

Energy Technology Perspectives 2017

Catalysing Energy Technology Transformations

Executive
Summary



International
Energy Agency
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INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 29 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

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

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The energy system is evolving, but policy signals are needed to accelerate and steer its transformation

A number of trends indicate that the global energy system is changing. The energy mix is being redefined; in the power sector, renewables and nuclear capacity additions supply the majority of demand growth. On the demand side, innovative transportation technologies are gaining momentum and are projected to increase electricity demand. Rising living standards mean more people will buy appliances, electronic devices and other goods powered by electricity, also driving up electrical needs.

Energy technology innovation can bring more benefits and facilitate transformation, but strong policy signals are needed. *Energy Technology Perspectives 2017 (ETP 2017)* highlights how energy innovation, i.e. scaled-up deployment of available technologies and further development of technologies in the innovation pipeline, can support multiple policy objectives while ensuring secure, reliable and affordable energy.

The annual *Tracking Clean Energy Progress (TCEP)* report, included in *ETP 2017*, examines how various technologies are moving in comparison with global climate targets. The results show that transformation towards a clean energy system is not in line with stated international policy goals. Many technology areas suffer from a lack of policy support, and this impedes their scaled-up deployment. Energy efficiency, bioenergy and carbon capture and storage (CCS) are notable examples of where significant potential for technology progress remains, but strong policy signals will be required to trigger the appropriate investments.

Overall, only a few surveyed energy technologies are on track to achieve sustainability goals. *TCEP* demonstrates, however, that where policies have provided clear signals on the value of technology innovation, such as in solar photovoltaics (PV), onshore wind, electric vehicles (EVs), and energy storage, progress has been substantial.

An integrated approach is essential for a sustainable energy future

Energy technologies interact and thus must be developed and deployed together. Affordable, secure and sustainable energy systems will feature more diverse energy sources and rely more heavily on distributed generation. Therefore, they will need to be better integrated and managed from a systems perspective. This can increase efficiency and decrease system costs, and it will require a broader range of technologies and fuels. However, success depends not only on individual technologies but also on how the overall energy system functions. The most important challenge for energy policy makers will be to move away from a siloed, supply-driven perspective towards one that enables systems integration. Effective planning tools, supportive regulatory frameworks, and increased policy dialogue are essential.

Integrated and connected electricity systems are key to the transformation of the energy sector. Increasing electrification provides opportunities to enhance the flexibility, efficiency and environmental performance of electricity systems. Systems integration technologies, such as energy storage, are being driven by decreasing costs, increasingly favourable regulatory treatment, and an improved understanding of their value. In 2016, deployment of

new storage capacity, mostly battery technologies, grew by more than 50%. The widespread application of digital technologies can help accelerate this transformation.

Energy system integration and enhanced demand response will bring new opportunities for optimisation and increased efficiency in delivering services. Smart energy systems can enable demand–response measures. Technologies such as advanced metering infrastructure, smart appliances, or bidirectional smart meters allow demand management and provide incentives for consumers to play an active role in energy systems. These approaches can stimulate more efficient energy use and contribute to load management and system flexibility.

Long-term co-ordinated planning for stronger and smarter infrastructure investment is needed to ensure continued system efficiency and reliability. An efficient and low-carbon energy system will need sustained investment in multiple infrastructure areas. Already, there are bottlenecks in electricity transmission capacity in large markets (such as, for example, Germany and the People’s Republic of China) that threaten to limit the future expansion of electrification and variable renewables. The deployment of carbon dioxide (CO₂) transport and storage infrastructure is another example: for most individual applications, the quantities of CO₂ will mean that project-specific transport and storage infrastructure are unlikely to be economical. Effective co-ordination and planning, from the local to the regional level, could help alleviate these barriers.

Technology progress needs strong co-ordinated policy support. While economic competitiveness of new technologies is improving, policy drivers do not always have sufficient market impact to steer technology choices in an optimal direction. Energy security and sustainability benefits need adequate market signals and regulations to encourage investments directed at long-term impacts. Market forces alone will not deliver the needed impetus. Strong and consistent policies co-ordinated across various energy sectors should account for energy policy objectives throughout the many facets of government and business decision-making, including taxation, international trade, urban planning, and innovation.

Higher ambitions for a sustainable energy system are not being translated into action

Today’s critical challenge is to ensure the momentum of the energy sector transformation and speed its progress. The ratification of the Paris Agreement and calls to implement the United Nations Sustainable Development Goals show strong global support to address climate change and other environmental concerns. Rapid and clear signals aligned with long-term objectives will be needed to steer the energy sector towards sustainability.

The current trajectory falls short. *ETP 2017* presents three pathways for energy sector development to 2060. The Reference Technology Scenario (RTS) provides a baseline scenario that takes into account existing energy- and climate-related commitments by countries, including Nationally Determined Contributions pledged under the Paris Agreement. The RTS — reflecting the world’s current ambitions — is not consistent with achieving global climate mitigation objectives, but would still represent a significant shift from a historical “business as usual” approach.

More ambitious decarbonisation requires increased effort and sustained political commitment. The 2°C Scenario (2DS) and the Beyond 2°C Scenario (B2DS) each sets out a rapid decarbonisation pathway in line with international policy goals. The 2DS has been the main climate scenario in the *ETP* series for many years, and it has been widely used by policy makers and business stakeholders to assess their climate strategies. For the first time, the B2DS looks at how far known clean energy technologies could go if pushed to their practical limits, in line with countries’ more ambitious aspirations in the Paris Agreement.

Technologies currently in the innovation pipeline need strong policy support to meet global climate ambitions. In the B2DS, the energy sector reaches carbon neutrality by 2060 to limit future temperature increases to 1.75°C by 2100, the midpoint of the Paris Agreement’s

ambition range. This pathway implies that all available policy levers are activated throughout the outlook period in every sector worldwide. This would require unprecedented policy action as well as effort and engagement from all stakeholders.

Co-ordinated action and a mix of technologies are needed for cost-effective solutions

Actions across all sectors will be needed to leverage the most cost-effective solutions.

Technological opportunities abound in both the supply and demand sides of the energy system. A portfolio of technologies is needed to deliver secure and affordable energy services while also reducing emissions.

End-use electrification is expanding, but decarbonising power systems while increasing electricity in end-uses brings new challenges and opportunities.

Current trends would increase the share of electricity in final energy demand across all end-use sectors from 18% today to 26% in the RTS by 2060, the largest relative increase of all energy carriers. End-use electrification can also enable a shift from direct reliance on fossil fuels to decarbonised power. In the 2DS and the B2DS, electricity becomes the largest final energy carrier, slightly ahead of oil. The shift is particularly notable in transport, where electricity becomes the primary fuel for land-based transport in the B2DS.

Decarbonised power is a backbone of the clean energy transformation. The global power sector can reach net-zero CO₂ emissions by 2060 under the 2DS scenario. This would require a scaled up deployment of a portfolio of technologies, including 74% of generation from renewables (including 2% of sustainable bioenergy with CCS [BECCS]), 15% from nuclear, 7% from fossil fuelled power plants with CCS, and the remainder from natural gas-fired generation.

More efficient buildings support the whole energy system transformation. Rapid deployment of high-efficiency lighting, cooling, and appliances could save 50 EJ or the equivalent of nearly three-quarters of today's global electricity demand between now and 2030. Those savings would allow greater shifts to electricity without additional burden to the power sector.

Technology and policy can steer transport towards increased sustainability. Electrification emerges as the major low-carbon pathway for the transportation sector. This trend is already partly underway, with the electric car stock projected to increase 28 times by 2030 in the RTS from today's two million vehicles. The 2DS scales up this ambition to 160 million electric cars, while the B2DS would require 200 million electric cars on the road in the same time frame, leading to 90% of all cars on the road being electric by 2060. Fast tracking electro-mobility will require major technological developments and infrastructure investments based on strong policy support. Policies and technologies that reduce the need for individual transportation — such as better urban planning or increased use of collective transportation — can make deployment of new technologies more manageable and significantly reduce the required investment.

Energy-intensive industries are essential actors in any sustainable transformation strategy.

Energy demand in industry is the highest of the end-use sectors, and it is projected to increase by about two-thirds by 2060 in the RTS. Opportunities exist to improve manufacturing efficiency, maximise the use of locally available resources, and optimise materials use. Technologies that are not yet commercial play an important role in industrial process decarbonisation, contributing to an 18% reduction in cumulative direct CO₂ emissions in 2DS and 36% in the B2DS. This demonstrates the need to support innovation in economically strategic sectors such as iron and steel, cement and chemicals.

There is a considerable potential for energy savings in heating and cooling that remains largely untapped.

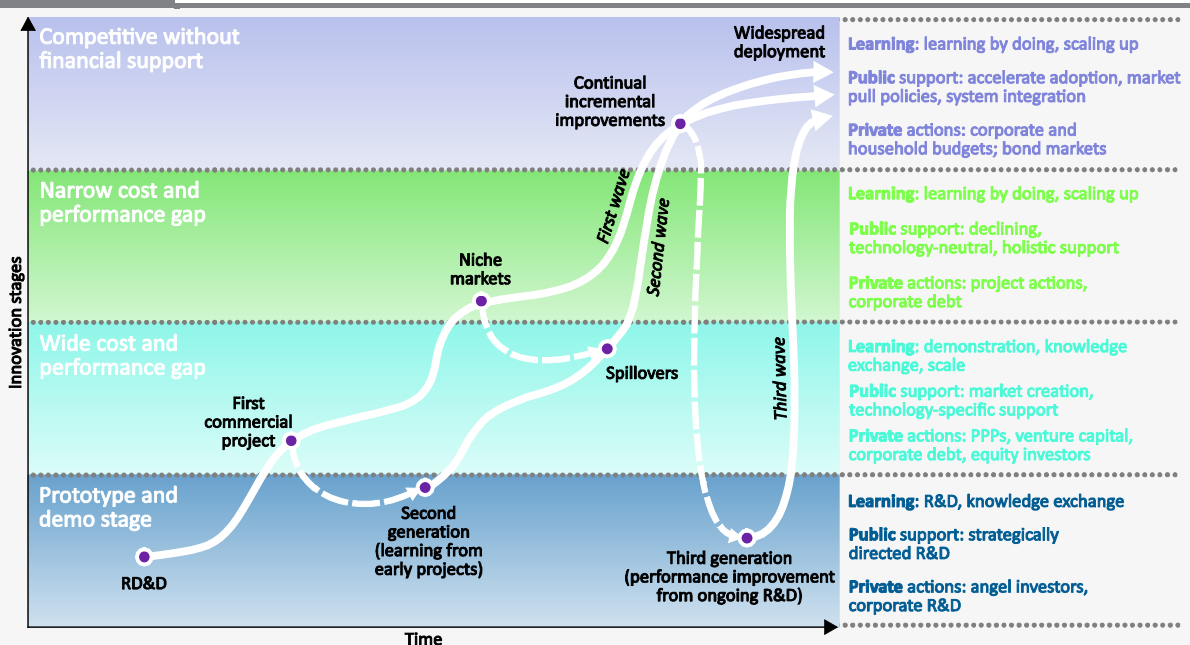
Today, heating and cooling in buildings and industry account for approximately 40% of final energy consumption — which is a larger share than transportation (27%). Additionally, nearly 65% of this demand relies on fossil fuel sources. Energy efficiency and switching to clean final energy carriers (including decarbonised

electricity and district heating) could cut fossil fuel consumption for heating and cooling in half by 2060 compared with today.

Negative emissions, notably in power generation and fuel transformation, become critical as low-carbon ambitions rise. In the B2DS, BECCS delivers almost 5 gigatonnes of “negative emissions” in 2060. These negative emissions are key to the energy sector becoming emissions-neutral by 2060. While BECCS technologies face substantial challenges, they compensate for residual emissions elsewhere in the energy system that are even more technically difficult or costly to abate directly. This will require massive technological learning and scale-up in both sustainable bioenergy and CCS, which have been lagging behind so far.

Innovation must be supported at all stages, from early research to full demonstration and deployment. Both incremental and radical innovations are needed to transition to a new energy system. Governments have an important role in ensuring predictable, long-term support in all stages of innovation – i.e. from basic and applied research through to development, demonstration and deployment phases. Allocation of resources to various technologies must consider both short- and long-term opportunities and challenges for innovation, as well as reflect the level of technology maturity (Figure 1.1).

Figure 1.1. Energy technology innovation process



Notes: PPP = public-private partnerships. RD&D = research, development and demonstration. R&D = research and development.

Key point *Energy technologies require support across all innovation stages.*

International co-operation between various levels of governments and with the private sector is essential. Multilateral collaboration can improve the cost-effectiveness of energy technology innovation and build confidence that progress is being achieved at a worldwide scale. Globalisation is sparking more open innovation frameworks that help pool resources to accelerate research and development (R&D), underwrite demonstration, and stimulate faster deployment of proven technologies. Increasing local innovation capacity is essential to the successful deployment of innovative technologies that can help meet local policy and environmental objectives and contribute to global sustainability goals. Existing initiatives, such as the IEA Technology Collaboration Programmes, the Clean Energy Ministerial and Mission Innovation should be properly anchored in all policy decision-making processes.

Key recommendations for policy makers

- **Governments should develop a vision for a sustainable energy future that addresses multiple energy policy challenges and tracks progress towards stated objectives.** Defining pathways and ensuring progress towards a long-term energy transformation that satisfies energy security, climate change and air quality objectives will be critical for the energy sector to respond optimally to multiple challenges and attain policy goals.
- **International collaboration needs to be enhanced to achieve global objectives.** Joint innovation programmes create market opportunities that benefit both manufactures and users of technologies while contributing to the most cost-effective transformation of global energy systems. Collaboration with local stakeholders to build capacity and share best practices can support local action adapted to local circumstances.
- **Policy support for technology should be accelerated at all stages of the innovation cycle.** Public support should be measurable and target all phases of innovation (including research, development, demonstration and deployment) to facilitate both incremental and radical innovation, as well as deployment measures for specific technologies. Initiatives such as the IEA Technology Collaboration Programmes, the Clean Energy Ministerial and Mission Innovation are key platforms to co-ordinate and accelerate global efforts.
- **Policy, finance and market mechanisms must be adapted to support new business models enabled by the changing technology landscape.** Market designs and regulations should leverage the opportunity brought by increased access to energy information to enable new energy transaction models. More efficient institutional dialogue and co-ordination should be established between national, regional and local governments as well as with other energy stakeholders to accelerate the energy sector transformation and to discover novel solutions.
- **Policy makers should develop a better understanding of opportunities and challenges that arise from increasing digitalization in the energy sector.** Digitalization and the energy sector are increasingly converging, bringing new prospects as well as risks. Better data and more rigorous analysis are needed to ensure that digitalization and the changing energy landscape work together in the most sensible and cost-effective manner.

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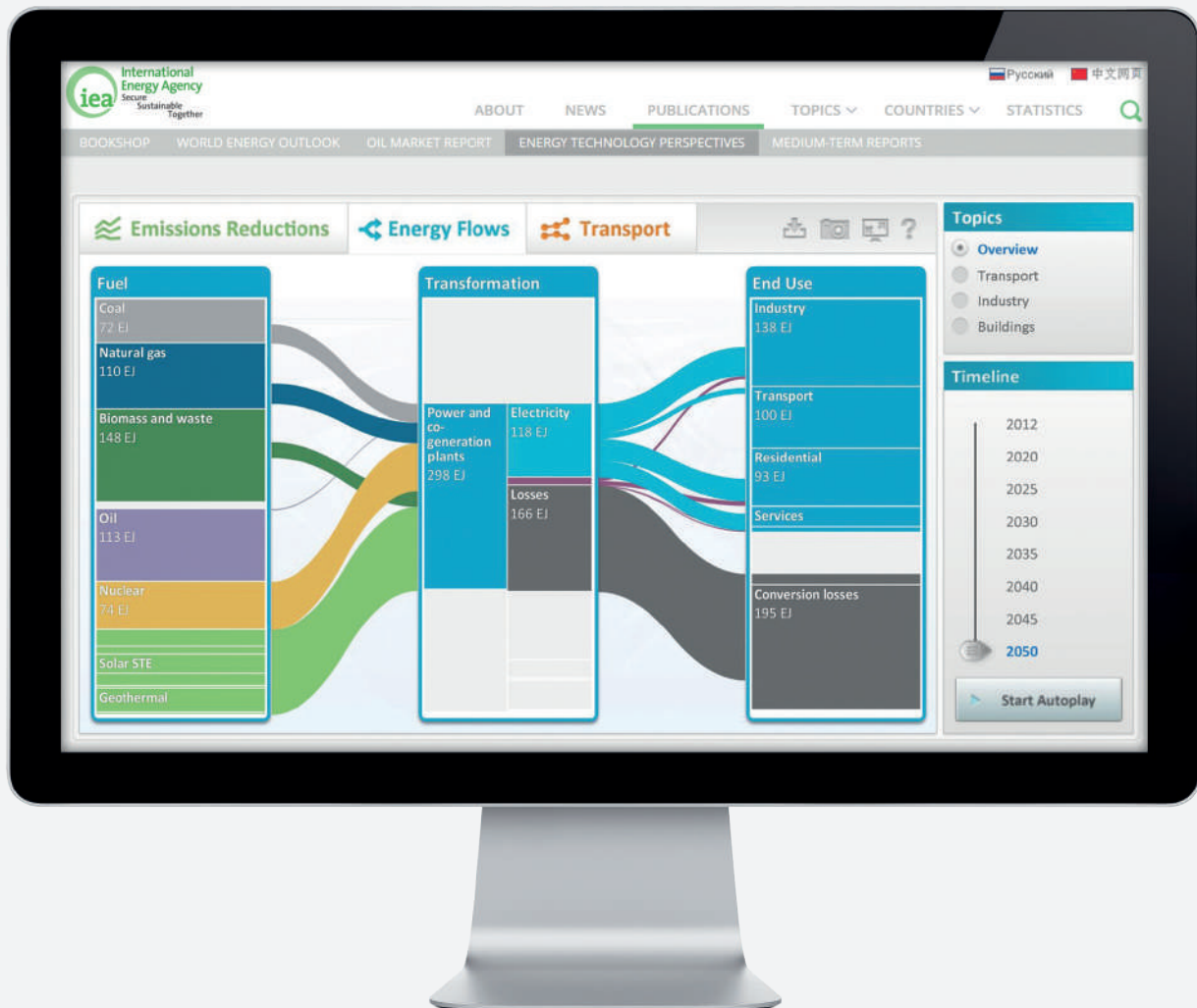
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Energy Technology Perspectives 2017

Catalysing Energy Technology Transformations

The global energy system is moving closer to a historic transformation. This year's edition of the International Energy Agency (IEA)'s comprehensive publication on energy technology focuses on the opportunities and challenges of scaling and accelerating the deployment of clean energy technologies. This includes looking at more ambitious scenarios than the IEA has produced before.

Improvements in technology continue to modify the outlook for the energy sector, driving changes in business models, energy demand and supply patterns as well as regulatory approaches. Energy security, air quality, climate change and economic competitiveness are increasingly being factored in by decision makers. *Energy Technology Perspectives 2017 (ETP 2017)* details these trends as well as the technological advances that will shape energy security and environmental sustainability for decades to come.

For the first time, *ETP 2017* looks at how far clean energy technologies could move the energy sector towards higher climate change ambitions if technological innovations were pushed to their maximum practical limits. The analysis shows that, while policy support would be needed beyond anything seen to date, such a push could result in greenhouse gas emission levels that are consistent with the mid-point of the target temperature range of the global Paris Agreement on climate change. The analysis also indicates that regardless of the pathway chosen for the energy sector transformation, policy action is needed to ensure that multiple economic, security and other benefits to the accelerated deployment of clean energy technologies are realised through a systematic and co-ordinated approach.

ETP 2017 also features the annual IEA *Tracking Clean Energy Progress* report, which shows that the current progress in clean energy technology development and deployment remains sub-optimal. It highlights that progress has been substantial where policies have provided clear signals on the value of technology innovation. But many technology areas still suffer from a lack of financial and policy support.

ETP 2017 purchase includes extensive downloadable data, figures and visualisations. For more information, please visit www.iea.org/etp2017