this background, it is worrying that the share of energy-related public RD&D has fallen to under 4% in 2010, down from a global average of 12% and an IEA member country average of more than 20% in 1980. This trend of declining public support to RD&D needs to be reversed. Moreover, RD&D policies need to be better aligned with measures to support market deployment. Expectations of new markets are a key factor in triggering additional private investment in RD&D and technological innovation.

Fossil fuels remain dominant and demand continues to grow, locking in high-carbon infrastructure. The *World Energy Outlook 2011* showed how the window of opportunity is closing rapidly on achieving the 2DS target. *ETP 2012* reinforces this message: the investments made today will determine the energy system that is in place in 2050; therefore, the lack of progress in clean energy is alarming.

Energy policy must address the entire energy system

Energy technologies interact and must be developed and deployed together. A low-carbon energy system will feature more diverse energy sources. This will provide a better balance than today's system, but it also means that the new system must be more integrated and complex, and will rely more heavily on distributed generation. This would entail increased efficiency, decreased system costs and a broader range of technologies and fuels. Success, however, will critically depend on the overall functioning of the energy system, not just on individual technologies. The most important challenge for policy makers over the next decade will likely be the shift away from a supply-driven perspective, to one that recognises the need for systems integration. Roles in the energy markets will change. Current consumers of energy will act as energy generators through distributed generation from solar PV or waste heat recovery. Consumers will also contribute to a smoother operation of the electricity system through demand response and energy storage. Enabling and encouraging technologies and behaviour that optimise the entire energy system, rather than only individual parts of it, can unlock tremendous economic benefits.

Investment in stronger and smarter infrastructure is needed. An efficient and low-carbon energy system will require investments in infrastructure beyond power generation facilities. Already, there are bottlenecks in electricity transmission capacity in important markets (such as Germany and China) that threaten to limit the future expansion of low-carbon technologies. Systems also need to be operated more intelligently. Better operation of existing heating technologies could save up to 25% of peak electricity demand from heating in 2050, reducing the need for expensive peak generating capacity (Chapter 5). Stronger and smarter electricity grids can enable more efficient operation of the electricity system through a greater degree of demand response (Chapter 6). In fact, demand response can technically provide all of the regulation and load-following flexibility needed to 2050, depending on the region. Investments in smart grids can also be very cost effective: *ETP* analysis shows that their deployment could generate up to USD 4 trillion in savings to 2050 in Europe alone, reflecting a 4:1 return on investment. A majority of these savings come from a reduction in investment needed for new generation capacity.

Low-carbon electricity is at the core of a sustainable energy system. Low-carbon electricity has system-wide benefits that go beyond the electricity sector: it can also enable deep reductions of CO_2 emissions in the industry, transport and buildings sectors. *ETP* analysis shows how emissions per kilowatt-hour can be reduced by 80% by 2050, through deployment of low-carbon technologies. Renewable energy technologies play a crucial role in this respect. In the 2DS, their share of total average world electricity generation increases from 19% currently to 57% by 2050, a sixfold increase in absolute terms. In fact, low-carbon electricity generation is already competitive in many markets and will take an increasing share of generation in coming years. Integrating a much higher share of variable generation, such as wind power and solar PV, is possible. In 2050, variable generation accounts for 20% to 60% of total electricity capacity in the 2DS, depending on the region.

Energy efficiency must achieve its potential. It is difficult to overstate the importance of energy efficiency, which is nearly always cost effective in the long run, helps cut emissions and enhances energy security. Energy efficiency must help reduce the energy intensity (measured as energy input per unit of gross domestic product [GDP]) of the global economy by two-thirds by 2050; annual improvements in energy intensity must double, from 1.2% over the last 40 years to 2.4 % in the coming four decades. Yet, a lack of incentives and a number of non-economic barriers continue to block broader uptake. Application of more stringent performance standards and codes will be necessary, particularly in the buildings and transport sectors. In this regard, information and energy management are proven and effective ways to encourage energy efficiency measures in industry. Economic incentives will be essential to unlock the energy efficiency potential and scale up private finance, but non-economic barriers must also be overcome.

Energy use becomes more balanced; fossil fuels will not disappear, but their roles will change

Reducing coal use and improving the efficiency of coal-fired generation are important first steps. To halve CO_2 emissions by 2050, coal demand in the 2DS would need to fall by 45% compared to 2009 (Chapter 8), and even further by 2075 (Chapter 16). Against that background, the current increase in the use of coal for electricity generation is the single most problematic trend in the relationship between energy and climate change. Nonetheless, given the dependency on coal in many regions, coal-fired power generation will remain substantial; increasing the efficiency of existing and new plants will be essential over the next 10 to 15 years. The potential for improvement is significant. Operations with higher steam temperatures will be capable of reducing CO_2 emissions from power generation plants to around 670 grams per kilowatt-hour, a 30% improvement over current global averages.

Natural gas and oil will remain important to the global energy system for decades. As emissions targets tighten, the share of natural gas will initially increase, particularly for base-load power plants, displacing both coal (in many regions) and some growth in nuclear (in fewer areas). Post-2030, as CO_2 reductions deepen in the 2DS, gas-powered generation increasingly takes the role of providing the flexibility to complement variable renewable energies and serves as peak-load power to balance generation and demand fluctuations (Chapter 9). Natural gas will remain an important fuel in all sectors in 2050, and demand is still 10% higher in absolute terms in 2050 compared to 2009. The specific emissions from a gas-fired power plant will be higher than average global CO_2 intensity in electricity generation by 2025, raising questions around the long-term viability of some gas infrastructure investment if climate change objectives are to be met. If near-term infrastructure development does not sufficiently consider technical flexibility, future adaptation to lower-carbon fuels and technologies will be more difficult to achieve. *ETP 2012* does not have a chapter dedicated to oil, as oil extraction has not seen the same technological revolution as natural gas. Even though global oil use falls by more than 50% by 2050 in the 2DS, oil will remain an important energy carrier in transport and as a feedstock in industry.

Carbon capture and storage remains critical in the long term. CCS is the only technology on the horizon today that would allow industrial sectors (such as iron and steel, cement and natural gas processing) to meet deep emissions reduction goals. Abandoning CCS as a mitigation option would significantly increase the cost of achieving the 2DS (Chapter 10). The additional investment needs in electricity that are required to meet the 2DS would increase by a further 40% if CCS is not available, with a total extra cost of USD 2 trillion over 40 years. Without CCS, the pressure on other emissions reduction options would also be higher. Some CO_2 capture technologies are commercially available today and the majority can be applied across different sectors, although storage issues remain to be resolved. While most remain capital-intensive and costly, they can be competitive with other low-carbon options. Challenges lie in integrating these technologies into large-scale projects.

Governments must play a decisive role in encouraging the shift to efficient and low-carbon technologies

Strong government policy action can help key technologies become truly competitive and widely used. The main barrier to achieving a low-carbon future is the unequal distribution – in time, across sectors and among countries – of the costs and benefits associated with transforming the global energy system. Governments need to take strong and collaborative action to balance, for all, the costs and benefits of achieving a low-carbon future. They should encourage national clean energy technology goals and escalate the ambition of international collaboration. Governments must seize the opportunity provided by the potential of technology and create the right framework to encourage its development and deployment, taking into account the driving interests of all involved (industry, finance, consumers, etc.). Broader perspectives will ensure that the combined benefits of technologies are maximised.

But governments alone cannot achieve the transition – clear incentives are needed for consumers, companies and investors. Governments need to set stringent and credible clean energy targets. Policies underpinning the targets must be transparent and predictable in order to adequately address and alleviate the financial risks associated with new technologies. Strong policies and markets that encourage flexibility and mitigate risks for investors in these technologies are vital. Ensuring that the true price of energy – including costs and benefits – is reflected in what consumers pay must be a top priority for achieving a low-carbon future at the lowest possible cost. Putting a meaningful price on carbon would send a vital price signal to consumers and technology developers. Phasing out fossil fuel subsidies – which in 2011 were almost seven times higher than the support for renewable energy – is critical to level the playing field across all fuels and technologies. Temporary transitional economic incentives can help to create markets, attract investments and trigger deployment. They will be even more effective if combined with other measures to overcome non-economic barriers, such as access to networks, permitting, and social acceptance issues. Finally, promoting social acceptance of new infrastructure development should be a priority.

Real-world examples demonstrate that decisive policy action is a catalyst for progress. The success of some renewable energy technologies provides evidence that new, emerging technologies can break into and successfully compete in the market place. Solar PV has averaged 42% annual growth globally over the last decade; onshore wind has averaged 27%. As a result of strategic and sustained policy support of early stage research, development, demonstration and market deployment, these technologies have reached a stage where the private sector can play a bigger role, allowing subsidies to be scaled back. In Chapters 2 and 11, *ETP 2012* highlights the dramatic cost reductions that are possible. For example, system costs for solar PV have fallen by 75% in only three years in some countries. Policy makers must learn from these examples, as well as from the failures in other technologies, as they debate future energy policies.

Governments need to act early to stimulate development of new, breakthrough technologies. Strategic and substantial support for RD&D will be essential. The technologies set in place by 2050 in the 2DS may be insufficient to deliver the CO_2 cuts required to reach zero emissions further into the future**.** *ETP 2012* provides the first quantitative analysis by the IEA of how emissions from energy-related activities could be eliminated completely by 2075, consistent with climate science estimates of what will be necessary to achieve the 2DS target (Chapter 16). The analysis reveals certain considerations for policy makers today. Breakthrough technologies are likely to be needed to help further cut energy demand, and expand the long-term opportunities for electricity and hydrogen, in part to help limit excessive reliance on biomass to reach zero emissions. RD&D efforts that aim to develop such options must start (or be intensified) long before 2050.

Recommendations to energy ministers

Each chapter of ETP 2012 *provides policy recommendations specific to individual sectors or challenge areas. Four high-level recommendations required to set the stage for a low-carbon future were identified across all areas:*

- ***Create an investment climate that builds confidence in the long-term potential of clean energy technologies.*** *Industry is key to the transition. Common goals supported by stringent and predictable policies are essential to establish the necessary credibility within the investment community.*
- ***Level the playing field for clean energy technologies.*** *Governments should commit to, and report on, progress on national actions that aim to appropriately reflect the true cost of energy production and consumption. Pricing carbon emissions and phasing out of inefficient fossil fuel subsidies, while ensuring access to affordable energy for all citizens, are central goals.*
- ***Scale up efforts to unlock the potential of energy efficiency.*** *The IEA has developed 25 energy efficiency recommendations to help governments achieve the full potential of energy efficiency improvements across all energy-consuming sectors. Committing to application of these recommendations would form a good basis for action and accelerate results.*
- ***Accelerate energy innovation and public research, development and demonstration.*** *Governments should develop and implement strategic energy research plans, backed by enhanced and sustained financial support. Additionally, governments should consider joint RD&D efforts to co-ordinate action, avoid duplication, and improve the performance and reduce the costs of technologies at the early innovation phase, including sharing lessons learned on innovative RD&D models.*

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