Tracking Clean Energy Progress 2014

Energy Technology Perspectives 2014 Excerpt
IEA Input to the Clean Energy Ministerial

International Energy Agency

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International Energy Agency

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

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

The International Energy Agency (IEA) *Energy Technology Perspectives (ETP)* analysis offers a comprehensive, long-term view of energy system trends and technologies essential to meet goals for affordable, secure and low-carbon energy. This long-term view is regularly challenged by developments that have lasting and transformative impacts, such as the shale gas boom in North America, cost reductions in several renewable technologies and the uncertainty in nuclear power progress. These examples clearly show that technology, market developments and external events influence the evolution of energy systems.

These interactions draw attention to a troubling fact. In the face of rapidly growing demand and the increasingly urgent threat of climate change, we are continuing to respond to the energy system as it evolves rather than actively managing its transformation towards the aim of achieving a clean, secure and economic energy supply. A radical change of course is long overdue, and *ETP* shows the necessity of technology to obtain these goals.

Considering the links between effective short- and long-term development of energy systems, the IEA has taken a strategic decision to transition *ETP* to an annual publication in which each edition sharpens its focus to allow a "deep dive" into analysis of timely topics and trends. The *ETP* online presence has been expanded to deliver downloadable analysis updates, data visualisations and sector specific commentary, maintaining its comprehensive analysis, while increasing usability.

We also continue to monitor the status of global technology efforts to meet long term targets through "Tracking Clean Energy Progress", a key chapter in *ETP* and is the IEA fourth submission to the Clean Energy Ministerial on global clean energy technology development and deployment. We find growing evidence that a partial energy transition is under way – and that emerging economies have stepped into the lead, achieving the greatest gains in the past year. But it is clear that some of the encouraging trends observed in 2013 are in dire need of renewed support.

The theme of *ETP 2014*, Harnessing Electricity's Potential, reflects an opportunity arising from the convergence of two trends: rapidly rising global electricity demand and the evident need for increased system integration. Electricity production uses 40% of global primary energy and produces an equal share of energy-based carbon dioxide emissions today. However, cost-effective and practical solutions exist that can increase efficiency and reduce electricity demand as well as carbon emissions between now and 2050. Four key points emerge in this year's analysis:

- The unrelenting rise in coal use without deployment of carbon capture and storage is fundamentally incompatible with climate change objectives.
- Natural gas can, in the short term, play a dual role of replacing coal and supporting integration of variable renewable energy (VRE), in the medium to longer term, gas must be seen for what it is – a transitional fuel, not a low-carbon solution.
- Deployment of VRE technology is growing, and in some cases becoming competitive; experience now shows that balancing VRE supply and patterns of energy demand must – and can – be actively managed.

- Electricity storage can play multiple roles in an integrated system, as can other technologies with which it must compete. Contrary to many other voices, *ETP* analysis finds that electricity storage *alone* is not a necessary game-changer for the future energy system.

A new feature of each edition will be a country case study of particular relevance to the theme, with the inaugural example being India's tremendous challenge of expanding both capacity and generation of electricity to meet a doubling of demand in the next decade. A low-carbon, more integrated future will require strong policy action to manage the use of its substantial coal resources and to address the administrative hurdles that impede both innovation and investment.

The timescale for this publication is 40 years. As the IEA enters its 40th year, energy challenges are as daunting as they were in 1974. While energy security is still a concern, shifting the world to a sustainable energy path has become an additional urgent priority. Our efforts during the last four decades have not addressed this challenge. The greater focus of *ETP* and the associated series of publications further the IEA's underlying aim of providing truly transformative "calls to action" so that governments can take the steps necessary to move to a cleaner path. But we must start now; we cannot afford to wait another 40 years.

This publication is produced under my authority as Executive Director of the IEA.

Maria van der Hoeven
Executive Director
International Energy Agency

Key Findings

Emerging economies step up clean energy ambition, but policy uncertainty stalls momentum in OECD countries.

- **Deployment of renewable power is accelerating in Asia and emerging economies.** Emerging markets more than compensated for slowing or more volatile growth in Europe and the United States. China accounted for the lion's share of new installations, becoming the first market in the world for both wind and solar photovoltaics (PV). Asia as a whole deployed more than half of global solar PV additions in 2013.
- **Policy remains vital to the competitiveness of clean energy technologies.** Clean energy, and in particular renewable power, is increasingly competitive with new-built conventional power plants. However, in Europe, decreasing wholesale prices originating from sluggish power demand, overcapacity, low CO_2 prices and increasing penetration of renewables make any new investment challenging. As a consequence, policy incentives are still needed to drive progress in clean energy technologies. But inability to agree on long-term clean energy policy goals and abrupt policy changes triggered by concerns over policy cost have deteriorated the clean energy investment environment.
- **China supports clean transport technologies to improve urban air quality.** Some 150 million electric 2-wheelers are already on the road in China, and deployment of electric buses is on the rise. A five-year Clean Air Action Plan (2013-17) for Beijing rules that out of the 600 000 new vehicles to be allowed in the city in the next four years, 170 000 should be battery electric, plug-in hybrid or fuel cell vehicles. In 2014, a quota of 20 000 new car registrations will be given to such vehicles.

Key Numbers

GLOBAL POPULATION **8** BILLION BY 2025
58% living in cities

81% of 2011 global energy demand was met by fossil fuels

20% SHARE OF RENEWABLE GENERATION IN 2011

2.7% growth of renewable generation in non-OECD in 2011
6.7% in the OECD

0.8 TRILLION USD yearly additional investment required for the clean energy transition

2012 global GDP **83** TRILLION USD

- **Sales of hybrid and electric vehicles (HEVs and EVs) set new records, but fall short of the trajectory in the 2°C Scenario (2DS).** Market shares for hybrid, plug-in hybrid and battery electric vehicles all grew in 2013, with EVs reaching 1% in the United States, the Netherlands and Norway. Eight out of ten manufacturers now offer electric vehicles, and several big manufacturers launched high-profile models. Still, the overall rate of growth was below previous years and, as a single year, 2013 was below 2DS trajectories.
- **Global investment in renewable power fell 12% from 2012, the second consecutive year of decline.** Technology cost reductions played a part as each gigawatt (GW) cost less to install, but changes and uncertainties in policy were a key factor. In the United States, wind power additions fell by more than 90%, with only 1.1 GW of new capacity in 2013. Ongoing policy uncertainty remains one of the largest sources of risk for investment in renewable technologies.

Hydro, wind and solar forge ahead; development is mixed for other clean energy supply.

- **Hydropower, onshore wind and solar PV kept pace with 2DS targets; other renewables lag behind.** Cost per unit of energy generated by onshore wind and solar PV continued to fall in 2013, albeit at a slower rate than in previous years. Their cost competitiveness is improving, in some countries also due to market design. Markets are also expanding geographically. In 2013, onshore wind again won the majority of awarded capacity in competition with conventional technologies in long-term energy auctions in Brazil. Bioenergy, offshore wind, geothermal power, concentrated solar power (CSP) and ocean energy all need ongoing stimulus to reach 2DS targets.
- **Global nuclear capacity is stagnating, despite a record 72 reactors under construction in 2013.** Modest capacity increase from new reactors coming on line was offset by retirements of ageing or non-profitable plants in OECD countries. Japan's operable nuclear fleet remains closed and only around 2350 TWh of nuclear electricity was generated in 2012, a 7% drop from 2011 levels. Signs of renewed growth exist, however, as China and Russia push ahead with ambitious nuclear plans.

350 000
electric vehicles on the road in 2013

102
COUNTRIES HAVE RENEWABLE POWER POLICIES

554
USD BILLION FOSSIL FUEL CONSUMPTION SUBSIDIES IN 2012

renewable energy subsidies
100
USD BILLION

100 MW PER DAY
SOLAR PV INSTALLED GLOBALLY IN 2013

186 GW
new nuclear capacity needed by 2025

Coal use continues to increase, underlining the need to scale up carbon capture and storage and improve coal plant efficiency.

- **The unrelenting rise in coal use is fundamentally incompatible with climate change objectives.** The 2DS trajectory requires a sharp decline in coal use in parallel with rapid development of carbon capture and storage (CCS). Coal is still the dominant energy fuel. Since 2010, the growth in generation from coal has been greater than that of all non-fossil sources of power generation combined, continuing a 20-year trend. The recent US development of switching from coal to gas has stalled (at least temporarily), and estimated coal use in the European Union rose by 1.5% in 2012 over 2011. As a result of these developments the International Energy Agency (IEA) Energy Sector Carbon Intensity Index (ESCII) rose by 1.09% in 2011 and the carbon intensity of global energy supply has not improved since 1990. It is imperative that this trend is reversed.
- **Efforts under way to curb coal demand and improve plant efficiency remain inadequate.** Legislation in China has taken close to 100 GW of inefficient plants offline since 2006, and decommissioning of old plants continues. Proposed policies in the United States would prohibit construction of new coal plants without CCS; proposals planned for existing plants would have an even higher impact. While important, these efforts do not yet offset the overall trend of increasing coal use.
- **CCS is advancing slowly, due to high costs and lack of political and financial commitment.** Few positive major developments were seen in 2013, and policies necessary to facilitate the transition from demonstration to deployment are still largely missing. Eight large-scale CCS projects are likely to come on line within the next two to three years, which will bring valuable experience. Given the importance of fossil fuels for a long time to come, CCS is a critical component in the pathway to a sustainable energy system.

Technology is changing how markets work.

- **As high capital costs of clean energy technologies deter investors, policy is needed to reduce risk.** The challenge of attracting private finance to clean

55 $MtCO_2$ captured and stored with monitoring so far

50% of new coal power plants use inefficient subcritical technologies

3.7 USD/MBtu 2013 US gas price

10.4 USD/MBtu in Europe

COAL IN 2011

29% of global energy demand,

44% of energy related CO_2 emissions

134 GW COAL CAPACITY ADDED IN 2013 at least double that of any other fuel energy technologies is especially evident in liberalised markets. A recent example of policy intervention to reduce risk is in the United Kingdom, where the government is offering guaranteed price levels over 35 years to a new nuclear facility. Although the proposal is still under review, it shows that the UK government is reconsidering market design in the light of requirements to meet environmental and energy security goals.

- **Flexibility is increasingly important for gas-fired power plants as electricity systems evolve.** Penetration of variable renewable electricity is firmly on an upwards trajectory. In principle, this creates value for flexible operation of thermal generation. However, the current wholesale market conditions in Europe, exacerbated by high gas import prices, lack of flexibility markets and extensive deployment of renewables, undermine the economics of combined-cycle gas turbines (CCGTs). Technical developments are set to improve flexibility of CCGTs; however, depending on power market structures, competing technologies such as engines and single-cycle turbines may become more competitive. This is particularly true if investors look to reduce capital and maintenance costs to compensate for fewer operating hours.
- **Emerging technologies can capture new niche markets through innovative business models.** EVs account for more than 10% of rapidly growing car-sharing programmes being launched in cities around the world — compared with 1% of global sales market share. This reflects the suitability of EVs in the car-sharing business model, where up-front costs and driving range are of less concern for users than in a decision to buy a vehicle. Growth in car-sharing may also herald behavioural changes that could have far-reaching consequences for urban mobility solutions.
- **Uncertainty on multiple fronts is delaying smart-grid deployment — and associated benefits.** To date, many aspects of smart-grid application, which involves multiple stakeholders, remain ill-defined: how to assign roles and responsibilities and how to share costs and benefits, for example. Another challenge is that cost savings enabled by smart grids do not necessarily accrue in the same sectors in which investments are made. Addressing regulatory and market barriers and enabling new business models that will engage end users, leverage existing infrastructure and better plan for future needs are essential to overcome delays in technology deployment.

3 countries with electric vehicle sales above 1% of the market

50 EUR/tCO_2 carbon price to effect coal-to-gas switch in Europe

4.5 EUR/tCO_2 2013 carbon price in Europe

61% share of population served by district heating in Denmark

141 GW CURRENT ELECTRICITY STORAGE CAPACITY

2.3% of electricity generated from variable renewables in 2011

End-use sectors show slow technology improvements; recent breakthroughs limited to passenger transport.

- **Battery costs keep improving, and fuel cells and gaseous fuels take steps forward.** The cost of batteries, a deciding factor in electrification of transport, continues to fall. At the end of 2013, it was estimated at some USD 400 per kilowatt (kW), down from USD 485/kW in 2012, and well on track to the IEA target of USD 300/kW by 2020. Fuel cell vehicles are receiving renewed attention, as are gaseous fuel technologies. While having lower energy efficiency than EVs, these technologies have advantages in heavy, long-haul transport.
- **The aviation industry took initial steps to reduce CO_2 emissions from international travel.** In October 2013, the International Civil Aviation Organization (ICAO) Assembly agreed to develop by 2016 a global market-based mechanism addressing international aviation emissions and apply it by 2020. Until then countries or groups of countries, such as the EU, can implement interim measures. ICAO member states also adopted aspirational goals to 2020, with a declared aim of improving efficiency by 2% annually. If realised, these initiatives would put the sector on a much-improved pathway.
- **Battling high costs, advanced biofuels pin hopes to first-of-their-kind, commercial-scale projects.** In 2013, two commercial-scale advanced biofuel production units opened in the United States and one in Europe. Together with several commercial plants scheduled to come on line in 2014, these will help to prove technologies at scale and build experience that can bring down costs for subsequent plants.
- **Intensified dialogue between industry and governments, particularly in Europe, is setting the stage.** While few significant changes occurred on the industry policy front in 2013, energy management systems and programmes are receiving increasing policy attention. China's new mandates for large energy users are the most important example. European industry associations in iron and steel, chemicals, and pulp and paper developed long-term roadmaps for sustainable development of their sectors, serving as a basis for dialogue with policy makers in the European Union.

582 $GtCO_2$
business as usual emissions to 2025
52% of the 2°C carbon budget to 2100

95g CO_2/km 2020 EU proposed fuel economy target
168 gCO_2/km 2011 global average

20%
of new cars sold in Japan are hybrids

485
USD/kWh 2012 EV battery cost

300
USD/kWh cost to make EVs competitive

- **Industry must cut energy use by 11% and direct CO_2 emissions by 14% by 2025 to meet 2DS targets.** Large economic values tied in existing plants slow the turnover of industrial equipment, but IEA analysis shows that wide application of best available technologies (BATs) could technically slash energy use by 11% to 26% in iron and steel, chemicals, cement, pulp and paper, and aluminium. Tapping this potential is particularly important as few energy-saving breakthrough technologies in these energy-intensive industries have emerged in recent years; any future breakthroughs would require significant time and investment to reach commercialisation. Deployment of current BATs and development of emerging technologies will both be necessary to meet industry targets.
- **Energy performance of new buildings needs a higher priority in emerging and developing economies of the world.** Policy efforts are increasing but are still insufficient to ensure implementation of cost-effective measures that are widely available already. Some European countries have adopted zero-energy goals for new residential construction around the 2020 time frame. The United States recently approved its most stringent energy-saving building code, which includes mandatory daylighting and automated lighting controls. Adapting and widely deploying advanced building technologies and materials in emerging and developing markets will be essential.
- **Efficiency standards and labels for appliances, lighting and equipment could be further improved.** Energy efficiency policies to promote advanced products have been widely demonstrated to save energy. New Zealand's programme achieved savings of 4% in 2012. Increasing resources for these programmes could address the growth in appliance and equipment penetration that is outstripping efficiency programme benefits.

Global policy action is urgently needed to curb growing electricity demand of network-enabled devices.

- **Global electricity demand associated with network-enabled devices is growing at an alarming rate.** As information and communication technology (ICT) becomes ubiquitous, network connectivity is rapidly spreading across all types of devices. More than 14 billion network-enabled devices are already in homes and

EMISSIONS REDUCTIONS POTENTIAL BY 2025

17 $GtCO_2$ IN BUILDINGS

13 $GtCO_2$ IN TRANSPORT

11 $GtCO_2$ IN INDUSTRY

44% OF EMISSIONS REDUCTIONS TO 2025 CAN BE DELIVERED BY END-USE ENERGY EFFICIENCY offices today; by 2020, the number is expected to skyrocket to more than 50 billion. Without concerted global policy action to improve their efficiency, electricity demand of these devices is expected to reach 1 140 terawatt hours per year by 2025.

- **Implementing BATs and solutions could cut this demand by more than 60%.** Network-enabled devices use up to 80% of their electricity in "standby mode", just to maintain a network connection. A range of existing technologies and solutions can be implemented to prompt devices to power down or reduce energy requirements without compromising the services that network connectivity enables.
- **Curbing escalating electricity demand from networked devices requires global policy action.** As market drivers for energy efficiency in networked devices are still weak, a strong case exists for policy intervention. Some measures are already under way: Korea and the European Union are front runners on policy initiatives. The global nature of ICTs warrants international policy and technology co-operation to ensure that network-enabled devices and systems deliver high functionality and service at low energy cost. The IEA guiding principles for good network design outline the foundation for action.

Poor quality and availability of data seriously constrains tracking and assessing progress.

- **Quality remains a broad concern for much energy data and is a particular constraint in emerging economies, for energy efficiency data in buildings and industry, and in cross-cutting areas such as smart grids and integration of heat and electricity systems.** Data that reflect the energy balance of each country need to be more timely and reliable so that the energy system as a whole can be analysed accurately. This would enhance the ability to replicate effective policies and investments. Research, development and demonstration (RD&D) data in emerging economies are still scarce, and few countries collect data for private RD&D.

2.73
BILLION PEOPLE ONLINE TODAY

16 800
gigabytes per second
global internet traffic in 2012

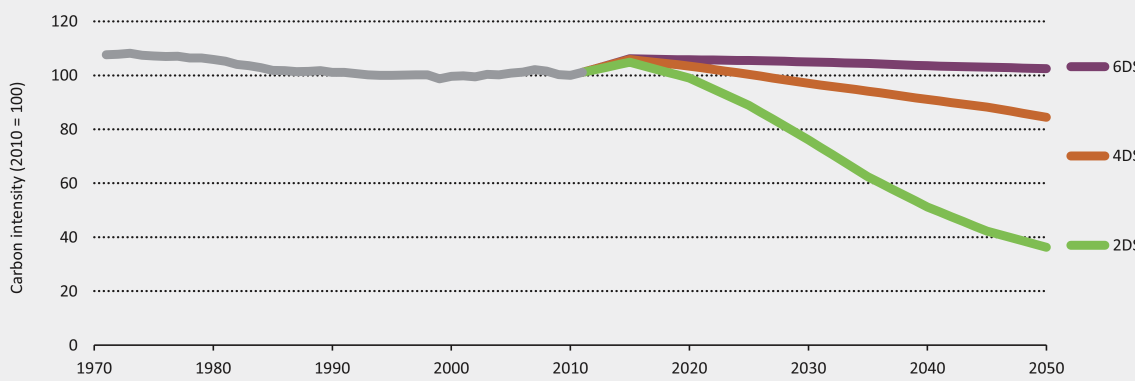
46 500
gigabytes per second
expected in 2017

750
MILLION HOUSEHOLDS HAVE INTERNET ACCESS

300%
INCREASE IN GLOBAL ICT-RELATED ELECTRICITY CONSUMPTION BY 2030

80%
of new TVs in the US are network enabled

Box I.1 The IEA Energy Sector Carbon Intensity Index (ESCII)



Note: the ETP scenarios (2DS, 4DS and 6DS) are defined in Box I.2. Figures and data that appear in this report can be downloaded from www.iea.org/etp/tracking. Unless otherwise noted, all tables and figures derive from IEA data and analysis.

The IEA ESCII tracks how many tonnes of CO_2 (tCO_2) are emitted for each unit of energy supplied. The index shows that the global aggregate impact of all changes in supply technologies since 1970 has been minimal. Responses to the oil shocks of the 1970s made the energy supply 6% cleaner from 1971 to 1990. Since 1990, however, the ESCII has remained essentially static despite the important climate policy commitments at the 1992 Rio Conference and under the 1997 Kyoto Protocol, as well as the boom in renewable technologies over the last decade (Figure I.1). In 1990, the underlying carbon intensity of supply was 57.1 tCO_2 per terajoule (TJ) (2.39 tCO_2 per tonne of oil equivalent [toe]); in 2011 it was 55.9 tCO_2/TJ (2.34 tCO_2/toe). This reflects the continued domination of fossil fuels – particularly coal – in the energy mix and the slow uptake of other, lower-carbon supply technologies. The ESCII shows only one side of the decarbonisation challenge, however: the world must slow the growth of energy demand as well as make its energy supply cleaner.

To meet 2DS targets, aggressive energy efficiency improvements are needed as well as a steep drop in the global ESCII. The index needs to break from its 40-year stable trend and decline by 12% by 2025, and 64% by 2050.

Figure I.1 Trade-off between improving ESCII and reducing energy demand

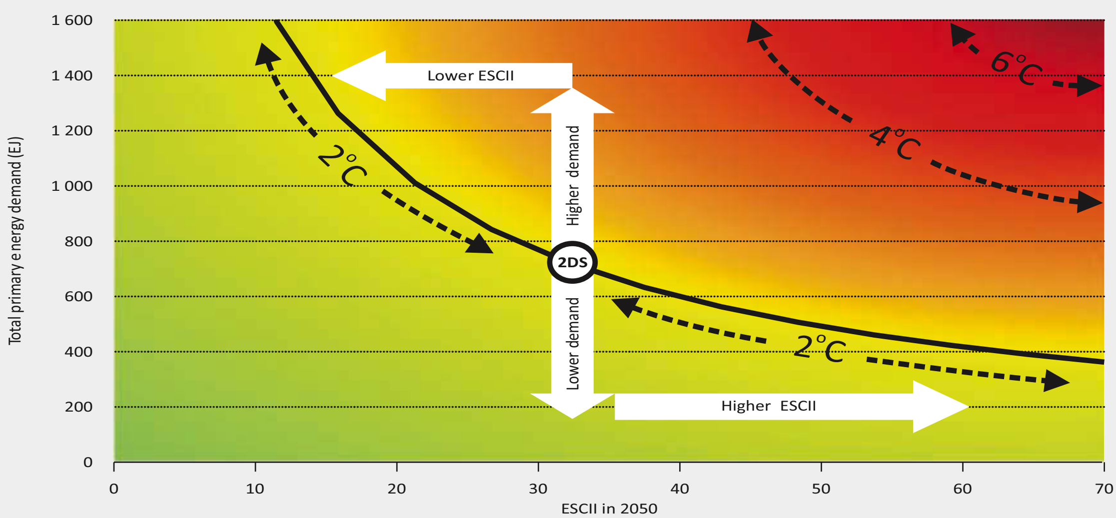


Table I.1 Summary of progress

On track?	Status against 2DS targets in 2025	Policy recommendations
Renewable power	Rapid progress, particularly in hydro, onshore wind and PV, on global scale; slightly slowing momentum in OECD. Offshore wind, bioenergy, concentrated solar power (CSP), ocean and geothermal technologies are lagging.	▪ Maintain a balance among sustainability, affordability and competitiveness while designing renewable power policies. ▪ For maturing markets, integrate renewables with greater exposure to market pricing and competition. ▪ Shift focus from high economic incentives to long-term policies that provide predictable and reliable market and regulatory frameworks offering a reasonable degree of certainty over remuneration. ▪ Reduce risks associated with policy uncertainty that ultimately drive up capital and project costs for capital-intensive renewable; avoid retroactive measures by all means.
Nuclear power	Installed capacity in 2025 likely 5% to 25% below 2DS target. Both new-build activity and long-term operation of existing reactors required.	▪ High capital and low running costs create need for policies that provide investor certainty, e.g. through more favourable market mechanisms and investment conditions. ▪ Implement safety upgrades in existing nuclear plants in a timely manner to ensure public confidence.
Gas-fired power	Decreasing power demand, overcapacity, the rise of renewable energy and low coal prices make the situation for gas power challenging, particularly in Europe.	▪ Carbon prices and other regulatory mandates needed to drive coal-to-gas switching outside the United States. ▪ Scaling up unconventional gas extraction requires careful regulation and monitoring to avoid adverse effects on the environment.
Coal-fired power	Current trends of increasing coal-fired power are incompatible with the 2DS. Accelerated development of carbon capture and storage (CCS) required.	▪ Policy incentives to drive emissions reductions, such as carbon pricing and regulation, are vital to control pollution and reduce generation from inefficient units. ▪ New coal power units should, at minimum, achieve the efficiency of supercritical units and be CCS-ready to have the potential to reduce even further the impact of coal use.
CCS	Global capacity of around 50 $MtCO_2$/yr in 2020 if projects in advanced stages reach operation. In the following decade, the rate of capture and storage must increase by two orders of magnitude.	▪ Demonstrate financial and policy commitment to CCS demonstration and deployment. ▪ Near-term policies should be supported by credible long-term climate change mitigation commitments. ▪ Recognise the large investments and long lead time required to discover and develop viable storage sites. ▪ Introduce CCS as a solution to address CO_2 emissions from industrial applications.
Buildings	Progress continues in most regions, but is insufficient. The 2DS target for 2025 constrains energy demand growth to 0.7%/yr from 2012; trend since 2000 is more than double at 1.5%/yr, throwing the sector off track.	▪ Promote deep energy renovation during normal refurbishment, and increase significantly the annual rate of renovation (to at least 2%). Pursue zero-energy building goals from 2020 onwards for all new construction, which will require significant effort now. ▪ Implement mandatory building codes that promote advanced building materials, integrated using a systems approach to reduce heating, cooling and lighting energy demand. Build capacity and infrastructure in emerging economies to promote building code development and compliance. ▪ Set MEPS to improve efficiency; continue and extend where possible. ▪ Apply labelling policies and standards to promote uptake of energy efficient models; develop measures to curtail increasing demand.

● Not on track ● Improvement, but more effort needed ● On track, but sustained deployment and policies required

Table I.1 Summary of progress (continued)

On track?	Status against 2DS targets in 2025	Policy recommendations
Industry	Some progress in energy efficiency, but energy use must be cut by 25% and direct CO_2 emissions by 17% by 2025.	▪ Promote widespread application of best available technologies (BATs) to help overcome the challenges of slow capacity stock turnover, high abatement costs, fluctuation in raw material availability, carbon leakage and industrial competitiveness. ▪ Support RD&D programmes to bring to technical and commercial maturity new low-carbon technologies that enable the use of low-quality feedstocks; demonstrate and deploy emerging energy- and emissions-saving technologies, including CCS. ▪ Promote technology capacity building in emerging economies.
Transport	Although OECD recently shows high vehicle efficiency improvement rates for PLDVs, and despite recent progress in hybrid and EV deployment the sector is lagging.	▪ Implement fiscal policies that reflect actual costs, e.g. remove fuel subsidies to incentivise switching to fuel-efficient vehicles. ▪ Continuously adapt ongoing policies such as fuel economy and emission standards, feebate systems, or emission-based taxes for PLDVs; develop and implement fuel economy policies for HDVs. ▪ Use urban development strategies, access restriction and congestion charging to manage travel demand and influence modal choice, promoting shifts to collective transport modes and stimulating innovative vehicle technologies. ▪ Apply market-based instruments, such as emissions trading, to internalise GHG-related costs, and regulatory measures to foster the uptake of efficient technologies in the aviation and shipping sector.
Electric and hybrid electric vehicles	Slow growth compared with previous years; tracking indicator dipped from green (2013) to orange. Annual sales must increase substantially for both EVs (80%) and HEVS (50%) until 2020.	▪ Direct subsidies, tax exemptions, feebate schemes and favourable conditions in urban areas enhance cost-competitiveness of EVs/HEVs and boost manufacturer and consumer confidence. ▪ Extend policy measures and programmes to give industry confidence that market demand will continue to grow in the short term. ▪ Develop standards for charging stations and integrate EVs in city mobility programmes (e.g. car sharing) to underscore broader benefits, including reduced local air pollution.
Biofuels	Global production must triple; advanced biofuels capacity must increase 22-fold.	▪ Develop fiscal measures that reduce investment risk associated with first commercial-scale advanced biofuels projects, to achieve technology learning and cost reductions. ▪ Promote international harmonisation of sustainability certification schemes, without creating unwanted trade barriers. ▪ Create a long-term policy framework to ensure sustained investments in production and use of sustainable biofuels that perform well in terms of emissions reduction and land-use efficiency, as well as economic and social impact.
Co-generation and district heating and cooling	Slow progress despite their enhanced conversion efficiency; deployment of co-generation accounts for only 9% of global electricity, and penetration of efficient district heating and cooling (DHC) is limited.	▪ Make the efficiency and flexibility benefits of co-generation visible by creating market conditions that reflect the real cost of generation. Facilitate investments in modernisation and improvement of networks. ▪ Develop strategic local, regional and national heating and cooling planning to identify cost-effective opportunities to develop co-generation and expand DHC networks. ▪ Streamline grid interconnection standards to achieve the flexibility potential of co-generation technologies.
Smart grids	Steady growth, but available deployment data do not give a full picture; current rate of deployment is insufficient.	▪ Develop and demonstrate new electricity regulation that enables practical sharing of smart-grid costs and benefits. ▪ Support the development of international standards to accelerate RDD&D. ▪ Promote the development metrics, national data collection and international data co-ordination.

● Not on track ● Improvement, but more effort needed ● On track, but sustained deployment and policies required

Tracking Progress: How and Against What?

Technology penetration, market creation and technology developments are key measures of progress in clean energy deployment. *Tracking Clean Energy Progress 2014 (TCEP 2014)* uses these criteria to probe whether current policy is effectively driving efforts to achieve a more sustainable and secure global energy system. What rates of deployment do recent trends demonstrate for key clean energy technologies? Are emerging technologies likely to be demonstrated and commercially available in time to fully contribute?

Tracking against near-term targets, while aiming for the long-term goal. This report uses interim 2025 benchmarks set out in the 2°C Scenario (2DS), as modelled in *Energy Technology Perspectives 2014 (ETP 2014)*, to assess if technologies, energy savings and emissions reduction measures are on track to achieve 2DS objectives by 2050. The near-term focus shows where actions necessary for profound decarbonisation post-2025, across the energy sector, are progressing as required. It also uncovers areas that need additional stimulus.

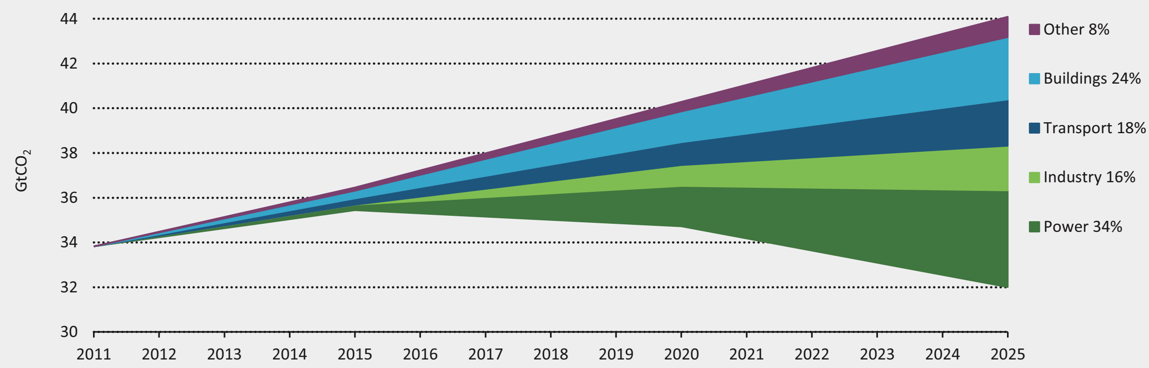
Published annually, the *TCEP* report highlights how the overall deployment picture evolves, year on year. Vitally, it highlights key policy and technology measures that energy ministers and their governments can take to scale up deployment for each technology and sector, while also demonstrating the relevant energy savings and emissions reduction potential. The report is structured by technology and sector, and uses graphical overviews[1] to summarise the data behind the key findings. This year's edition contains a special feature on energy use associated with devices that operate in network standby mode.

All three *TCEP* measures are essential to the success of individual technologies. The 2DS relies on development and deployment of lower-carbon and energy-efficient technologies across the power generation, industry, transport and buildings sectors (Figure I.3). On the basis of available quantitative and qualitative data, this report assesses for each sector:

- **Technology penetration.** What is the current rate of technology deployment? What share of the overall energy mix does the technology represent? Is the technology being distributed or diffused globally at the rate required?
- **Market creation.** What mechanisms are in place to enable and encourage technology deployment, including government policies and regulations? What level of private sector investment can be observed? What efforts are being made to drive public understanding and acceptance of the technology? Are long-term deployment strategies in place?
- **Technology developments.** Are technology reliability, efficiency and cost evolving and if so, at what rate? What level of public investment is being made into technology RD&D?

1 Enhanced interactive data visualisations are available at: www.iea.org/etp/tracking.

Figure I.2 Sector contributions to emissions reductions



Key point *All sectors must contribute to achieve the 2DS goal of limiting global emissions across energy generation and use.*

Box I.2 *ETP 2014* scenarios

The **6°C Scenario (6DS)** is largely an extension of current trends. By 2050, energy use grows by more than two-thirds (compared with 2011) and total GHG emissions rise even more. In the absence of efforts to stabilise atmospheric concentrations of GHGs, average global temperature rise is projected to be at least 6°C in the long term. The 6DS is broadly consistent with the *World Energy Outlook (WEO)* Current Policy Scenario through 2035.

The **4°C Scenario (4DS)** takes into account recent pledges made by countries to limit emissions and step up efforts to improve energy efficiency. It serves as the primary benchmark in *ETP 2014* when comparisons are made among scenarios. Projecting a long-term temperature rise of 4°C, the 4DS is broadly consistent with the *WEO* New Policies Scenario through 2035. In many respects, this is already an ambitious scenario that requires significant changes in policy and technologies compared with the 6DS. Capping the temperature increase at 4°C requires significant additional cuts in emissions in the period after 2050, yet still potentially brings forth drastic climate impacts.

The **2°C Scenario (2DS)** is the main focus of *ETP 2014*. It describes an energy system consistent with an emissions trajectory that recent climate science research indicates would give at least a 50% chance of limiting average global temperature increase to 2°C. The 2DS also identifies changes that help ensure a secure and affordable energy system in the long run. It sets the target of cutting energy- and process-related CO_2 emissions by more than half in 2050 (compared with 2011) and ensuring that they continue to fall thereafter. Importantly, the 2DS acknowledges that transforming the energy sector is vital, but not the sole solution: the goal can be achieved only provided that CO_2 and GHG emissions in non-energy sectors are also reduced. The 2DS is broadly consistent with the *WEO* 450 Scenario through 2035.

Chapter 1

Tracking Clean Energy Progress

Renewable Power

On track

Renewable power generation continues to progress quickly and is broadly on track to meet targets of the *Energy Technology Perspectives 2014 (ETP 2014)* 2°C Scenario (2DS). It grew 5.5% annually from 2006-13, up from 3% annually in 2000-06, and is expected to rise by around 40% between 2013 and 2018 (approximately 5.8% annually), to reach 6 850 terawatt hours (TWh). This compares well with the 2DS in terms of absolute generation but not in terms of renewables' target share in global power generation of over 35% by 2025. In addition, this expected growth of renewables is subject to strong regional differences, and depends on tackling policy uncertainty.

Technology penetration

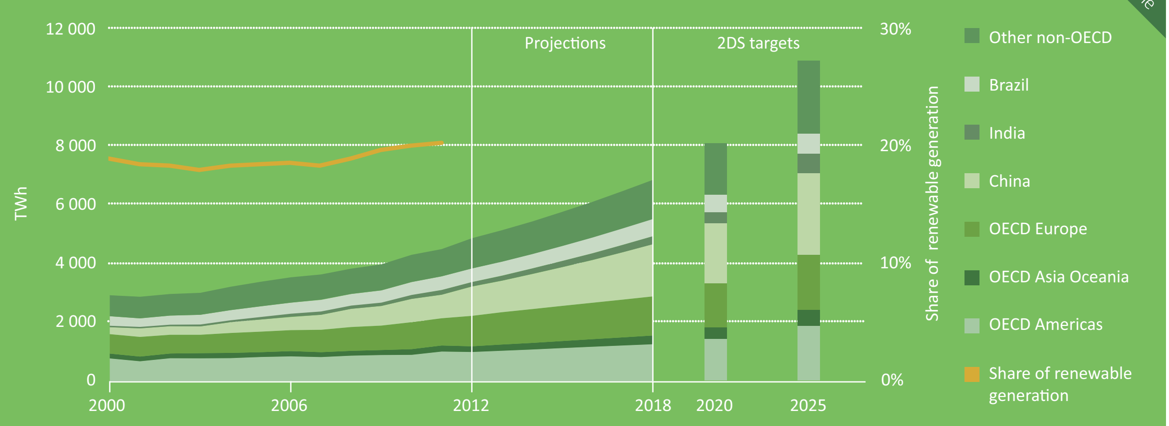
Growth is shifting beyond traditional markets mainly in Europe to an increasing number of non-OECD countries. In 2013, the number of countries with installed non-hydro renewable power cumulative capacity from onshore and offshore wind, bioenergy and solar photovoltaics (PV) above 100 megawatts (MW) rose significantly compared with 2006 levels. Led by China, India and Brazil, non-OECD countries now dominate global renewable power generation with around 54% of the total, up from 52% in 2012 (IEA, 2013a). This share is expected to further increase up to 58% in 2018. This trend is also in line with 2DS results, where the largest proportion of renewable electricity generation in 2025 would come from China (26%), followed by OECD Europe (17.3%), the United States (11%), Brazil (6.3%) and India (6.1%).

In 2013, installed cumulative capacity continued to grow strongly in both OECD and non-OECD countries. Solar PV grew by an estimated 37 gigawatts (GW) (+ 37%) and wind (onshore and offshore) by 35.5 GW (+ 12.5%). Asia, led by China and Japan, deployed more than half of global solar PV additions in 2013.

Certain technologies are doing better than others in terms of reaching 2DS targets. Hydropower continued its stable growth globally in 2013, and remained the largest generator of renewable electricity. Onshore wind is also on track to meet 2DS targets thanks to increasing deployment levels in non-OECD countries compensating for the slowing or more volatile growth in OECD Europe and Americas. Solar PV shows even stronger growth, and may exceed 2DS targets – with non-OECD cumulative capacity likely surpassing OECD before 2025.

In contrast, offshore wind, bioenergy, concentrated solar power (CSP), ocean and geothermal technologies are lagging behind. In order to reach the 2DS targets, these technologies need to achieve higher growth rates in coming years, which require further policy action to tackle technical and financing challenges that currently hinder deployment.

1.1 Renewable power generation by region



1.2 Renewable power generation by technology

For sources and notes see page 71

Market creation

By the end of 2013, over 100 countries had a renewable electricity support measure (e.g. targets, feed-in tariffs [FiTs], tenders, tax incentives). During 2013, new or revised policies supporting the deployment of renewable power were adopted in 16 countries.

A major policy challenge is to balance the affordability of support schemes with effectiveness and the need for investor certainty in order to drive deployment. In 2013, governments continued to be mindful of the affordability aspect of renewable energy deployment, allowing faster downward adjustment to cost changes.

In Germany, the revision of supported solar PV system categories and the monthly adjustment of solar FiTs have so far worked well. However, several countries made more drastic and even retroactive changes to renewable energy policies, which damaged investor confidence for future projects and affected the profitability of existing renewable energy assets in some markets. Onshore wind and solar PV have been affected, resulting in boom and bust investment cycles in some markets.

Installations of new wind capacity in the United States tumbled to 1 GW in 2013, a fraction of the record 13 GW in 2012. Developers rushed to finish projects before an expected expiration of the renewable electricity production tax credit (PTC) at the end of 2012, leaving an empty project pipeline for 2013. The situation is foreseen to partly recover since the PTC was extended in late 2012, with around 15 GW of new wind projects expected to come on line by 2015, but it has hurt the industry.

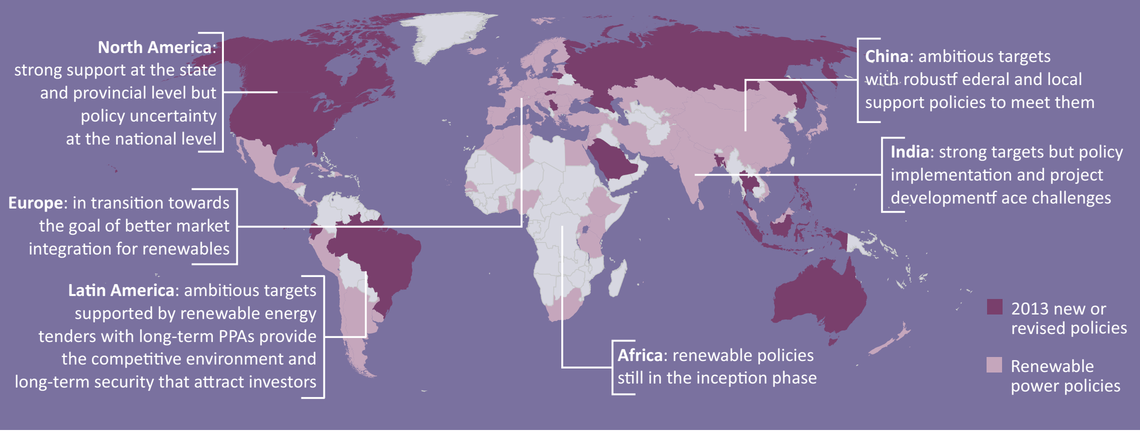
Greece experienced a solar PV boom in 2012 but introduced FiT cuts and retroactive taxes in 2013, which dramatically decreased investor interest in solar PV. The Romanian government has proposed suspending half of the wind certificates due under current incentive arrangements until 2018, applying retroactively to all projects started after 1 July 2013. In Spain, the 2013 electricity reform abandoned all FiTs and premiums provided to renewables retroactively by introducing a cap to limit projects' profits based on the average yield of Spanish government bonds. Also, the moratorium on renewable energy subsidies and the additional 7% tax for all power generators are still in place.

Inflexible and overly generous remuneration mechanisms may also be detrimental. Japan revised its PV FiT downward by only 10% in 2013, still maintaining tariff levels more than twice as high as Germany. This led to record deployment in 2013 but at a relatively high cost, and prompted questions over the financial sustainability of the FiT.

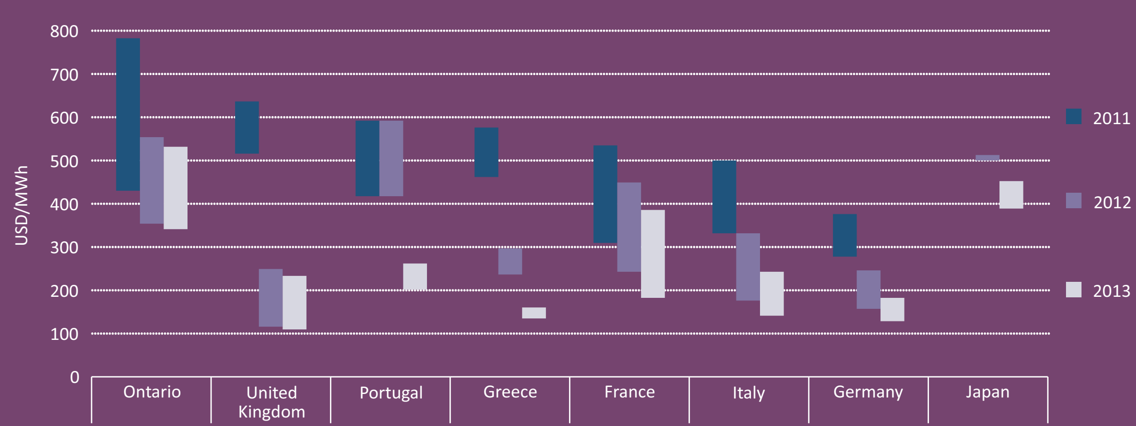
Stable policy can lead to lower cost of capital, which helps renewable technologies that have relatively high up-front costs. Long-term market power planning combined with competitive bidding (such as tenders and auctions for long-term power purchase agreements) has proved effective in triggering competitive deployment of renewables. In 2013, wind power won the majority of long-term contracts in Brazil in competition with other technologies, including natural gas. South Africa announced its third bid window for several renewable energy technologies with costs for onshore wind being around 30% lower than those for new coal plants. Saudi Arabia unveiled a white paper detailing the tender process for new solar PV and CSP plants.

Early estimates indicate that investment in renewable power was USD 211 billion in 2013, down 12% compared with 2012 and 22% lower than the record USD 270 billion in 2011, partly reflecting cost reductions but also due to uncertain policy and market frameworks.

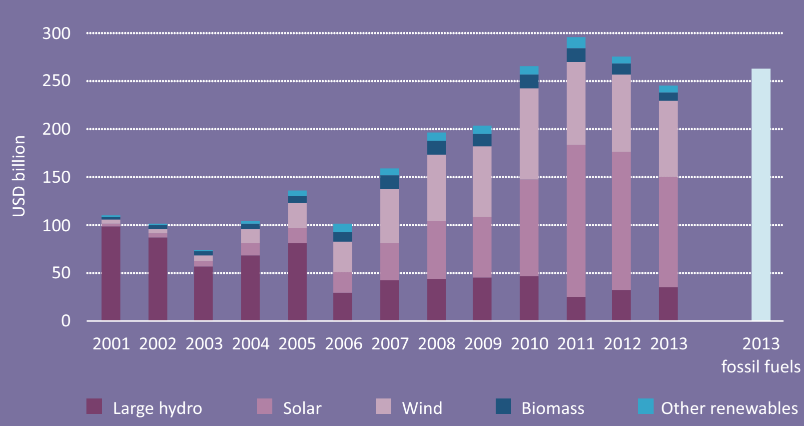
1.3 Renewable power policies



1.4 Solar PV feed-in tariffs



1.5 Capacity investment



55%

ASIA'S SHARE OF NEW SOLAR PV INSTALLATIONS IN 2013, LED BY CHINA AND JAPAN

For sources and notes see page 71

Technology developments

In 2013, price reductions of solar PV modules slowed considerably following a consolidation in the industry. Between 2008 and 2012, module prices decreased by around 80% from USD 3.98 per watt (W) to USD 0.79 per watt, while in 2013 prices remained more or less stable. The European Union and China agreed on a minimum export price (EUR 0.56/W) for Chinese solar panels in the EU, with imports at this price from China capped at 7 GW (a high import tariff is applied to additional imports from China).

Reductions in investment costs for CSP are expected to accelerate following the commissioning of large new projects in 2013 and early 2014. The United States commissioned the three largest CSP plants in the world: Ivanpah (391 MW tower with direct steam generation at an investment cost of USD 5 600 per kilowatt [kW]); Solana (280 MW with six-hour storage at USD 7 600/kW); and Crescent Dunes (110 MW with ten-hour storage at USD 9 000/kW). Offshore wind projects totalling 1.6 GW became operational in Denmark, Germany and the United Kingdom in 2013, but investment costs are expected to increase in coming years as projects will be installed farther from the coast.

Costs per kilowatt hour (kWh) of electricity can fall more quickly than costs per installed kW. Wind turbine manufacturers have focused on turbines that can harness more energy at equal capital costs, and on site-tailored overall project development and management. These are often low- and medium-wind turbines in the 2.0 MW to 2.5 MW capacity range. Similarly, higher efficiency of PV systems in areas with higher capacity factors led to increased average output per installed MW capacity in 2013. The world's first unsubsidised, utility-scale solar PV power plant was financed in Chile in 2013, and is to sell electricity to the wholesale market without a power purchase agreement. In Brazil, utility-scale solar PV was included for the first time in energy auctions, although no PV project was selected in the end. The government is now planning to open solar-only auctions.

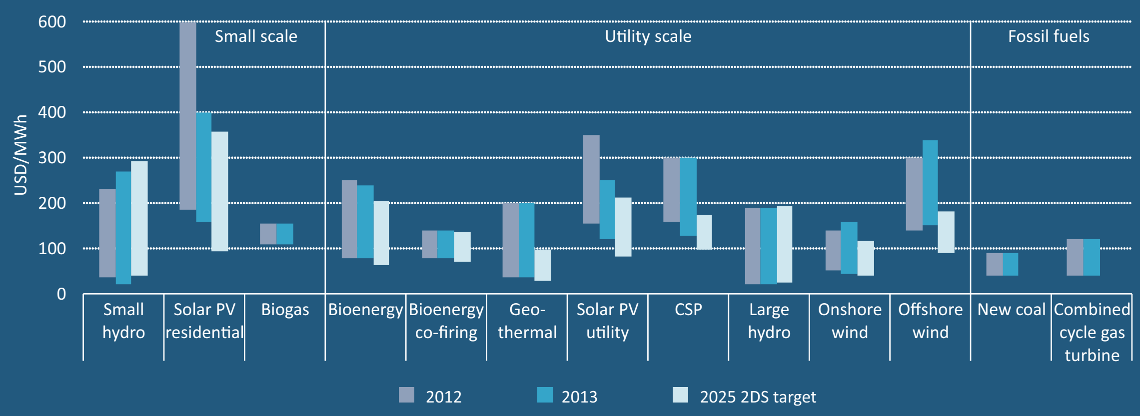
The falling costs of distributed solar PV systems are increasingly supporting deployment for self-consumption in markets such as Italy, Germany and California where costs for self-generation are on par with household electricity prices. Turkey's first commercial self-consumption solar PV plant was commissioned in 2013.

For geothermal, early-stage exploration and drilling risks remain a major deployment challenge. Technology development activities focus on enhanced geothermal systems, which can be used to upgrade existing wells or create geothermal reservoirs where none previously existed. Several testing activities are under way in the United States. Still, the degree to which commercial-scale deployment in existing plants or new projects will transpire over the next five years is uncertain.

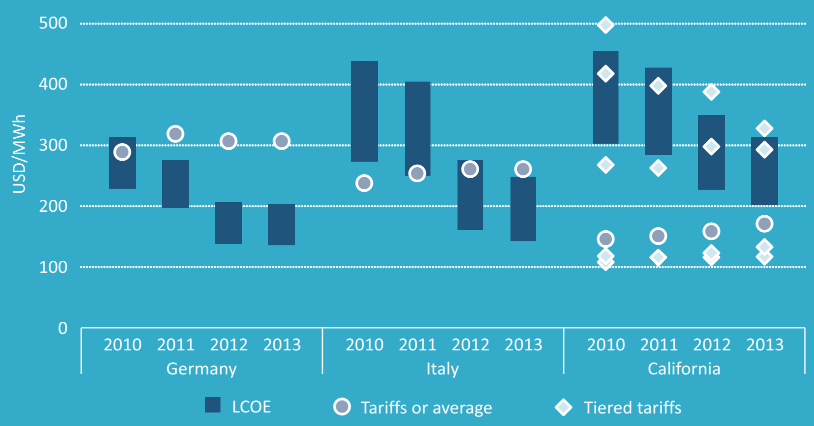
Ocean power technologies are still at the research and development (R&D) stage, and most remain relatively expensive. As of 2013, there were ten wave and tidal single-device test machines operational ranging from 250 kW to 1000 kW in the European Marine Energy Centre (EMEC), the largest ocean energy test centre in the world. The SeaGen tidal stream device in the United Kingdom, commissioned in 2008, remains the largest operational generating capacity.

Increased investment in research, development and demonstration (RD&D) in emerging technologies, particularly ocean and enhanced geothermal, is needed to enhance competitiveness. In 2012, public RD&D expenditure on fossil fuels and nuclear combined was 80% higher than on renewable technologies.

1.6 Levelised cost of electricity



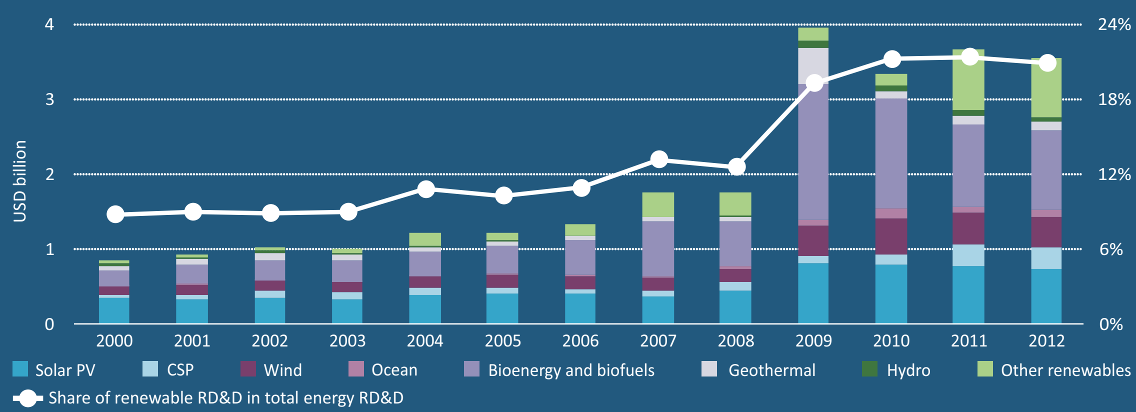
1.7 Residential solar PV LCOE and electricity prices



56%

IEA COUNTRIES PUBLIC RD&D EXPENDITURE ON RENEWABLE TECHNOLOGIES COMPARED TO FOSSIL FUELS AND NUCLEAR COMBINED IN 2012

1.8 IEA public RD&D spending



For sources and notes see page 71

Nuclear Power

Not on track

Global nuclear generation declined to around 2 350 TWh in 2012,[2] a 7% decrease from 2011 levels. Installed nuclear capacity remained virtually unchanged in 2013 at 393 GW (gross), yet 2013 also saw ten construction starts, representing some 11 GW, up from seven starts in 2012. A record 72 nuclear reactors were under construction at the end of 2013.

Technology penetration

Several new countries show interest in nuclear power: units are under construction in Belarus and the United Arab Emirates, and projects are well advanced in Turkey and Viet Nam, and under discussion in Bangladesh, Jordan, Poland and Saudi Arabia.

The transition to Generation III (Gen III) light-water reactors, which are designed to increase efficiency and reduce the likelihood and mitigate the consequences of severe accidents, is accelerating. Thirty of the reactors currently under construction are Gen III, and China has announced it will build only Gen III reactors. Construction spans of Nth of a Kind (NOAK) Gen III reactors in China seem close to 60 months, helped by established supply chains and workforces.

Still, installed capacity in 2025 will likely be 5% to 24% below the 2DS target. All of Japan's 50 reactors are now idle after the last two operational units were stopped in 2013. Four reactors were closed in the United States due to the cost of refurbishment and unfavourable economics compared to gas-fired generation.

Market creation

Nuclear energy policies have been debated in countries with mature nuclear industries, such as Japan, Korea and France. In February 2014 Korea set a target for the share of nuclear capacity to 29% by 2035 (down from the previous target of 41%), and Japan confirmed that nuclear energy will be part of its energy mix, though the level is yet unknown. A number of other countries have confirmed their desire to build new nuclear reactors.

The United Kingdom is pushing ahead with guaranteeing energy prices for low-carbon technologies including nuclear. For two new nuclear units, the government has proposed a guaranteed "strike price" of GBP 92.50 per megawatt hour over 35 years, meaning the government will top up the income to this level if wholesale prices are lower or recover the difference from the utility if prices are higher. This investment framework still has to be authorised by the European Commission.

Russia's "build, own, operate" model is attracting interest as it allows countries to transfer the high capital costs of nuclear investments to long-term guaranteed electricity prices paid by the customers. In addition, Russia is offering part-equity financing in a number of other countries.

Overall, financing of nuclear power, which has high capital costs and low running costs, is increasingly challenging – a problem shared with other low-carbon technologies such as carbon capture and storage (CCS) and offshore wind.

Technology developments

Following the Fukushima Daiichi accident, many existing Gen II plants are being equipped with additional emergency power supply systems and cooling capabilities, and other accident mitigation systems.

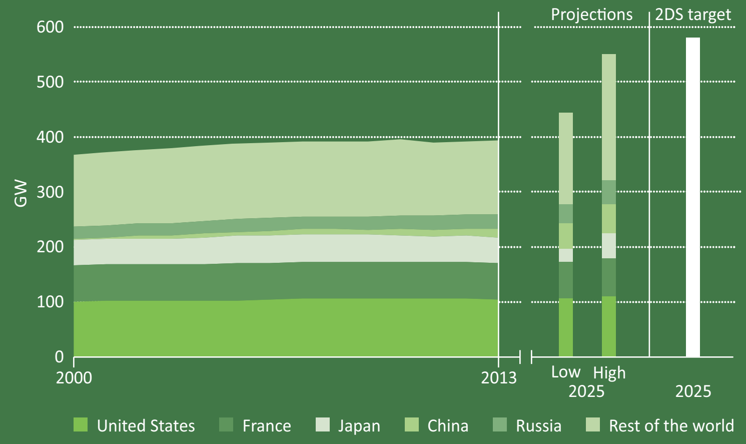
Development of small modular reactors has continued, with various levels of pre-licensing activity, especially in the United States, but only two construction projects have been launched (in Russia and recently in Argentina).

Some prototypes of advanced reactors with Gen IV type technologies are being built, but no industrial deployment is expected for several decades.

Projects for geological disposal of high-level waste made progress in Sweden, Finland and France. In the United States, the review of application to operate the Yucca Mountain site as a repository for high-level waste was resumed. The European Commission has required all European countries to submit their plans for disposal of radioactive waste by 2015.

2 Statistics in this section derive from the International Atomic Energy Agency (IAEA) Power Reactor Information System (PRIS) database.

1.9 Installed gross nuclear capacity



Recent developments

Japan confirmed that nuclear energy will be part of its energy mix, though the level is yet unknown

Korea lowered its target for the share of nuclear capacity to 29% by 2035

The UK government offered guaranteed price levels over 35 years to a new nuclear facility

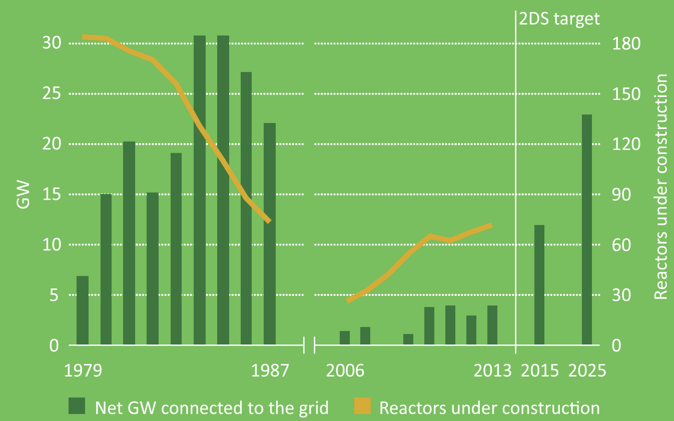
23

GW REQUIRED CAPACITY ADDITIONS YEARLY FROM 2020 TO 2030

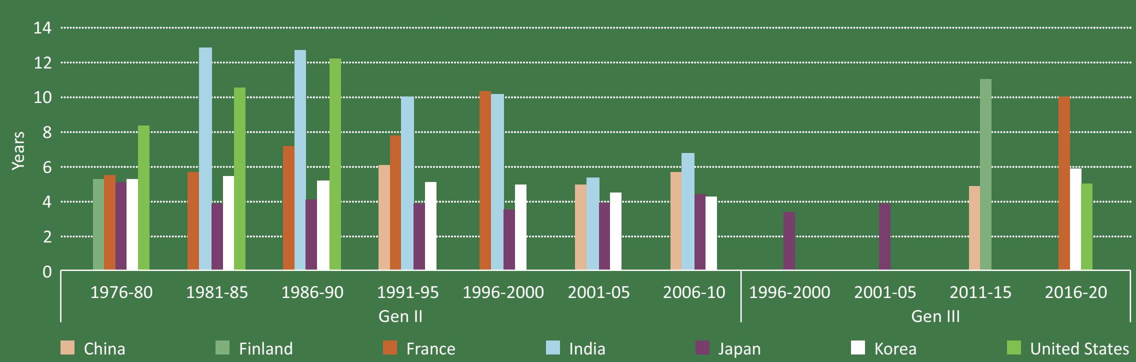
30

GW HISTORIC HIGH IN CAPACITY ADDITIONS

1.10 Capacity additions



1.11 Construction span for Gen II and Gen III reactors



For sources and notes see page 71

Natural Gas-Fired Power

Improvement needed

Natural gas lowers carbon dioxide (CO_2) emissions in two principal ways: directly by displacing coal and indirectly by providing flexible support for variable renewables. With a 1.5% increase over 2010, natural gas-fired power generation reached 4 850 TWh globally in 2011, 22% of total power generation.

Technology penetration

In the OECD region, growth is even quicker, 6% in 2012 compared with 2011. A five-year period of shift from coal to gas in the United States stalled in 2013 though, following a slight rebound in natural gas prices and a relatively cool summer.

Despite high prices, Japan increased its dependence on imported natural gas to ensure reliable electricity supply, following the shutdown of all nuclear reactors subsequent to the Fukushima Daiichi accident. The future of nuclear and the possibility of electricity system liberalisation will define the future of natural gas power. Natural gas remains the dominant fuel in ASEAN countries, but high natural gas prices and power demand growth double the global average make coal an increasingly attractive alternative.

In the European Union 20 GW of combined-cycle gas turbine (CCGT) plants were either mothballed in 2013 or are under threat of being so as utilisation rates fell below 25% for some units. In OECD Europe the share of natural gas in the power mix fell from 22% to 19% between 2011 and 2012. Decreasing power demand, overcapacity, the rise of renewable energy and low coal prices make the situation for natural gas power challenging.

Market creation

Development of natural gas trade capacity is accelerating, sparked by high price spreads among regions. Liquefaction capacity increased to roughly 400 billion cubic metres (bcm) globally, with an additional 140 bcm under construction (IEA, 2013b). As of end-2013, the United States had approved applications to build four terminals to export liquefied natural gas (LNG) to countries outside the US free trade agreements (non-FTA countries). China began the last phase to increase the capacity of a 5 000 km west-east pipeline that connects to the Central Asia pipeline system (completion in 2015).

Replication of the US shale gas boom in other regions seems unlikely in the short to mid term. Governments remain divided on exploration policy and geological uncertainty is high. In China, a number of appraisal wells have been drilled, but extraction is expected mainly after 2020: the official target is 6 bcm by 2015 and 100 bcm by 2020. The Indian government approved shale gas exploration. In Europe, a handful of countries have banned fracking while others issue exploration licenses. So far test drilling has shown less favourable conditions than in the United States and local opposition is strong in some places.

Technology developments

The focus of gas turbine design is shifting to flexibility performance as the role of natural gas evolves. High cycle efficiency that includes good ramping capabilities, quick start-up time, low turndown ratio and good part-load behaviour are now major design parameters. All major turbine manufacturers have released upgrades or new designs since 2012 to meet the power sector's need for flexibility.

In parallel, moderate full-load efficiency improvements continue. Top open-cycle gas turbine (OCGT) efficiency has risen to around 42% from around 35% in 1990. The best CCGT efficiency now exceeds 60%, up from about 55% in 1990.

Rising flexibility needs make internal combustion engines (ICEs) increasingly attractive for power, as single-unit plants (< 20 MW), stacked in so-called "bank" or "cascade" plants (20 MW to 200 MW), or operated with a combined steam cycle (> 250 MW). At 48% full-load efficiency, ICEs outperform OCGTs (< 42%) but fall short of CCGTs (< 61%), while having better flexibility and part-load efficiencies. Nine of the world's ten largest ICE-based power plants were to start between 2010 and 2014, all in developing countries.

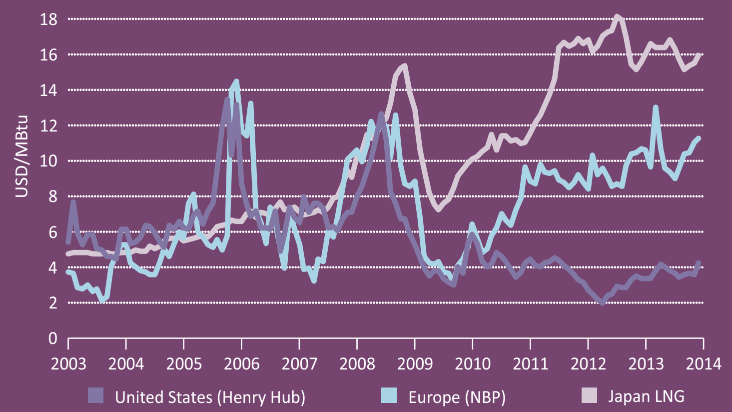
Coal-to-gas or gas-to-coal?

Regional market dynamics are producing divergent trends in coal to gas fuel switching

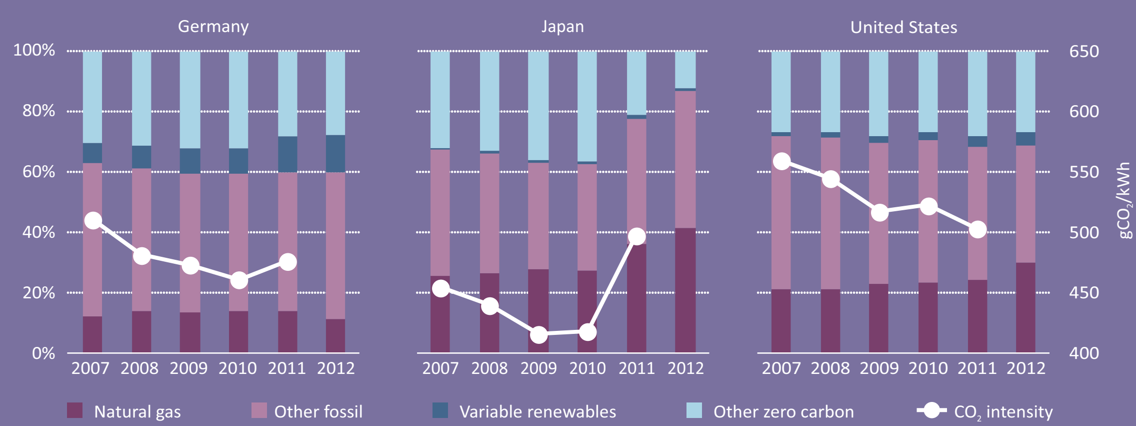
A replication of the United States shale gas boom in other regions seems unlikely in the short to mid-term

A five-year period of shift from coal to gas in the United States stalled in 2013

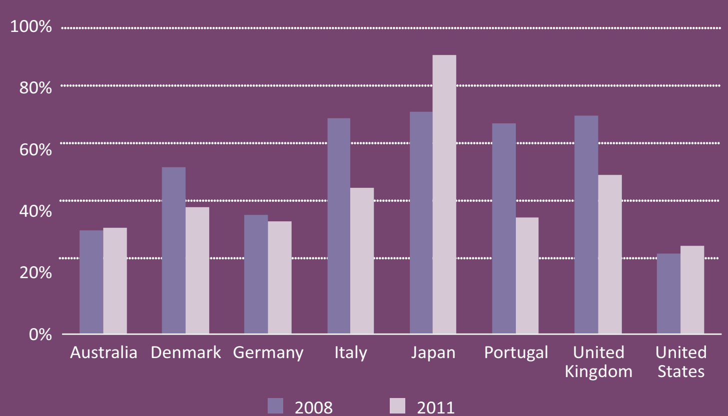
1.12 Natural gas spot prices



1.13 Power generation mix and related CO_2 intensity



1.14 Natural gas-fired power capacity factors



EU CO_2 PRICE

50 €/tCO_2

FOR SHORT-TERM COAL-TO-GAS GENERATION SWITCH

20 €/tCO_2

FOR LONG-TERM CAPACITY INVESTMENT SWITCH

For sources and notes see page 71

Coal-Fired Power

Not on track

Coal continues to dominate global power generation. In 2011, coal-fired electricity generation was over 9 100 TWh, a 52% increase over 2000 levels. At 41%, coal has the largest share in global generation by far. Driven by coal-to-gas switching in the United States, the share of coal in power generation fell to 32.1% in OECD in 2012, down from 33.4% in 2011.

Technology penetration

China and, to a lesser extent, India play key roles in driving this growth in demand. In 2012, China built 48 GW of new coal capacity and accounted for almost 50% (3 678 million tonnes [Mt]) of global coal consumption; India's share (753 Mt) was almost 10%. In Germany, 2.7 GW of lignite capacity became operational in 2012. Primary coal demand is estimated to increase from 158 exajoules (EJ) (7 697 Mt) in 2012 to 186 EJ (8 799 Mt) in 2018 (+ 2.3% per annum). These trends are not compatible with the 2DS.

The efficiency of generation is increasing. Globally, 64% of plants under construction are supercritical or ultra-supercritical, up from 50% in 2012. More than 60% of subcritical units under construction are in India. Between 2006 and 2010, China retired 77 GW of old inefficient plants, with a target to retire a further 20 GW by 2015. Having recently retired 1.4 GW, Germany plans to retire a further 1.5 GW by 2015. These essential trends to increase global generation efficiency must be combined with accelerated development of CCS if 2DS targets are to be reached.

Market creation

Policy offers routes to emissions reductions. China's recently released Air Pollution Action Plan aims to reduce the share of coal below 65% of total power generation by 2017 (from 79% in 2011). In September 2013, China announced that it will ban construction of new coal-fired power plants in the Beijing, Shanghai and Guangdong regions. Overall, the provinces around Beijing will reduce annual coal consumption by 73 Mt, around 10% of 2012 levels.

While Canada has already imposed emissions performance standards on its coal plants to become effective in 2015, the US Environmental Protection Agency's proposal to limit CO_2 emissions to 500 gCO_2 per kilowatt hour for new coal-fired plants, a level that cannot be achieved without CCS, was published in the Federal Register in January 2014. Furthermore, the EPA proposes to issue emissions standards for existing power plants by mid-2014, to be finalised by mid-2015.

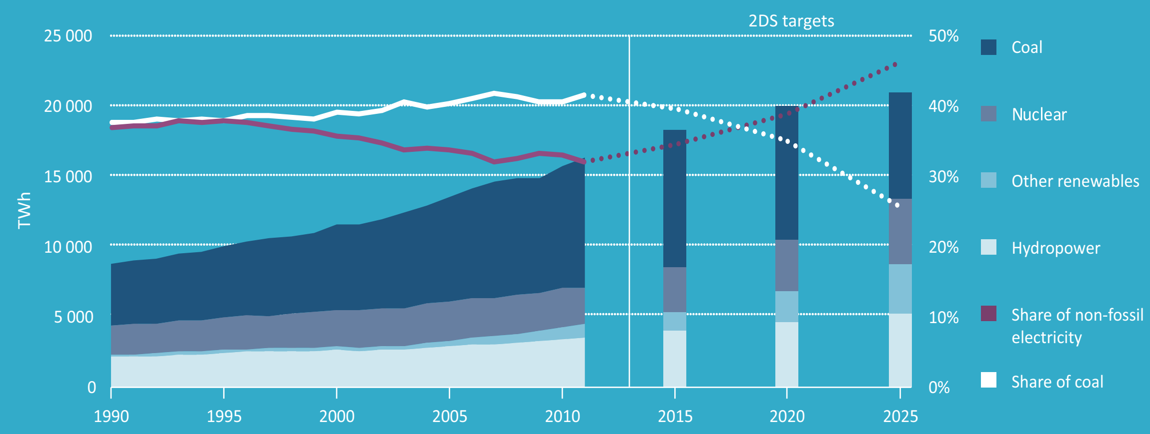
Cleaner use of coal can be achieved by strengthening bilateral or multilateral co-operation. China and the United States, the world's two largest coal users, emphasised in 2013 further co-operation in cleaner coal use, pollutant control in pulverised power generation plants, CCS, and selected CO_2 utilisation options.

Technology developments

The size of units is increasing, again, trends are most pronounced in China. The country has become a world leader both in number of installed units and in unit size. China installed the first 1 GW ultra-supercritical coal-fired unit in 2006, and by mid-2012, a further 46 units of this size were in operation. Japan's 600 MW Isogo Power Station Unit 2 possesses the world's most advanced environmental control system to minimise sulphur dioxide (SO_2) and nitrogen oxide (NO_X) emissions, as well as waste-water discharge. With a net efficiency of 45%, it emits over 25% less CO_2 than a plant operating with global average efficiency.

A major advantage of integrated gasification combined cycle (IGCC) plants is that they may reduce the cost of CO_2 capture. Climate change targets therefore offer the technology a second opportunity, after the cost of generation halted commercial interest after the first wave of IGCCs was commissioned in the 1990s. IGCC plants have recently been commissioned in China (GreenGen in Tianjin) and the United States (Edwardsport in Indiana), with further plants following closely behind in the United States (Kemper County, Hydrogen Energy California and Summit Texas Clean Energy) and in Japan (Osaki).

1.15 Coal and non-fossil power generation



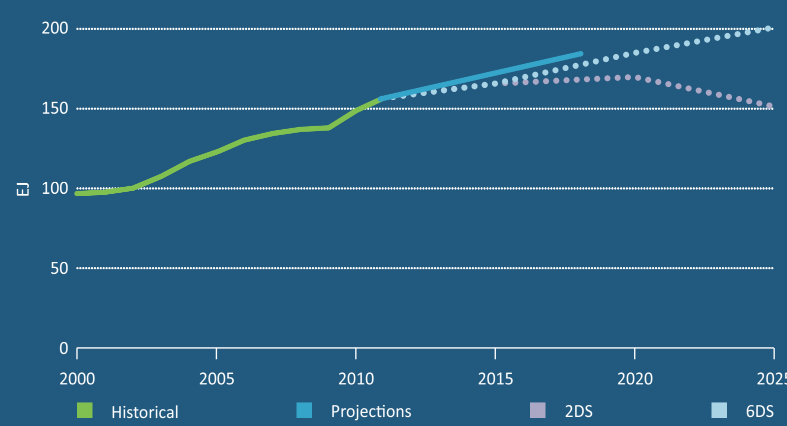
Key trends

Around half of new power plants in 2012 used inefficient subcritical technologies

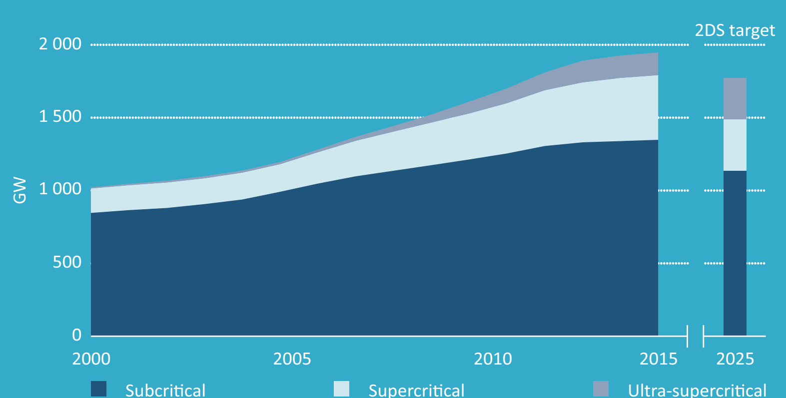
Decommissioning of old plants continues in China with close to 100 GW of inefficient plants taken offline since 2006

Proposed policies in the United States would prohibit construction of new coal plants without CCS

1.16 Global coal demand



1.17 Coal capacity deployment



33%

GLOBAL COAL FLEET AVERAGE EFFICIENCY, COMPARED TO 46% WITH ULTRA-SUPERCRITICAL

For sources and notes see page 71

Carbon Capture and Storage

Not on track

Deployment of CCS in both power and industry is critical to address climate change. While progress is being made in demonstrating elements of capture, transport and storage the current pace of development must grow rapidly if CCS is to fulfil its potential.

Technology penetration

As of end-2013, four large-scale CCS projects are in operation and have captured and stored approximately 55 $MtCO_2$ in total. In addition, four large-scale enhanced oil recovery (EOR) projects that demonstrate elements of CO_2 capture, transport and storage entered operation in 2013, bringing the number of projects using anthropogenic CO_2 for EOR to eight.

Construction of nine large-scale projects with combined potential to capture and store an additional 14 $MtCO_2$ per year by 2016 is proceeding in Australia, Canada, Saudi Arabia, the United Arab Emirates, and the United States. Among these are two of the first projects built in the electricity sector. An additional 15 projects are in advanced stages of planning; if built, they could contribute an additional 29 $MtCO_2$ per year.

Of these 36 projects, 28 are in OECD countries. In the 2DS in 2025, OECD countries contribute only one-third of the CO_2 captured – additional demonstrations are thus needed in non-OECD countries. In the 2DS, 226 $MtCO_2$ per year are captured and stored by 2025, which means that the rate of capture and storage must increase by two orders of magnitude in the next decade to achieve 2DS targets.

Market creation

One CCS project took a positive final investment decision in 2013, and increasing the cumulative investment in CCS by USD 123 million to USD 10.5 billion. Up to six projects are expected to take final investment decisions in 2014.

OECD governments offered approximately USD 22 billion in direct financial support to large-scale CCS projects between 2008 and 2012. Most funded projects in North America are progressing, but few projects were funded in Europe and Australia, and many have since been cancelled or face serious delays.

Development of co-ordinated policy packages that address distinct market risks will be crucial in the coming years. In late 2013, the United Kingdom passed legislation that will allow the government to provide operating support to CCS projects. This mechanism will operate alongside a CO_2 price floor and emissions performance standard for new power generation. Carbon pricing is a critical long-term driver for CCS but is unlikely to stimulate deployment in the short term. In 2013, the US EPA proposed a rule that would require new coal-fired generation to be equipped with CCS. If this rule is adopted, the United States will join Canada and the United Kingdom in having regulations that effectively prohibit construction of new coal-fired generation without CCS. Moreover several international financing banks restricted funding for coal plants without CCS.

In the near term, utilisation of captured CO_2 (such as in EOR), will continue to drive interest in CCS, particularly from private investors: 24 large-scale projects are providing, or are expected to provide, CO_2 for EOR.

Technology developments

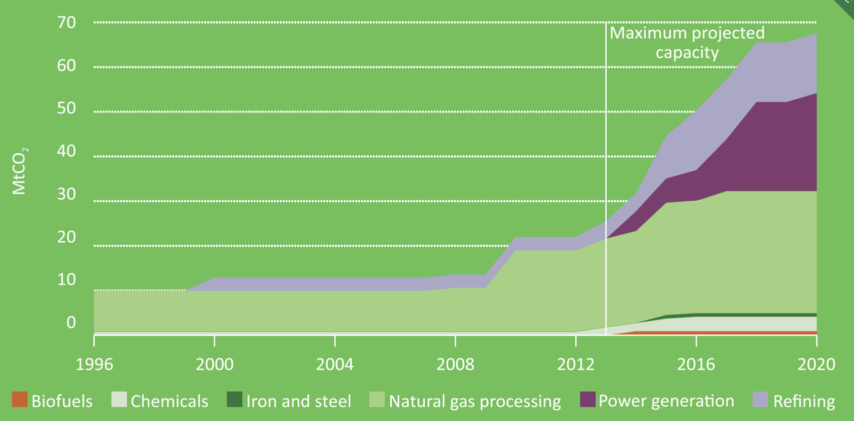
At least six CCS pilot projects began operation in 2013, and construction of several other projects has been announced, including a capture demonstration at a cement plant in Norway. This brings the total number of CCS pilot projects to approximately 60.[3]

IEA member governments spent an estimated USD 1.1 billion on RD&D for CCS in 2012, about 6.6% of their total energy RD&D expenditure, up 21% from 2011. The share of CCS in fossil fuel RD&D expenditure has increased significantly since 2008, from 22% to almost 54% in 2012. The number of new patent applications that relate to CCS continues to grow each year. Commercial interest in developing relevant technologies is still growing, but the level of patenting activity in 2012 may signal a slight softening of the exponential growth between 2006 and 2011.

3 Pilot projects are defined as those that test one or more elements of capture, transport or storage at a scale that is one or two orders of magnitude below that required for commercial use, in this case on the order of 10 kilotonnes of CO_2 per year. For information on storage projects, see GHG IA, 2013 for capture, see Aldous et al., 2013.

1.18 Large-scale CO_2 capture projects

More online



55

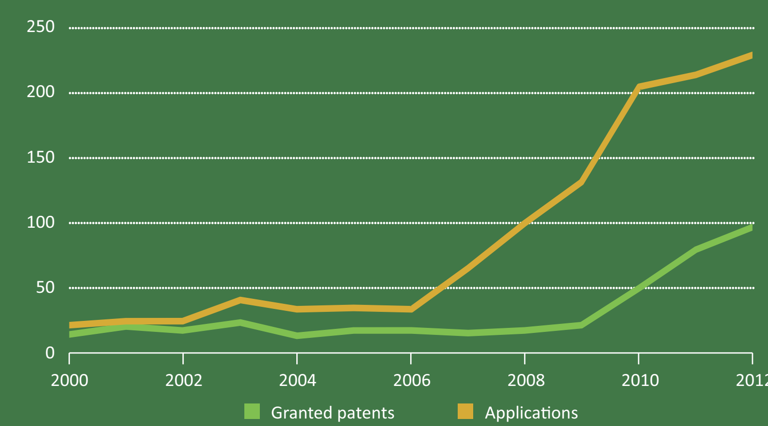
MILLION TONNES OF CO_2 STORED WITH MONITORING SO FAR

Key developments

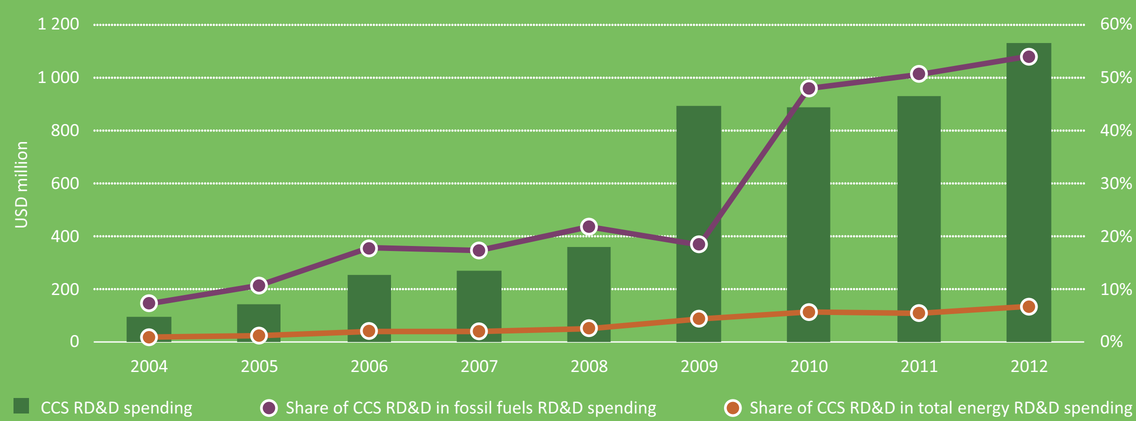
The first two coal-fired power plants to capture over 1 million tonnes of their CO_2 per year will start operation in 2014

Commercial CO_2 capture in the refining and gas processing sectors continues to provide CO_2 for EOR, increasing confidence in the technology

1.19 Patenting activity in CCS-related technologies



1.20 IEA public RD&D spending



For sources and notes see page 72

Industry

Improvement needed

Global industrial energy intensity has decreased 10% since 2000, mainly as a result of efficient capacity additions in emerging economies outweighing the upward effects of structural changes in the sector.[4] Despite this trend, industrial energy use and CO_2 emissions increased significantly.

Technology penetration

Industrial energy use reached 143 EJ[5] in 2011, up 36% since 2000. The increase is largely fuelled by rising materials demand in non-OECD countries, which now use 66% of industrial energy, up from 50% in 2000. Growth in industrial energy use must be cut to 1.7% per year in the period from 2011-25 compared with 3.3% per year in 2000-11. Similarly, trends in industrial CO_2 emissions must be reversed: from 2007 to 2011, emissions grew by 17%; by 2025, they must be reduced by 17% to meet 2DS targets.

Improvements in energy efficiency have offset the upward effect of structural changes in the industrial sector, such that overall industrial energy intensity is decreasing; in 2011 most regions were below a level of ten gigajoules (GJ) per thousand USD purchasing power parity (PPP) of industrial value added. China (2.4%) and India (1.9%) have had the highest annual reductions since 2000. Thanks to high shares of new capacity, China is now among the world's most energy-efficient primary aluminium producers.

Substantial potential to further improve energy efficiency exists. By applying current best available technologies (BATs), the technical potential to reduce energy use in the cement sector is 18%, 26% in pulp and paper, and 11% in aluminium. These potentials are unlikely to be fully tapped by 2025 due to slow turnover of capacity stock, high costs and fluctuation in raw material availability. Meeting 2DS targets will also require resolving challenges related to increased use of alternative fuels and clinker substitutes, and greater penetration of waste heat recovery (WHR)[6] in the cement sector, among others.

Market creation

Energy management systems (EnMS) can be effective tools to enable energy efficiency improvements, but in most countries they are still voluntary. In 2013, China mandated provincial-level implementation of energy management programmes in companies covered by the Top-10 000 Program, an energy conservation policy for large energy users. In the United States, pilot companies in the Superior Energy Performance programme on average improved their energy performance by 10% in 18 months. The Australian Energy Efficiency Opportunities programme, which is mandatory for large energy users, was estimated to have enabled 40% energy savings in participating firms. A growing number of industrial sites have certified EnMS (ISO 50001) in place: 6 750 in 70 countries in March 2014, up by more than 300% over the previous year (Peglau, 2014).

Technology developments

Innovative energy-saving technology developments have been relatively slow in energy-intensive industries over the last decade and need to accelerate: in the 2DS for instance, deployment of CCS starts before 2025. To stimulate investment in CCS, industry is investigating opportunities for CO_2 use in EOR and developing processes that use CO_2 as a feedstock (e.g. in polymer production).

In pulp and paper, the Confederation of European Paper Industries (CEPI) announced in 2013 promising lab-scale results of deep eutectic solvents (DES) allowing the production of pulp at low temperatures and atmospheric pressure. Applying DES-based pulp making throughout the sector could reduce CO_2 emissions by 20% from current levels by 2050 (CEPI, 2013).

4 Structural changes in the industrial sector refer to a shift in the share that energy-intensive industries represent in total industrial energy use. The energy-intensive sectors increased their share to 67% in 2011 from 57% in 1990.

5 Industry energy use data includes feedstock in the chemicals and petrochemicals sector, and coke ovens and blast furnaces in the iron and steel sector.

6 IEA analysis shows that 12% to 15% of the power consumption of a cement plant can be generated by WHR technologies.

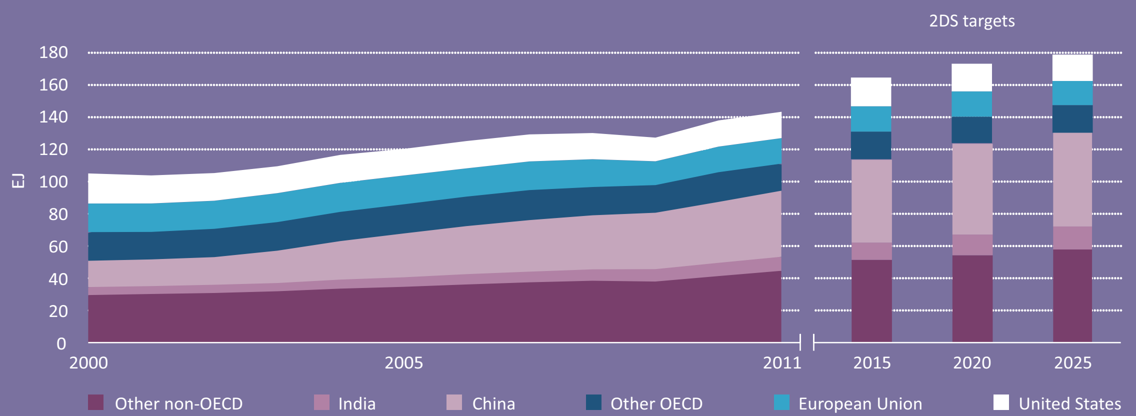
1.21 Energy intensity by product

	2011				2025 2DS targets		
	Current BAT	World	OECD	Non-OECD	World	OECD	Non-OECD
Paper and paperboard (GJ/t)	n.a.	7.6	7.5	7.7	6.7	6.8	6.6
Clinker (GJ/t)	3.0	3.7	3.6	3.7	3.6	3.5	3.6
Primary aluminium (kWh/t)	13 611	14 788	15 587	14 509	13 383	14 833	13 141

26%

TECHNICAL POTENTIAL TO REDUCE ENERGY USE IN THE PULP AND PAPER SECTOR BY APPLYING BATS

1.22 Global industrial energy use

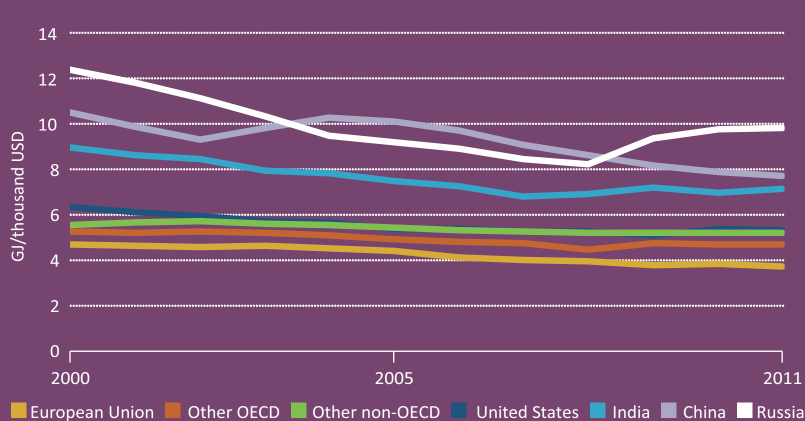


Key developments

12% to 15% of the power consumed in a cement plant can be generated through waste heat recovery

Energy management systems and programmes are receiving increasing policy attention

1.23 Aggregated industrial energy intensity



For sources and notes see page 72

Chemicals and Petrochemicals

Improvement needed

Accounting for 28% of total industrial energy use in 2011, the chemicals and petrochemicals sector is the largest industrial energy user. Energy use in the sector grew by 2.5% annually from 2000 to 2011. With demand for chemical and petrochemical materials projected to grow even faster in the coming years, the annual increase in energy use must be kept to 4.3% to meet 2DS targets; this will still result in a total increase of 60% in 2025 over 2011 levels. In parallel, CO_2 emissions must be cut by 30% compared with 2011. Both targets require significant improvements over current trends.

Technology penetration

In the 2DS, production of high-value chemicals (HVC)[7] is expected to grow from 320 Mt in 2011 to 485 Mt in 2025 (up 52% on 2011 levels), with notable production growth in ammonia (31%) and methanol (126%). The Middle East and China remain the major HVC producers and have the highest growth projections, even though the availability of cheap natural gas and natural gas liquid products from the exploitation of unconventional gas resources has driven a recent regional shift of production towards North America. Improvements in efficiency (based on increased levels of process integration driven by increasing energy prices), along with waste heat recovery and expansion of new, more efficient capacity, can help decouple materials demand growth from energy use.

Application of best practice technologies (BPTs) could save 24% of current energy use. This technical energy savings potential is unlikely to be fully tapped by 2025 due to dependency on existing production capacity stock turnover, demands for returns on investment for upgrades/refurbishment projects, fluctuation in raw material availability, etc. Reaching the 2DS targets requires that all new and refurbished plants adopt BPTs, switch to low-carbon fuels and increase recycling, and that emerging technologies start playing a role by 2020. Savings on process heat has the largest savings potential; the United States, a leading producer of chemicals and petrochemicals, has the largest savings potential of any country.

Market creation

No major new energy policy initiatives affecting the chemicals industry occurred in 2013; however, increased discussion between policy makers and industry was evident, particularly in Europe. The ongoing debate centres on how to reconcile sustainability and competitiveness (CEFIC, 2013).

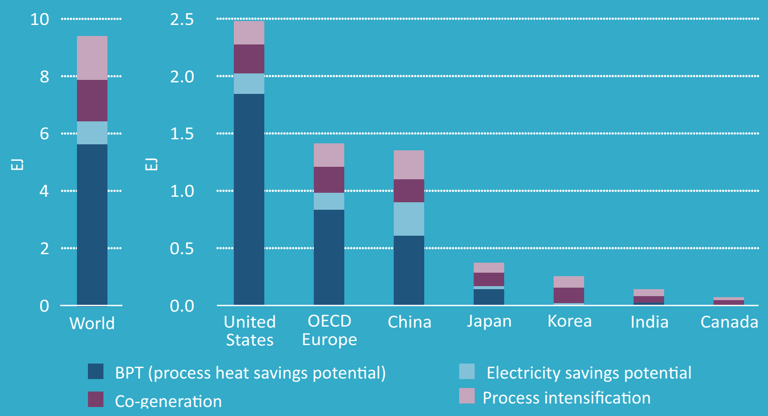
The IEA collaborated with the International Council of Chemical Associations (ICCA) and DECHEMA, the Society for Chemical Engineering and Biotechnology, to publish (in 2013) the *Technology Roadmap: Energy and GHG Reductions in the Chemical Industry via Catalytic Processes*. The roadmap also provides recommendations to policy makers and industry to enable implementation of identified savings potential (about 5 EJ by 2025,[8] or 13% of current sector energy use) (IEA, ICCA and DECHEMA, 2013).

Technology developments

Broad deployment of emerging technological improvements would be required to meet 2DS targets for the chemical industry. CCS applications should be successfully demonstrated by 2020 and should capture about 4% of the sector's CO_2 emissions by 2025. The methanol-to-olefins route, while more energy-intensive than steam cracking when the methanol production stage is included, allows for using biomass instead of fossil resources as feedstocks. Catalytic cracking can provide further energy efficiency benefits, using up to 20% less energy than steam cracking (Ren, Patel and Blok, 2006). This technology is currently at pilot scale.

7 HVCs include ethylene, propylene and BTX (benzene, toluene and xylene).
8 Energy savings resulting from comparing Business as Usual scenario and the Emerging Technologies scenario in 2025.

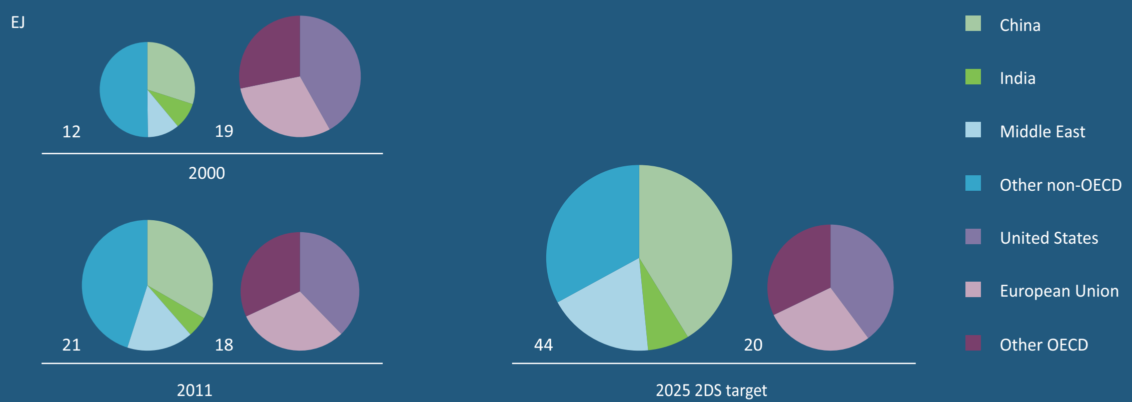
1.24 Energy savings potential in 2011



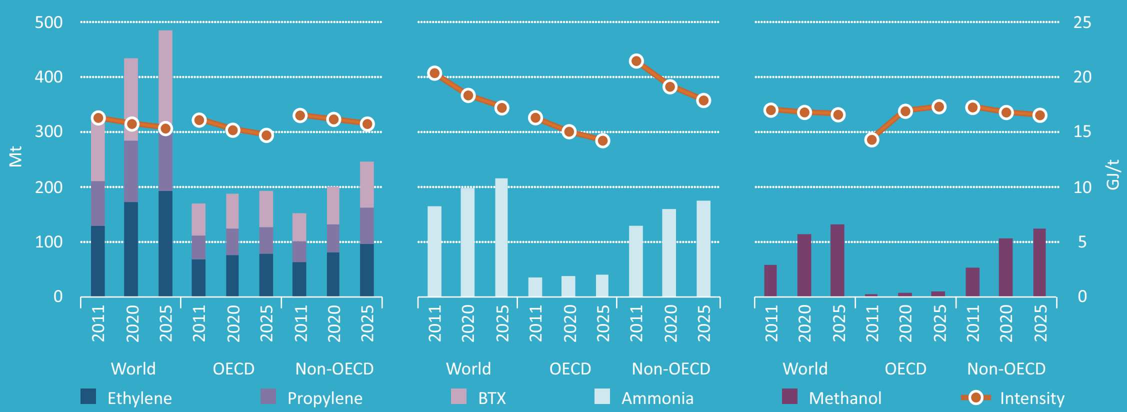
24%

OF ENERGY COULD BE SAVED WITH THE APPLICATION OF BEST PRACTICE TECHNOLOGIES IN THE SECTOR (6.6% OF INDUSTRIAL ENERGY)

1.25 Global energy consumption by region



1.26 Production and energy intensity



For sources and notes see page 72

Iron and Steel

Improvement needed

The iron and steel sector is the second-largest industrial energy consumer, accounting for 22% of total industrial energy use in 2011. The sector's energy use grew by 6.2% annually from 2000 to 2011, driven by increases in crude steel production (7.1% in 2011). In the 2DS, growth in annual energy use must be limited to 1.2% and CO_2 emissions must be 13% lower in 2025 compared with 2011 levels, even though crude steel production is expected to grow by 27%. Current trends run counter to this projection.

Technology penetration

Energy intensity is relatively stable in the steel industry: 20.7 GJ/t crude steel in 2011 versus 21.7 GJ/t crude steel in 2000. Positive effects of more efficient production capacity have been offset by a decline in recycling as a share of total crude steel production; from 47% in 2000 to 29% in 2011. Primary drivers include China's increased share of blast furnace/basic oxygen furnace technologies rather than scrap-intensive electric arc furnace (EAF) due to insufficient scrap availability, as well as the increasing amount of steel in products still in use. The overall share of EAF production from total crude steel must increase to 37% by 2025 to meet 2DS targets.

About 21% of energy use could be saved if current BATs were applied, but inertia in capacity stock turnover and high costs are slowing progress. Reaching 2DS targets requires that all new and refurbished plants adopt BATs, phase out open-hearth furnaces (OHFs) and limit coal-based direct reduced iron (DRI) production. Greater availability and use of scrap, as well as emerging technologies, must start playing a role by 2020. In total, global energy intensity must decrease to 18.9 GJ/t crude steel by 2025, down 10% compared with 2011.

Market creation

No major new policy developments specific to the iron and steel industry occurred in 2013, but dialogue regarding solutions for a low-carbon future has increased. To provide policy recommendations on the steel sector's contribution to decarbonisation, the European Commission published an *Action Plan for a Competitive and Sustainable Steel Industry in Europe*, and Eurofer (the European Steel Association) published a *Steel Roadmap for a Low Carbon Europe 2050*. The International Organization for Standardization (ISO) published a standardised method to calculate CO_2 emission intensity from iron and steel production (ISO, 2013).

Technology developments

Emerging technologies – such as CCS, smelting reduction and blast furnace with top-gas recycling – need to be deployed in order to reach 2DS targets. The Ultra-Low Carbon Dioxide Steelmaking (ULCOS) consortium, comprising 48 European companies and organisations, aims to dramatically reduce CO_2 emissions of the steelmaking process. But in late 2012, an ULCOS-supported demonstration plant with top-gas recycling was delayed due to technical and financial issues. Steel industry stakeholders are now pursuing the Low Impact Steel making project, which aims to demonstrate a commercial-scale blast furnace with CCS.

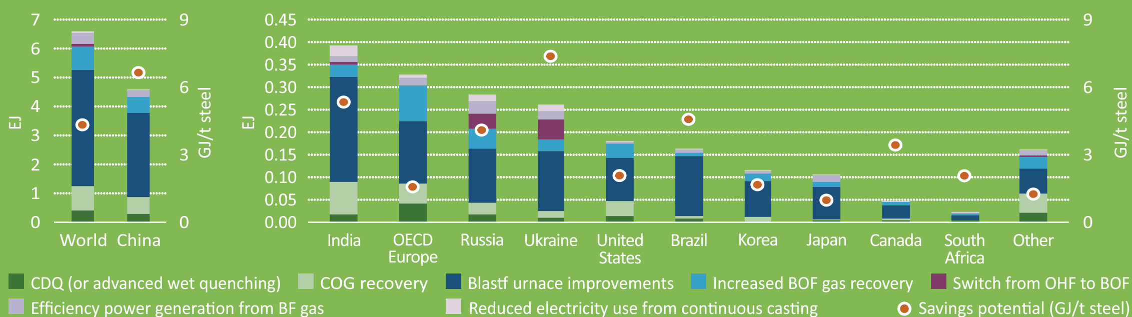
The COURSE50[9] program in Japan is a NEDO[10]-funded partnership with the Japanese steel industry that provided JPY 10 billion from 2008 to 2012 (Phase 1 Step 1). It seeks to develop technologies to reduce CO_2 emissions from steelmaking by 30%, including hydrogen reduction and capture and recovery of blast furnace gases. A trial hydrogen reduction operation was successfully completed in 2012, and the project aims to commercialise the technologies by 2050. Phase 1 Step 2 of this program is expected to be completed in 2017.

9 CO_2 Ultimate Reduction in Steelmaking Process by Innovative Technology for Cool Earth 50.
10 New Energy and Industrial Technology Development Organization.

1.27 Progress in emerging technologies

	Status	Description	Recent developments
HISmelt®	Commercial, not currently operational.	Direct smelting process producing pig iron directly from ore using a smelt reduction vessel. Eliminates need for traditional blast furnace and coking coal.	■ First plant relocated from Australia to China with planned operation in 2014 and 500 kt capacity. ■ 1 Mt to 1.2 Mt steelworks planned in India, to be operational in 2016.
HISarna®	Pilot stage, demonstration needed.	Iron-making process combining HISmelt® bath smelting process with a cyclone furnace, using thermal coal and fine iron ore to combine the coking and agglomeration. Allows more fuel flexibility, including hydrogen use.	■ Pilot project complete. ■ Commercial grade steel produced at pilot plant in 2013. ■ No large-scale demonstration currently planned.
COREX®	Commercial, not widely deployed.	Direct smelting process using non-coking coal as reducing agent and energy source with sinter, lump ore or pellets. Eliminates need for traditional blast furnace.	■ Commercialised in 1989. ■ Three plants currently in operation in India and South Africa.
FINEX®	Commercial, not widely deployed.	Direct smelting process using non-coking coal as reducing agent and energy source, with unagglomerated fine iron ore. Eliminates need for traditional blast furnace.	■ Commercialised in Korea in 2007. ■ 3 Mt integrated steelworks planned in China following feasibility study and Memorandum of Agreement.
Top-gas recycling blast furnace	Pilot stage, demonstration needed.	Separation of blast furnace off-gases into components for reuse in the furnace as reducing agents. Reduces coke needs and can facilitate CCS performance.	■ Full-scale demonstration was planned in France, but cancelled for technical and financial reasons. ■ No demonstration currently planned.

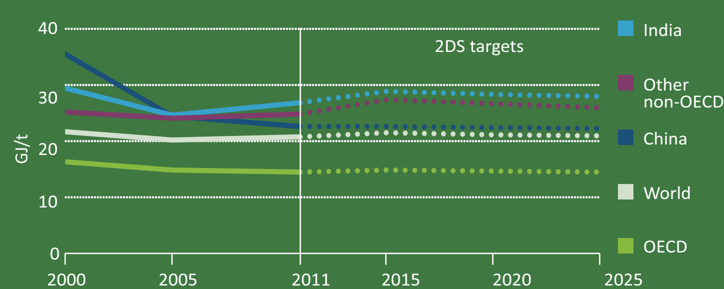
1.28 Energy savings potential in 2011



6.6

EJ COULD BE SAVED IF BEST AVAILABLE TECHNOLOGIES WERE APPLIED (4.6% OF INDUSTRIAL ENERGY)

1.29 Aggregate energy intensity



For sources and notes see page 72

Transport

Improvement needed

Energy consumption in transport reached 102 EJ in 2011, a 25% increase from 2000 (2% per year), with road transport taking the largest share (76 EJ). Passenger light-duty vehicles consume slightly more than 40% of total transport energy demand and cover half of global passenger mobility (expressed in passenger-kilometres). Road freight accounts for nearly 30% of energy use and about half of inland tonnage (tonne-kilometres). Shipping and air take up 10% of demand; 7% is needed for buses and trains. All transport accounted for 22% of global CO_2 emissions in 2011.

Technology penetration

Recent progress in hybrid electric vehicles and electric vehicles (HEVs and EVs) delivered important fuel economy improvements for road transport (see separate section). Renewed interest in diversifying energy sources is influencing vehicle technology, especially in areas where natural gas prices have decoupled from oil (EUNGVA, 2013). Bus rapid transit (BRT) systems are gaining ground as a means to shift passenger travel to more sustainable modes. By 2013, more than 200 cities in 48 countries had BRT (EMBARQ, 2014).

Various measures bring aviation close to the 2DS trajectory. Per-tonne fuel efficiency has improved by 1.2% per year since 2005 (IATA, 2013); the industry aims for 1.5% per year to 2025 (ATAG, 2013).

Market creation

Fiscal policies on fuels affect transport activity, modal choice and vehicle technology. Fuel taxation should ensure that driving costs reflect actual costs; dropping fuel subsidies (as Indonesia did in 2013) is one way to prompt switching to fuel-efficient vehicles.

Access restriction and congestion charging can rationalise travel choices, shift travel to collective transport modes and stimulate innovative vehicle technologies.

Fuel economy policies for new light- and heavy-duty vehicles, coupled with consumer information schemes, are important market drivers for energy efficient transport. Fuel economy standards for light vehicles are in place in Australia, Canada, China, the European Union, Japan, Korea, Mexico and the United States; Brazil recently undertook policy action in this area. Only Japan, China and the United States have fuel economy standards for heavy road transport. The European Union plans to implement such standards by 2015; Korea, Canada and Mexico are developing policy proposals.

In October 2013, the International Civil Aviation Organization (ICAO) set a framework for carbon-neutral growth starting in 2020, supported by market-based mechanisms. ICAO member states also adopted aspirational goals to 2020, with a declared aim of improving efficiency by 2% per year until 2020 (ICAO, 2013).

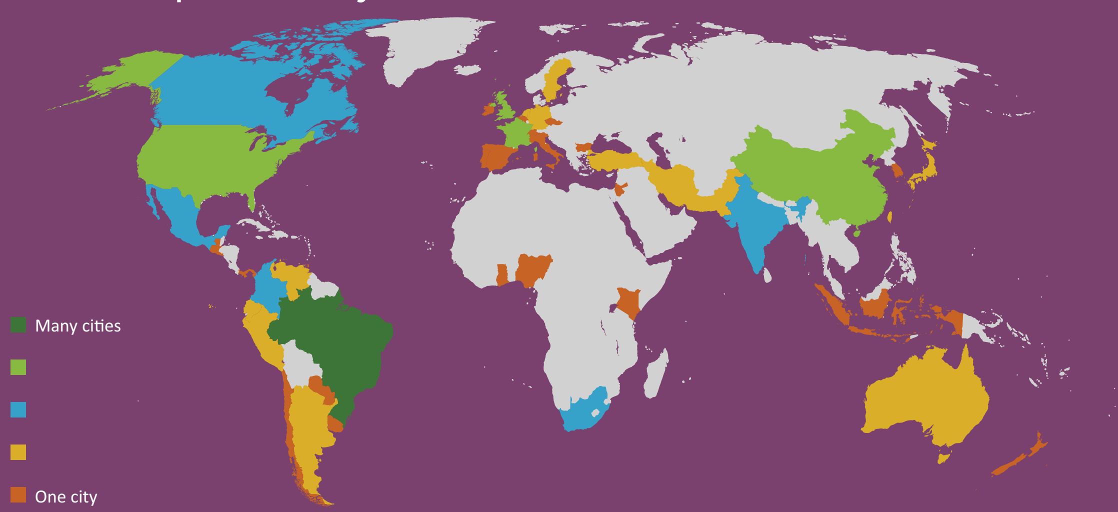
Technology developments

Fuel economy solutions on ICEs can deliver the largest fuel savings in the short term. Hybridisation could deliver the savings required by fuel economy improvement policies. HEVs are seen as a bridging solution towards massive deployment of EVs and plug-in HEVs (PHEVs). Electric motors, coupled with fuel cells, open the possibility of using hydrogen for transportation (IEA, 2014). While some production and distribution barriers remain for using natural gas and/or electricity for cars, hydrogen deployment faces substantial challenges,

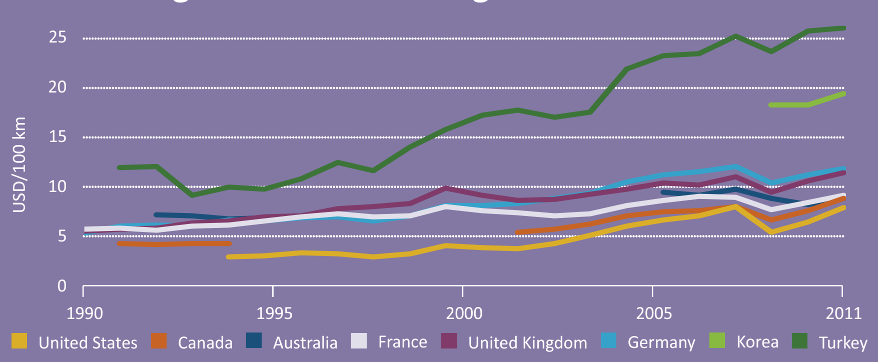
Newer aircraft have more electrified systems to improve overall energy efficiency; installation of carbon fibre parts is helping to lighten the body and save fuel.

1.30 Well-to-wheel CO_2 intensity

1.31 Bus Rapid Transit systems



1.32 Average new vehicle driving cost in selected countries



3

COUNTRIES HAVE FUEL ECONOMY STANDARDS FOR HEAVY ROAD TRANSPORT

For sources and notes see page 73

Electric and Hybrid Electric Vehicles

Improvement needed

Sales of EVs grew 50% from 2012 to 2013, reaching 170 000; sales of non-plug-in HEVs remained stable at 1.3 million. This is encouraging, but it falls below the levels needed to meet the ambitious 2DS targets, as in 2025 EV and HEV sales should grow 80% and 50% per year respectively.

Technology penetration

With almost 100 000 vehicles sold, the United States had the biggest increase and almost matched global EV sales in 2012 (115 000).

The global EV stock reached 350 000 vehicles at the end of 2013, still far from the 2DS target of 1 million in 2015 and the extremely ambitious target of 80 million EVs by 2025. In the Netherlands, Norway and the United States, among other countries, EVs now account for over 1% of sales.

Sales of non-plug-in HEVs reached 1.6% of global market share in 2013, with 52% of sales in Japan and 39% in the United States. The 2DS sees annual HEV sales at 17 million in 2025 (15% market share).

Growth of electric bikes is also significant. China has the biggest fleet, with more than 150 million battery-electric 2-wheelers on the road (over 50% of the 2-wheelers stock). The 2 600 plants in China that manufacture 36 million e-bikes annually will drive the stock increase in all of Asia.

Market creation

Early estimates [11] show that the EV charging infrastructure has continued to expand rapidly, with 12 500 (+ 27%) slow and 1 300 (+ 67%) fast chargers installed in 2013.

Governments participating in the Clean Energy Ministerial (CEM) Electric Vehicles Initiative (EVI) continued putting in place policy measures such as rebates or tax credits on vehicles, purchase subsidies, or exemption from vehicle registration taxes or license fees. Policy measures and programmes should have longer time frames and create favourable conditions in urban areas subject to access restriction and congestion charging to boost industry confidence that market demand will continue to grow over the short term and beyond.

Car sharing of EVs is growing in popularity and accounts for 10% of global vehicles in such schemes. Renting or leasing EVs helps to mitigate some consumer concern about battery life and range.

A five-year Clean Air Action Plan (2013-17) for Beijing rules that of 600 000 new vehicles to be allowed in the city in the next four years, 170 000 should be EVs, PHEVs or fuel-cell vehicles. In 2014, a quota of 20 000 new car registrations will be given to such vehicles.

HEVs failed to expand beyond core markets in Japan and the United States (91% of global sales in 2013). Japan's initial subsidies for HEVs were discontinued at the end of September 2012, with no further incentives envisioned. A tax reduction still exists for HEVs, PHEVs, battery-electric vehicles (BEVs) and clean diesel vehicles. The United States has no subsidies at the federal level, although HEVs qualify within vehicle acquisition laws that promote alternative fuel vehicles in government fleets. Several state incentives exist, both financial and non-financial (e.g. priority access on highways).

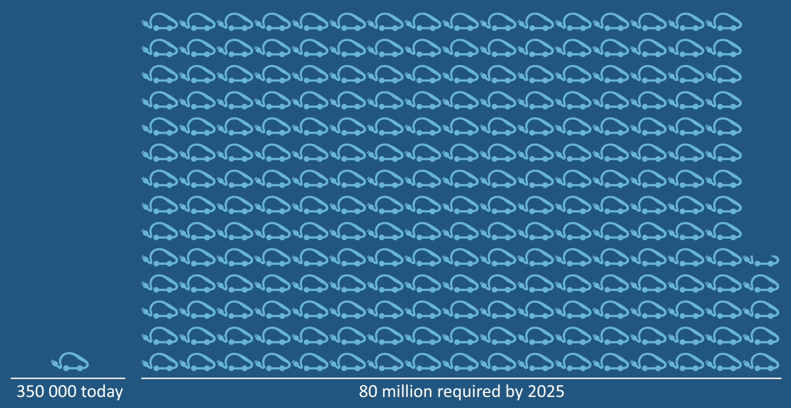
Technology developments

Batteries remain the most costly component of EVs. Encouraging signals are emerging from research laboratories, [12] with costs moving towards the target of USD 300/kWh by 2020 (from the 485 USD/kWh estimate of 2012), which should make EVs competitive with ICEs.

11 Data only available for six countries until end of September 2013.

12 According to the US Department of Energy (personal communication), battery cost is based on development efforts costing USD 400/kWh of usable energy at the end of 2013. Costs do not include warranty costs or profit, and are based on a production volume of at least 100 000 batteries per year.

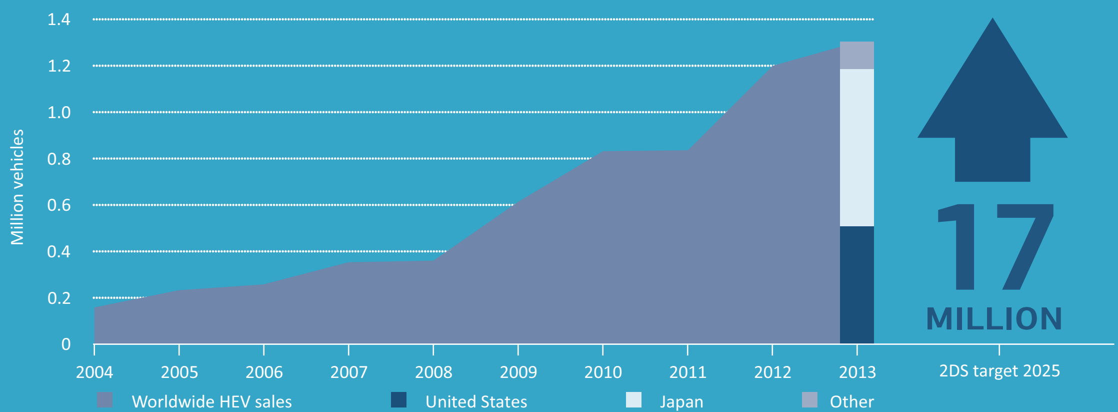
1.33 Global electric vehicles stock



10%

OF VEHICLES IN CAR-SHARING PROGRAMMES AROUND THE WORLD ARE EVS

1.34 Global hybrid electric vehicle sales



REQUIRED ANNUAL SALES GROWTH RATE TO 2025

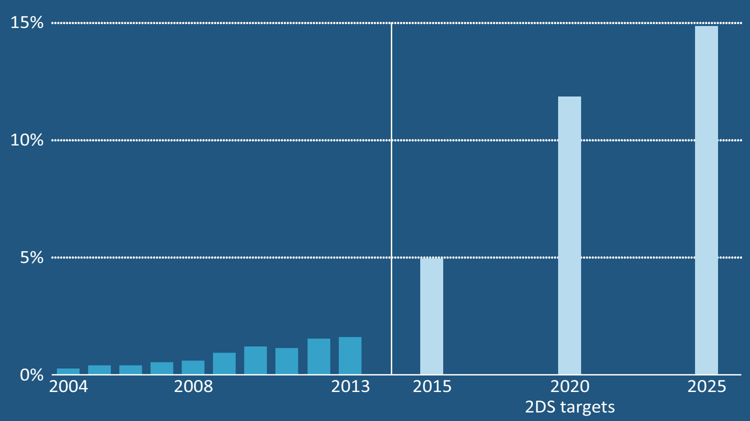
50%

FOR HEVs

80%

FOR EVs

1.35 Global hybrid electric vehicle market share



For sources and notes see page 73

Biofuels

Not on track

Biofuel production increased to 113 billion litres in 2013, buoyed by higher ethanol output in Brazil due to improved economics and the readjustment of the domestic ethanol mandate to 25%. High feedstock prices in the United States and European Union (among others) in the first half of the year reduced output there. Global biofuel production should reach 140 billion litres in 2018, undershooting the volumes required to reach 2DS targets.

Technology penetration

Advanced biofuels,[13] produced from lignocellulosic biomass, algae and other innovative feedstocks, have progressed more slowly than expected in recent years. Production capacity in 2013 increased by around one-third from 2012 levels, but will need to grow 22-fold to reach 2DS targets in 2025. This will require dedicated policy support for advanced biofuels and increased government funding for research and market creation.

Globally, operating of advanced biofuels capacity was 5.4 billion litres in 2013, an increase of over 1 billion litres compared to 2012. Looking forward, global advanced biofuel capacity could reach 8.7 billion litres in 2018, less than 10% needed to meet the 2025 2DS target.

Market creation

Over 50 countries worldwide have implemented biofuel blending mandates and targets, often accompanied by financial support measures such as tax incentives. These measures have been effective in driving biofuel production in general, but do not necessarily promote technologies that perform best in terms of land use, greenhouse-gas reductions, and social and economic impacts. Despite international efforts to establish sound sustainability criteria and certification schemes, only the European Union and the United States have set sustainability requirements for fuels that count towards biofuel targets. Also, requirements in these two regions are not currently aligned: EU standards consider a broader and more detailed set of criteria.

Most current blending mandates for biofuels do not specifically support advanced biofuels. Only the United States (dedicated blending quota for cellulosic biofuels) and the European Union (advanced biofuels based on waste, and cellulosic biomass, are counted twice towards the 10% renewable energy target in transport in 2020) have policies targeting advanced biofuels. But time horizons are limited to 2020 for the European Union and 2022 in the United States.

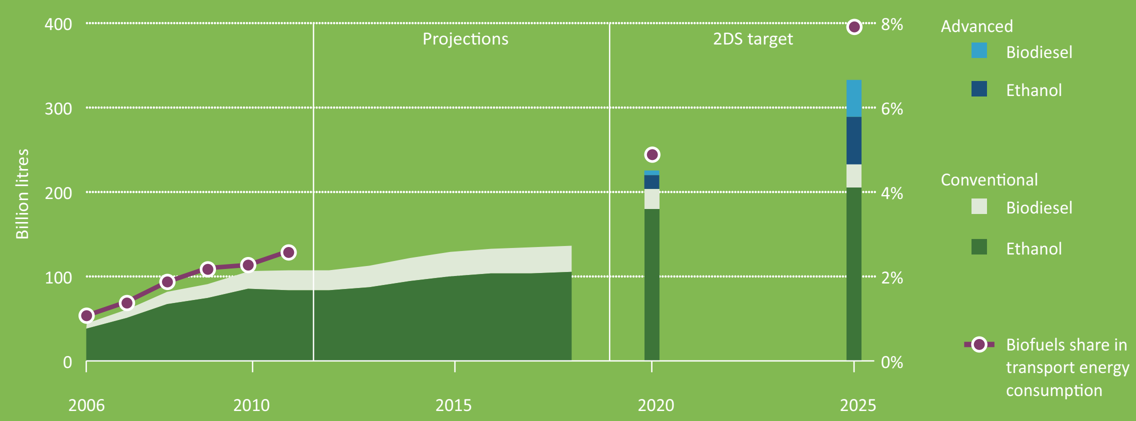
Long-term, stable policy frameworks that reduce the risks associated with advanced biofuels projects are needed to trigger further investments into commercial-scale advanced biofuel plants. This can be, for instance, in the form of a dedicated advanced biofuel quota or a premium paid for each litre of advanced biofuel blended to the fuel pool.

Technology developments

More than 100 advanced biofuel pilot and demonstration plants were established over the last decade. The recent opening of the first commercial-scale production units (such as the Beta Renewables 60 million-litres-per-year cellulosic-ethanol plant in Italy) as well as a number of plants scheduled to come online in the United States, Europe and Brazil in 2014 indicate substantial progress in technology development. But the units are relatively small, and several other projects were cancelled. More commercial-scale plants are needed to reach economy of scale and bring down costs.

13 Conventional biofuels (commonly referred to as first generation biofuels) include sugar- and starch-based ethanol, oil crop-based biodiesel, and straight vegetable oil, as well as biogas derived through anaerobic digestion. Advanced biofuels (commonly referred to as second generation) are conversion technologies that are still in the R&D, pilot or demonstration phase. This category includes hydrotreated vegetable oil, which is based on animal fat and plant oil, as well as biofuels based on lignocellulosic biomass, such as cellulosic-ethanol, biomass-to-liquids-diesel and bio-synthetic gas. Furthermore novel technologies such as algae-based biofuels and the conversion of sugar into diesel-type biofuels using biological or chemical catalysts are included.

1.36 Global biofuels production

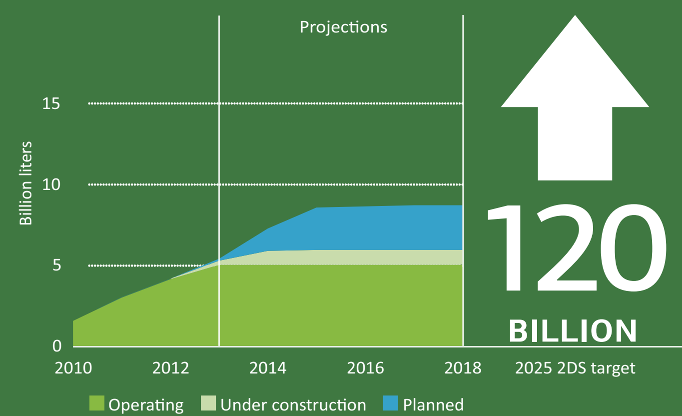


Recent developments

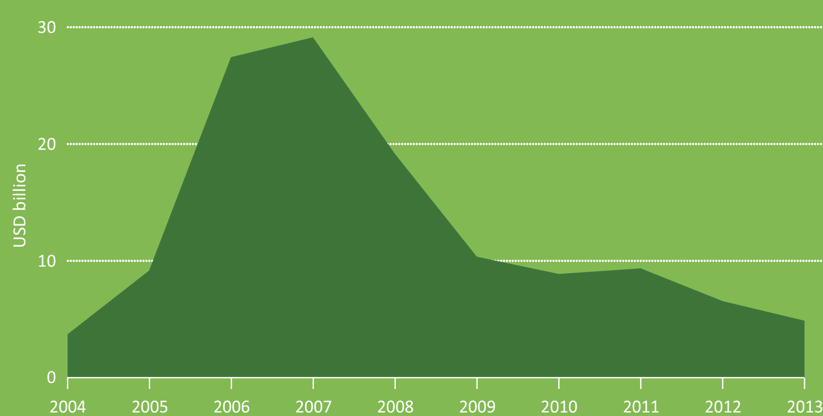
In 2013 two commercial-scale advanced biofuel production units opened in the United States and one in Europe

Over 50 countries have biofuel blending mandates and targets but only the United States and the European Union have policies targeting advanced biofuels

1.37 Global advanced biofuel capacity



1.38 Production capacity investment



1.4

USD BILLION SPENT ON BIOFUELS R&D IN 2013, 40% FROM PRIVATE INVESTORS

For sources and notes see page 73

Buildings Energy Efficiency

Not on track

Buildings are the largest energy-consuming sector, accounting for 31% of final energy consumption globally, and a substantial source of CO_2 emissions: 2.9 gigatonnes (Gt) from direct emissions and 3.8 Gt from indirect emissions due to electricity in 2011. Final energy use increased by 19% between 2000 and 2011, to 119 EJ. The trend is expected to continue, driven by rising population (1 billion people by 2025) and increasing wealth in some regions.

Technology penetration

Despite the recent global economic stagnation, which led to severe retraction in the buildings sector in several countries, global buildings energy consumption continues to rise. Concerns over the continuation of this trend have increased the call for further efforts to improve buildings energy efficiency. In 2013, *Transition to Sustainable Buildings: Strategies and Opportunities to 2050* was published to highlight the path to an alternative future (IEA, 2013c).

Heating per unit of floor area, the largest end-use, is becoming more efficient. Continued growth in floor area per capita in residential buildings across all regions, however, is driving up overall demand. The 2DS target for 2025 allows for energy demand growth of 0.7% per year from 2012; the trend over the last decade, 1.5% per year, throws the sector off track. Disaggregation of builders, coupled with varying levels of building stock, makes implementing energy efficiency improvements particularly challenging.

Market creation

Current policies are insufficient to make the construction of high-performance buildings routine, even though near-zero-energy, zero-energy and energy-plus buildings are being pursued around the world.[14] Some European countries have adopted zero-energy goals[15] for new residential construction around the 2020 time frame, even though debate continues on the specific performance criteria for the underlying EU Directive.[16] To achieve 2DS, deep energy renovation will need to become common practice during normal building refurbishment, with the current rate of renovation at least being doubled. Europe is leading this effort with a co-ordinated group of advocates and businesses through Renovate Europe and through the EU Directive to refurbish 3% of public buildings per year. This Directive, however, should be reviewed to include public and non-public housing stock.

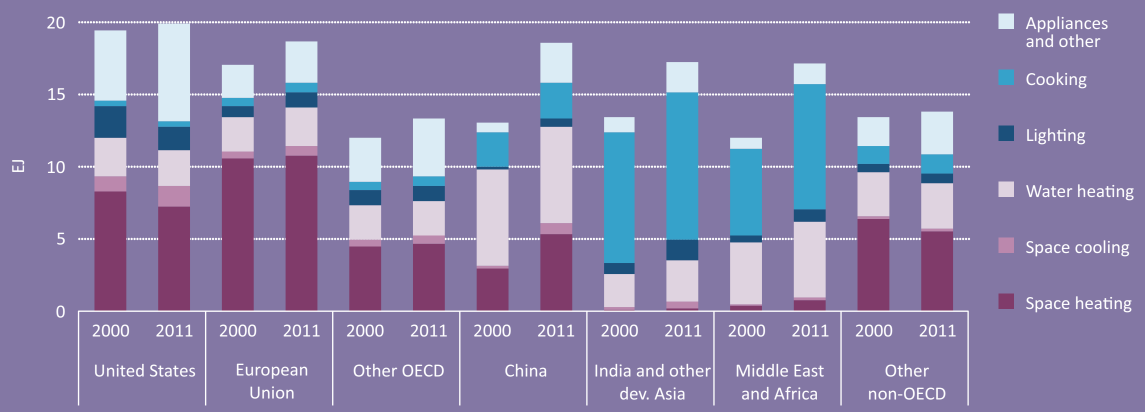
Sustainable building practices are growing through voluntary programmes such as the UK BREEAM and US Green Building Council LEED programmes. Russia recently introduced a new building energy efficiency label in association with the European Bank for Reconstruction and Development. Deep renovation could be significantly accelerated through financial incentives and policies that target stringent energy performance criteria. California recently launched a new approach, called CO_2 to EE, to enhance building renovation financing from climate change policy, which may be an effective way to stimulate the existing building market.

Technology developments

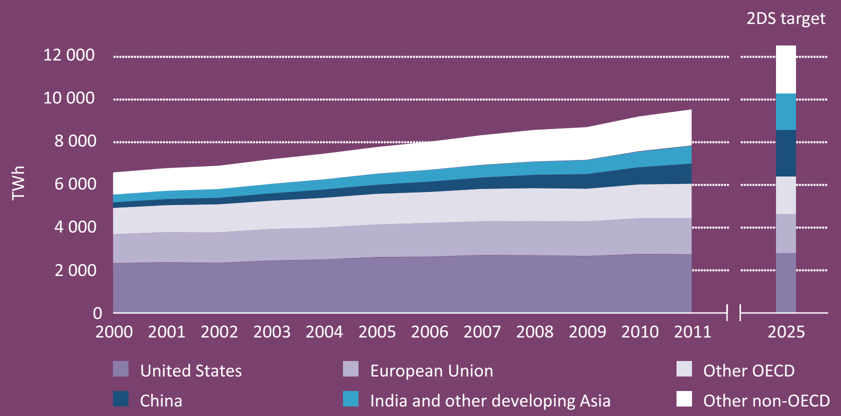
Systems-level research that promotes integrated solutions can significantly reduce the overall cost of building upgrades while maximising energy savings. R&D can lead to higher performing products and more favourable investment opportunities with more cost-effective applications. The core technology development need, however, centres on building equipment and envelope materials (see following sections).

14 China has adopted a National Green Building Action Plan with a goal of 1 billion square metres (m^2) of green buildings by 2015.
15 Zero-energy goals for all residential construction go beyond the EU Directive for near-zero-energy.
16 Data for annual progress are not available, but see www.buildup.eu/news/33980 for more information.

1.39 Buildings energy consumption by end use



1.40 Buildings electricity consumption



Key trends

Residential consumption has been relatively static since 1990, despite energy efficiency improvements

The current rate of renovation should at least double to meet 2DS targets

1.41 Floor area by sub-sector

Building Envelope

Not on track

The thermal performance of the building envelope determines energy requirements for heating and cooling, and can reduce artificial lighting requirements. A systems approach for new construction and deep renovation is essential, as are advanced building materials that enable the construction of high-performance buildings.

Technology penetration

With space heating and cooling accounting for one-third of all energy consumed in buildings – and the figure rising to 60% in residential buildings in cold climates – building envelopes have a significant impact on global energy consumption. Global residential heating represents the largest end use; overall growth was low (0.1% per year from 2000) despite China's average growth being over 5.4%. Cooling demand increased dramatically since 2000 (4.5% per year), with developing countries being the largest driver and high US growth (2.8% per year) playing a role.

Market creation

Mandatory building codes are the most effective policy to reduce heating and cooling demand; progress continues in most regions, but not aggressively enough to reach 2DS targets. The United States recently implemented its most stringent energy-saving building code, which includes mandatory daylighting and automated lighting controls. Future stringency to achieve near-zero energy performance is unlikely. In 2013, Viet Nam implemented a new building code that was significantly influenced by previous policy action within the Asia-Pacific Economic Cooperation (APEC),[17] and progress continued on a regional building material testing and rating centre in Thailand.

The *IEA Technology Roadmap for Energy Efficient Building Envelopes* includes a market assessment of high-priority building envelope components. From a technological perspective, insulation and low-emissivity (low-e) windows have been the most successful measures; from a regional perspective, Canada, the European Union and the United States have been the most successful. Highly insulated windows have achieved 54% market share in a few European countries, but remain very low in other parts of the world. More programmes are required to promote and mandate advanced building materials such as double-glazed, low-e windows for the world and highly insulated windows (triple-pane low-e windows with low conductive frames) for cold climates.

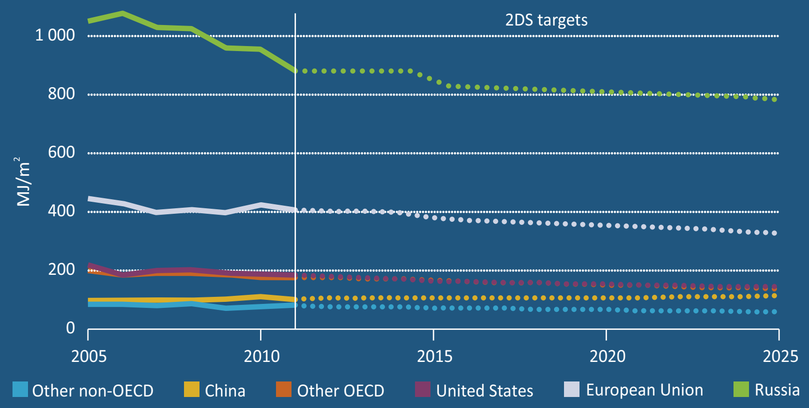
The Cool Roofs and Pavements Working Group of the Global Superior Energy Performance Partnership (GSEP), an initiative of CEM and the International Partnership for Energy Efficiency Co-operation (IPEEC), continues to pursue policies to adopt reflective surfaces that provide building energy efficiency and reduce urban heat islands while increasing global cooling benefits. The group's recent analysis showed that switching to cool roofs could reduce Mexico's cooling load by 22%; now Mexico preferential green mortgages can be used to install cool roofs.

Technology developments

Significant progress has been made in dynamic glazings that can improve passive heating benefits, reduce lighting loads (up to 60%), reduce cooling loads (up to 20%) and lower peak electricity demand (up to 25%). More R&D and economy of scale are needed to improve market viability, which is also true for automated solar control shading for regions that cannot eliminate cooling equipment due to severe climatic conditions. R&D continues on advanced insulation, such as aerogel and vacuum-insulated panels, and is needed to pursue lower cost validated air sealing techniques, reflective materials and the development of highly insulated windows for zero-energy buildings (U-values[18] $\leq$ 0.6 W/m^{2}k while the typical best practice U-value is 1.8W/m^{2}K) (IEA, 2013d).

17 For example, APEC's effort on Cooperative Energy Efficient Design for Sustainability effort on building codes.
18 Thermal transmittance is a term to describe heat transfer across a material or assembly over a specified difference in temperature, the most common descriptor being a U-value.

1.42 Residential heating per square metre



32%

SHARE OF SPACE HEATING AND COOLING IN BUILDINGS ENERGY CONSUMPTION (AROUND 60% IN COLD CLIMATES)

1.43 Market maturity for high-priority building envelope components

	ASEAN	Brazil	China	European Union	India	Japan/Korea	Mexico	Middle East	Australia/ New Zealand	Russia	South Africa	United States/ Canada
Double-glazed low-e glass	●	▲	▲	★	▲	●	●	▲	●	●	●	★
Window films	▲	▲	▲	●	▲	●	▲	▲	●	▲	▲	●
Window attachments (e.g. shutters, shades, storm panels)	●	▲	●	★	▲	●	▲	●	●	▲	●	●
Highly insulating windows (e.g. triple-glazed)		▲	▲	●		▲		▲	▲	▲	▲	▲
Typical insulation	★	●	★	★	●	★	●	★	★	★	●	★
Exterior insulation	●	▲	●	★	●	●	▲	●		▲	▲	★
Advanced insulation (e.g. aerogel, VIPs)				▲		▲				▲	▲	▲
Air sealing	●	▲	▲	★	▲	●		▲	▲	▲		●
Cool roofs	▲	▲	▲	●	▲	▲	▲	▲	▲			★
BIPV/ advanced roofs	▲	▲		▲	▲	▲			▲	▲	▲	▲

★ Mature market ● Established market ▲ Initial market

Appliances and Equipment

Improvement needed

Improved energy efficiency of appliances and equipment can moderate demand in energy without sacrificing features. Labelling and standards programmes have been very effective when pursued aggressively and should be expanded further to reach 2DS targets.

Technology penetration

Extensive evaluations show that voluntary and mandatory policies have underpinned significant progress towards more efficient appliances and equipment in developed regions. Savings achieved, however, have in many cases been eroded by increased "productivity" such as larger dwellings, larger refrigerators, brighter spaces and improved comfort.

Average growth of electricity in the buildings sector was 3.4% per year[19] from 2000 through 2011, driven by the demand of appliances and electronics reaching 34 EJ. To achieve 2DS targets, this figure must be reduced to 2% per year through 2025. Space cooling, which increased by 4.5% per year, needs to be reduced to 1.8% per year. The more modest growth of water heating (0.9% per year) still needs to be halved, to 0.5% per year through 2025. More effort is needed to develop new programmes where they do not exist, and to expand the scope, stringency and compliance of existing programmes.

Market creation

Mandatory requirements for condensing boilers in the United Kingdom, and a similar requirement for new construction in France, have helped to temper residential heating, which represents the largest end use in buildings.

Improved lighting deployment continues to grow thanks to efforts such as the United Nations Environment Programme (UNEP) Global Environment Facility (GEF) en.lighten initiative's Global Efficient Lighting Partnership Programme, which supports 55 countries in following an integrated approach to implement policies and measures to accelerate the market transformation to efficient lighting technologies by 2016 (27 countries will complete the transition by 2014). Many countries now ban inefficient incandescent lamps (IIL), although some still allow "halogen" (which use around 80% the energy of a typical IIL). Current compact fluorescent lamps (CFLs) and light-emitting diode (LED) technologies use one-third to a fifth of the energy of IILs. With potential to become twice as efficient as CFLs, LEDs are growing in market share: global sales were about USD 24 billion in 2012, and are expected to reach USD 57 billion by 2018. In the United States, LEDs saved 75 petajoules (PJ) of primary energy in 2012 of an annual savings potential of 4 086 PJ.

Voluntary (ENERGY STAR) and mandatory (minimum energy performance standards) programmes enabled New Zealand to reduce total electricity demand for buildings by 4% in 2012. China recently introduced ten new efficiency standards. Japan expanded its Top Runner programme in 2013, and is developing improved energy performance ratings to ensure they reflect real-world conditions. The European Union issued several new directives, including one to improve the labelling and promotion of heat pump water heaters and solar thermal systems. The CEM-IPEEC Super-Efficient Appliance and Equipment Deployment (SEAD) initiative pursued several lighting, air conditioning and electronic efforts to reduce energy use.

Technology developments

Development of cold climate and gas thermal heat pumps[20] within the IEA Technology Network, continues but with a limited number of country participants. Japan has seen significant growth in sales of heat pump water heaters (500 000 sold in 2012) while high cost and market barriers limit EU sales (58 000 sold in 2012, mostly in France, Denmark and Poland) and the United States (26 000). With millions of electric resistance water heaters being sold annually around the world, more R&D and economies of scale to drive lower cost of heat pump water heaters is a priority.

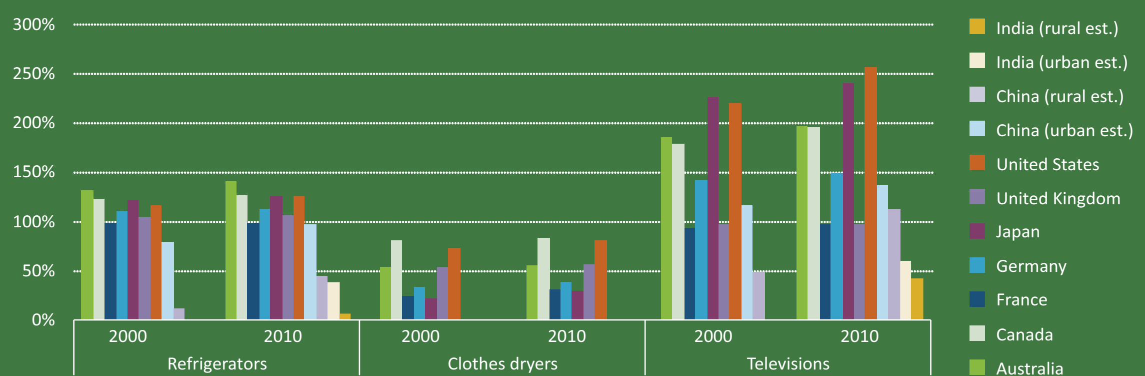
19 Significant variation exists, with the United States growing at 1.5% per year whereas China grew at 12.2% per year.
20 Current performance of heat pumps in cold climates is severely degraded and the most efficient source of gas heating is condensing boilers at around 95%; gas thermal heat pumps can improve that by around 25% (IEA, 2013d).

1.44 Labelling and standards programmes within the SEAD initiative

	Australia	Canada	European Union	India	Japan	Korea	Mexico	South Africa	United States
Phase-out of conventional incandescent light bulb	Mandatory standard	Mandatory standard; Mandatory label	Mandatory standard; Mandatory label			Mandatory standard; Mandatory label	Mandatory standard		Mandatory standard; Mandatory label
Clothes washers	Mandatory label	Mandatory standard; Mandatory label	Mandatory standard; Mandatory label	Voluntary label		Mandatory standard; Mandatory label	Mandatory standard; Mandatory label		Mandatory standard; Mandatory label
Residential refrigeration	Mandatory standard; Mandatory label	Mandatory standard; Mandatory label	Mandatory standard; Mandatory label	Mandatory standard; Mandatory label	Mandatory standard; Mandatory label	Mandatory standard; Mandatory label	Mandatory standard; Mandatory label	Mandatory label	Mandatory standard; Mandatory label
Commercial refrigeration	Mandatory standard	Mandatory standard			Mandatory standard	Mandatory standard; Mandatory label	Mandatory standard; Mandatory label		Mandatory standard
Computers	Mandatory standard		Mandatory standard		Mandatory standard; Voluntary label	Voluntary label			Voluntary label
Distribution transformers	Mandatory standard	Mandatory standard		Mandatory label	Mandatory standard; Mandatory label	Mandatory standard; Mandatory label	Mandatory standard		Mandatory standard
Fans		Mandatory standard	Mandatory standard	Voluntary label		Mandatory standard; Mandatory label			Mandatory standard; Mandatory label
Motors	Mandatory standard	Mandatory standard	Mandatory standard	Voluntary label		Mandatory standard; Mandatory label	Mandatory standard; Mandatory label		Mandatory standard
Room air conditioners	Mandatory standard; Mandatory label	Mandatory standard; Mandatory label	Mandatory standard; Mandatory label	Mandatory standard; Mandatory label	Mandatory standard; Mandatory label	Mandatory standard; Mandatory label	Mandatory standard; Mandatory label		Mandatory standard; Mandatory label
Standby power		Mandatory standard	Mandatory standard			Voluntary label			
Televisions	Mandatory standard; Mandatory label	Mandatory standard	Mandatory standard; Mandatory label	Voluntary label	Mandatory standard; Mandatory label	Mandatory standard; Mandatory label			Mandatory label

● Mandatory standard   Comparative label: ● Mandatory   ● Voluntary

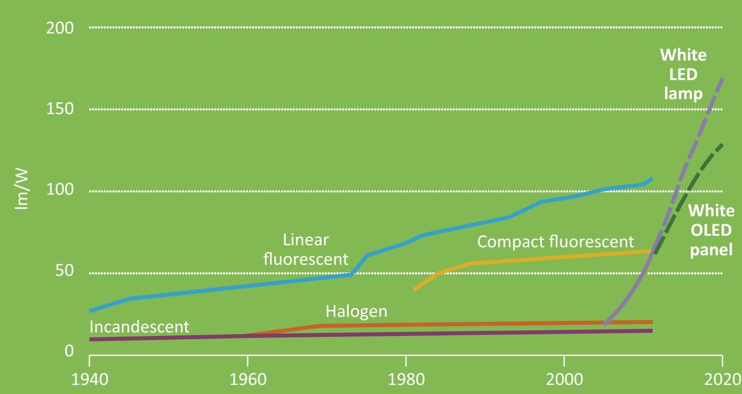
1.45 Selected appliance ownership



166

lm/W, MINIMUM TARGET EFFICIENCY OF LED SYSTEMS BY 2020 IN THE US (12 lm/W, COMMON INCANDESCENT LAMP EFFICIENCY)

1.46 Typical lamp efficacies



For sources and notes see page 73

Co-generation and DHC

Improvement needed

Global electricity generation from co-generation technologies remained stagnant at around 10% over the last decade, and deployment of efficient district heating and cooling (DHC) systems has also been limited, despite their significant potential for efficiency gains, emissions reductions and enhanced flexibility.

Technology penetration

With a global average efficiency of 58% in 2011, co-generation of heat and power is much more efficient than conventional thermal power plants (37%)[21] In fact, state-of-the-art plants can reach efficiencies of up to 90% (IEA, 2011). When coupled with DHC, the system-wide benefits of co-generation increase further. Yet global penetration of co-generation technologies is low and progress is sluggish; co-generation produced only 9% of global power in 2011, of which 26% was in industrial facilities.

Penetration and performance of DHC vary by region. Highly efficient district heating (DH) serves 61% of Denmark while emitting only 26 tonnes of CO_2 per terajoule. China and Russia have the world's largest networks but with lower efficiencies and higher emissions. China is the fastest-growing region expanding its DH network (trench length of DH pipeline doubled in the period 2005-11). The United States has the greatest reported DC sales (24.7 TWh) and DC capacity in Korea more than tripled in the period 2009-11 (Euroheat&Power, 2013).

Micro co-generation technologies, such as gas engines and fuel cells, are gaining wider deployment in some countries, such as Japan and Korea.

Market creation

Co-generation faces several deployment barriers, such as higher up-front capital investment needs, often grid access limitations, limited demand for local heat and in some cases failure of local markets to reward energy efficiency.

Strategic and integrated planning is key for co-generation and DHC since assets are long-lived and future improvements costly. Lack of data (especially heat-related) makes it difficult to assess existing potential for cost-effective deployment. In 2012, EU countries were mandated to map national heating and cooling demand and generation to establish the base for a cost-benefit assessment of the application of these technologies (EU, 2012). Korea designated urban areas that must include a heat supply network connecting buildings, and introduced policies to improve efficiency and fuel diversification of district energy (Third Basic Supply Plan of District Energy). Japan released a national co-generation roadmap that calls for a 250% increase in capacity (to 22 GW) by 2030. The United States bolstered efforts on industrial co-generation, including a focus on deployment with technical assistance, best practice guidance, increased co-ordination across agencies and new funding opportunities (US, 2012). Russia has implemented market reforms to reward energy efficiency, and although more is needed these will incentivise network improvements and more efficient use of heat by consumers.

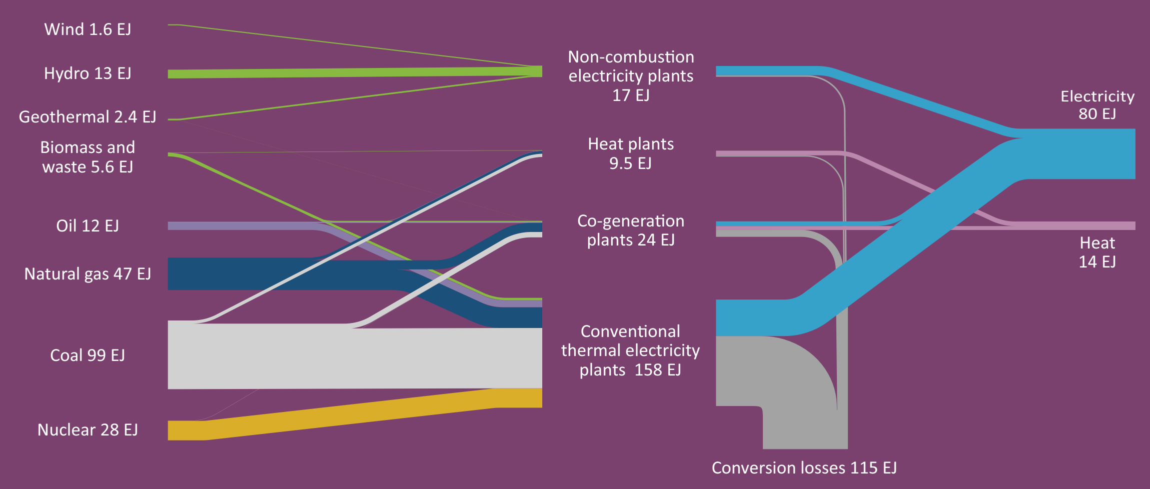
The IEA CHP/DHC Collaborative published country scorecards for Finland, Japan and Korea in 2013, and will release additional reports in 2014.

Technology developments

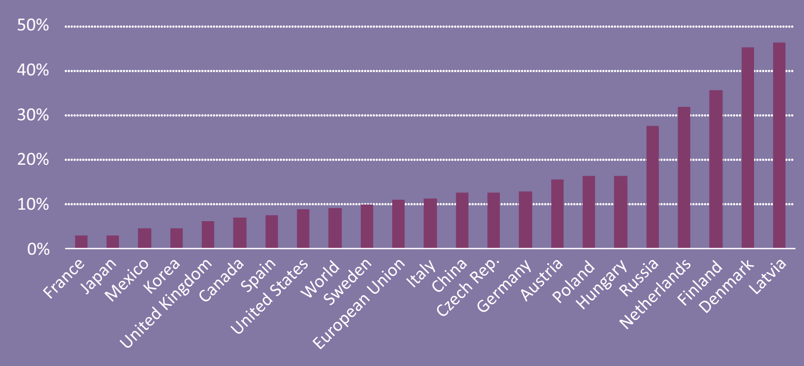
DHC networks with low supply and return temperature have been demonstrated, and could provide significant energy savings, as could improved control systems and insulation materials. Similarly, demonstration projects show the feasibility of very low-carbon DHC networks that integrate different energy sources including renewables, energy storage and heat pumps to enhance flexibility. These networks are already used commercially in Denmark. The 2DS envisions a decarbonisation of DH with the average CO_2 intensity peaking in 2020 before falling to 70% of current levels.

21 According to IEA energy balance conventions, for auto-producer co-generation plants, only heat generation and fuel input for heat sold are considered, whereas the fuel input for heat used within the auto-producer's establishment in not included, but accounted for in the final energy demand in the appropriate consuming sector. Transmission and distribution losses are not included.

1.47 Global power and heat generation energy flows, 2011



1.48 Co-generation share of power production in 2011



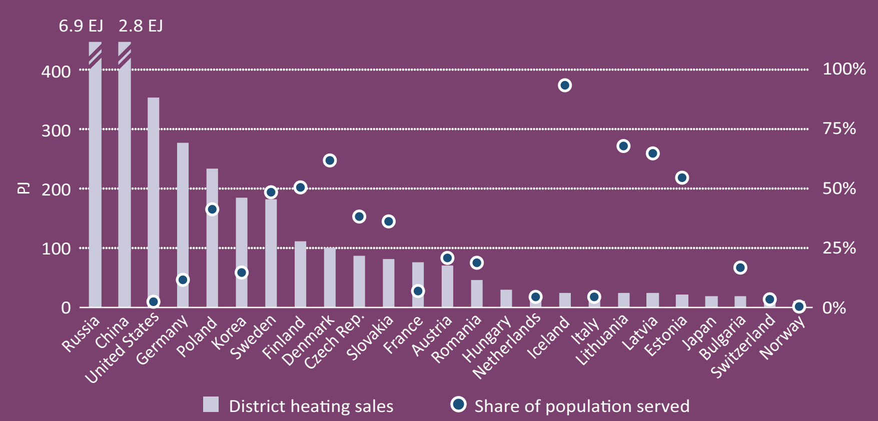
58%

GLOBAL EFFICIENCY OF CO-GENERATION SYSTEMS (37% IN THERMAL POWER PLANTS)

Key point

Fast-growing regions open a big opportunity for efficient DHC deployment; China doubled its DH trench length from 2005 to 2011. At this fast pace, energy infrastructure strategic planning becomes even more important.

1.49 District heat sales and share of population served, 2011



For sources and notes see page 74

Smart Grids

Improvement needed

Improved efficiency, ability to integrate renewable energy and EVs, and enabling customer involvement in shifting electricity consumption: smart grids are vital to transforming electricity grids into systems that can support the transition to the 2DS. Electricity will exceed a 20% share of overall energy demand in the 2DS by 2025, with variable renewable capacities growing from less than 6% of overall electricity generation capacity in 2011 to over 21% by 2025.

Technology penetration

Data are limited on smart-grid pilots and technology deployments globally. Improved effort is needed to develop effective indicators and collect data to track progress and impacts on the electricity system. At present, consensus is lacking as to which technologies can be considered authoritative indicators of the smartening of grids, though there are several agreed-upon groups emerging from the debate.

Global penetration of smart meters reached 20% in 2013, and is projected to achieve 55% by 2020 (Navigant Research, 2013a). Phasor measurement units (PMUs), as part of high-voltage wide-area monitoring, protection and control (WAMPAC) of the power systems, grew from almost zero to 5 356 units between 2002 and 2013 (ISGAN, 2013). Although smart-grid systems are growing steadily in many technology applications, the current rate of deployment does not appear sufficient to adequately support 2DS goals.

Market creation

Global smart-grid technology investments reached USD 45 billion in 2013, up from USD 33 billion in 2012, covering five main applications: transmission upgrades, substation automation, distribution automation, smart-grid information and operations technology, and smart meters. Investments are expected to reach over USD 70 billion by 2020 (Navigant Research, 2013b).

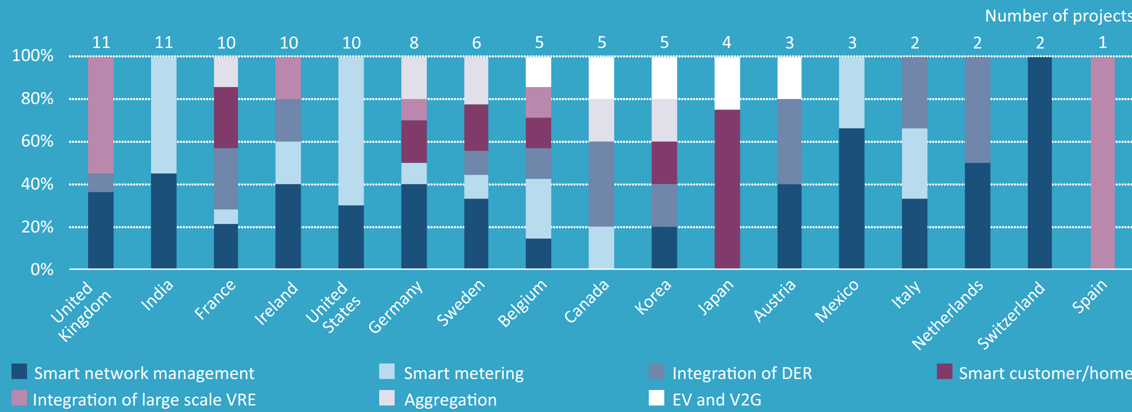
Development of international standards for interoperability stimulates market creation by increasing efficiency for manufacturers, encouraging supplier competition, and facilitating cost savings that benefit both utilities and consumers. European standardisation organisations are employing Mandate M/490 with the Smart Grid Coordination Group to tackle the challenge of interoperability within Europe. In North America, the Smart Grid Interoperability Panel provides a framework for co-ordinating stakeholder efforts to accelerate standards harmonisation.

The smart-grid market is expanding, but deployment slowed in some regions because of uncertainty over roles and responsibilities in some applications, and the need to share costs and benefits among different stakeholders. Cost reductions enabled by smart grids do not necessarily accrue in the same sectors in which investments are made. This creates the need for clear regulation and business models that manage cross-sectoral cost recovery such as: appointing a distribution system operator as a neutral market facilitator; demand-response programmes and aggregation models; and enabling net metering on solar energy projects.

Technology developments

The need to integrate diverse technologies is the greatest barrier in developing and deploying smart grids. The Smart Grid International Research Facility Network (SIRFN), part of the International Smart Grid Action Network (ISGAN), is a newly co-ordinated network of smart-grid research test-bed facilities that determines how new technologies, services and demonstrations can be reliably incorporated in different utility systems.

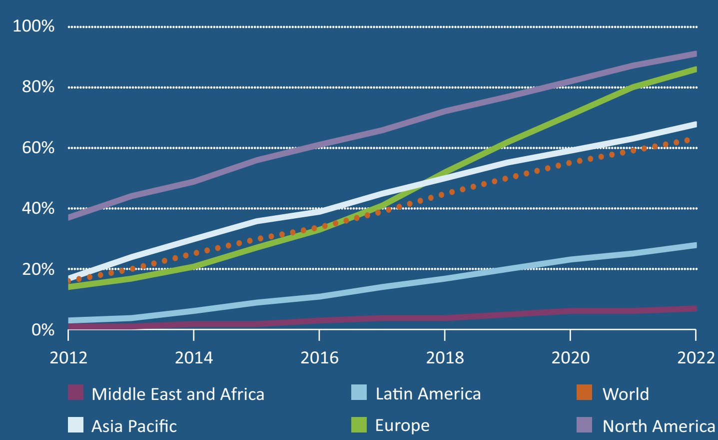
1.50 Sample smart-grid projects by application



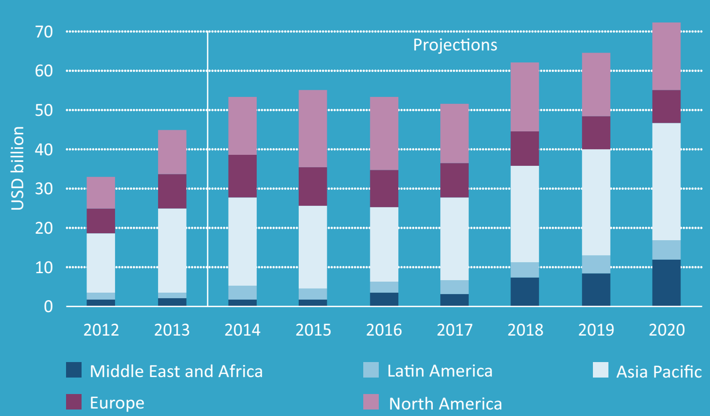
5 356

PHASOR MEASUREMENT UNITS DEPLOYED IN THE WORLD, 56% IN CHINA AND 31% IN NORTH AMERICA

1.51 Smart meter penetration



1.52 Smart-grid technology investments



Key points

Clear regulations and business plans are needed to define stakeholders' roles and responsibilities in sharing costs and benefits

Widespread research collection and sharing will accelerate development and deployment

Market penetration continues to grow, though metrics for tracking progress remain uncertain

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Chapter 2

Getting "Smart" about Staying on Line

Getting "Smart" about Staying on Line

More people on line, more devices connected to networks, more data transferred: these characteristics define the future, as a vast array of devices become "smart" and interconnected. Today, over 14 billion of these devices outnumber people on the planet by a ratio of 2:1; by 2030, the device population may grow to 500 billion. Left unchecked, corresponding energy demand would soar to 1 140 terawatt hours (TWh) per year by 2025 compared to 615 TWh today – most of it consumed when devices are in standby, i.e. "ready and waiting", but not performing their main function.

Key findings

- Energy demand from information and communication technology (ICT) is on the increase, largely driven by the massive deployment of network-enabled devices in homes and offices.
- The electricity demand of network-enabled devices is expected to almost double between 2013 and 2025; as these devices spend most of their time in "standby mode", up to 80% of their electricity consumption is just to maintain connection to the network.
- Implementing best available technologies (BATs) and solutions could reduce this demand by up to 65%.
- High-efficiency mobile devices can maintain a network connection at 50 milliwatts (mW).

Opportunities for policy action

- There are no technical barriers impeding the potential to integrate the energy efficiency and power management solutions in mobile devices into other network-enabled devices. What's lacking are market drivers to achieve the same level of efficiency, creating a strong case for policy intervention.
- Policy options proven to be effective in tackling the issue of energy demand from network standby include minimum energy performance requirements or standards, voluntary agreements with industry, and consumer awareness campaigns.
- A few governing bodies have started to develop and implement network standby policies, notably the European Union, Korea, Switzerland and the United States. As network-enabled devices are traded globally, international policy co-ordination and co-operation provides the most efficient means to initiate action and ensure that efforts contribute to shared goals.
- To stimulate international dialogue and policy co-operation, the International Energy Agency (IEA) has developed a digital energy efficiency plan outlining how diverse measures can unlock vast energy savings – without compromising the quality of services delivered by network-enabled devices.

The ability to be "on line all the time" relies on two things: a complex infrastructure of network equipment and the ability of "edge devices" (computers, smartphones, etc.) to connect. A largely invisible aspect of our increasingly networked society is a rapid surge in energy demand to power an increasingly broad array of network-enabled devices. The ICT sector, which comprises end-use devices, network equipment and network infrastructure, accounted for more than 8% of total final global electricity consumption in 2013 (IEA and 4E IA, 2014 forthcoming).

To participate in a network, edge devices such as set-top boxes and smart TVs are "on" or "almost on" 24 hours a day, seven days a week, the end result being that two-thirds or more of their electricity consumption occurs when they are not actually in use (NRDC, 2010). For some device categories the situation is even more extreme: some games consoles use 80% or more of their electricity not to provide entertainment but just to maintain a network connection (Hittinger, 2011; NRDC, 2013).

At present, some 14 billion network-enabled devices have been deployed globally. The vast majority, irrespective of whether they are in "active" or "standby" mode, draw energy as though they were constantly in use. In reality, a very large proportion of this energy demand is simply wasted – as much as 80% in some cases. The underlying default is the inability of network-enabled devices to power down to low-power modes at times of low usage.

Lack of technical solutions is not the barrier: rather, with rapid response being the prime selling feature and low consumer awareness of energy draw, there is little market incentive to embed technologies that could change the equation. Analysis shows that – with existing solutions – energy consumption of network-enabled devices could be slashed by 65% (Bio Intelligence Service, 2013; IEA and 4E IA, 2014 forthcoming). The current situation creates a strong case for policies to support the development and implementation of energy efficient solutions to tackle network standby.

The European Union, Korea, Switzerland and the United States are front runners in developing policies that cover diverse aspects of standby in network-enabled devices using varied approaches. As network-enabled devices evolve rapidly and are traded globally, a strong case can be made for the need to develop international policies and standards: co-operation by all stakeholders can ensure resource efficiency and enable rapid and well-targeted policy responses in a complex technology environment. Political leadership is vital to enable this high level of co-operation.

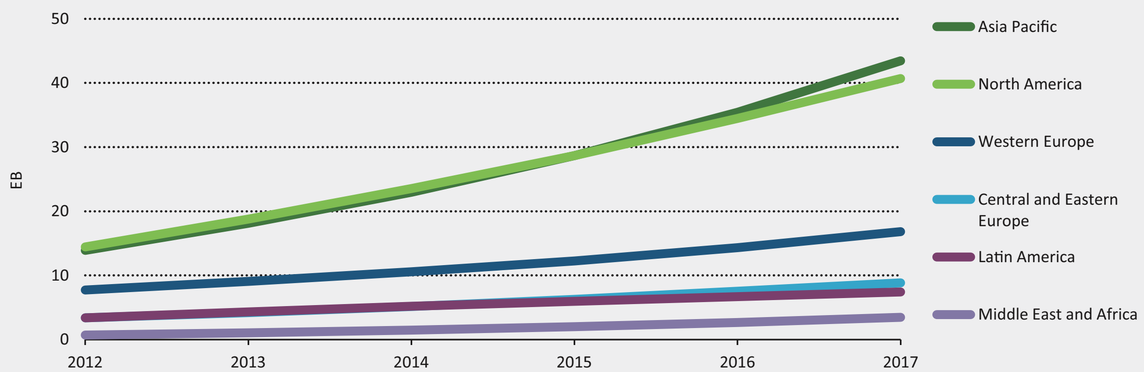
The importance of network standby as an increasingly urgent issue has prompted the IEA together with the Implementing Agreement for a Co-operative Programme on Energy Efficient End-Use Equipment (4E IA) to publish a book that provides an overview of trends, technology and technical solutions, and policy initiatives. *More Data, Less Energy: Making Network Standby More Efficient in Billions of Connected Devices*, scheduled for release in mid-2014, provides actionable policy guidance and outlines a work plan for action (IEA and 4E IA, 2014 forthcoming).

Everyone and Everything is Becoming Connected

More people are going online, in more ways. From 1990 to 2013, Internet users increased from 3 million to 2.7 billion. Today, they use many more types of devices to take advantage of diverse on-line technologies such as broadband connectivity, wireless mobility, cloud computing, e-commerce, social media and sensors. Already, more than 4.3 billion video-enabled devices – such as tablets, smart TVs, games consoles, smartphones, set-top boxes and Blu-ray players – are connected to the Internet. This is expected to almost double to 8.2 billion units by 2017 (IHS, 2013), as nearly all electronic and electrical technologies will become networked in the near future.

Internet traffic is growing at an exponential rate. During 2000-10, global Internet traffic grew more than 100-fold, yet in some regions access is still very low: future growth will continue a steep upward curve. In 2012, 74% of Internet protocol (IP) traffic and 94% of consumer Internet traffic originated from personal computers (PCs). By 2017, analysts estimate that 49% of IP traffic and 39% of consumer Internet traffic will originate from devices such as smart TVs.

Figure 2.1 **Projected growth of monthly IP traffic by region**



Notes: figures and data that appear in this report can be downloaded from www.iea.org/etp/tracking/. The byte is a unit of digital information in computing and telecommunications. One exabyte (EB) corresponds to 1 billion gigabytes (GB).
Source: adapted from Cisco, 2013.

Key point *IP traffic is expected to grow rapidly in all regions; particularly strong growth is expected in emerging and developing economies.*

Homes and offices are becoming increasingly networked with "smart" devices and "smart" systems, driven by consumer demand for new services, applications and functionalities and by business incentives such as demand-side management and deployment of "smart" meters and monitoring systems.

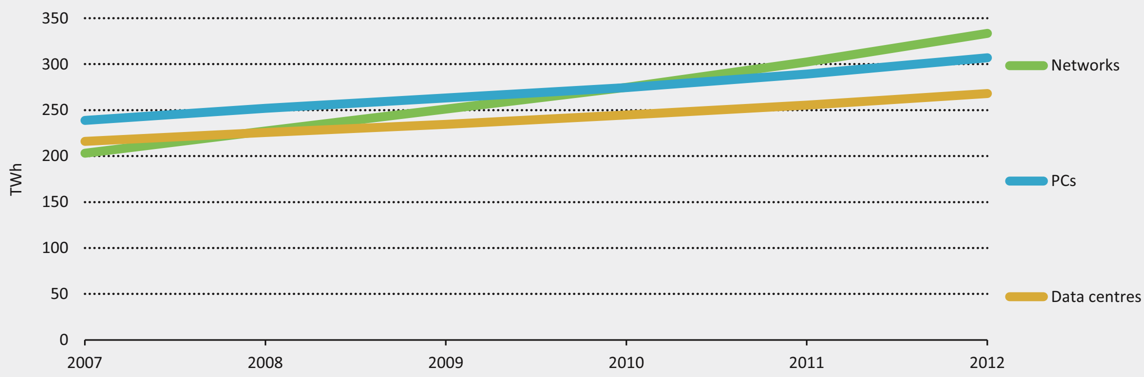
Network-enabled devices are forecast to increase fivefold by 2020 (World Economic Forum and INSEAD, 2012) and industry experts project an uptake of 50 billion network-enabled devices by 2020, reaching towards 500 billion over the coming decades (OECD, 2012). Globally, there were already more than 14 billion networked devices in 2012 – two per capita. Projections indicate that globally there will be nearly three networked devices per capita in 2017 (Cisco, 2013).

Manufacturers are already building "smart" home appliances that can interact with their owners and with one another, connect to smartphones, call a repairman when something goes wrong – even negotiate energy rates with the power company. Additionally, network equipment is needed to create the infrastructure for passing data among the networked devices and to connect to the Internet. More electronic devices are getting network connectivity, notably audio/video devices, and many non-electronic devices are beginning to acquire it, such as kitchen and laundry appliances; heating, ventilation and air-conditioning (HVAC) systems; lighting; and other end uses.

Rapidly Expanding Digital Economy Carries an Energy Cost

ICT energy demand is growing faster than all other energy end uses as appliances and equipment are increasingly network-connected, and networks and infrastructure are expanding to support growing communication traffic volumes. Worldwide electricity use is increasing at a compound annual growth rate (CAGR) of less than 3%; by contrast, the electricity to fuel networks is increasing at a CAGR of more than 10%, PC electricity demand at more than 5%[1] and data centre electricity demand at more than 4% (Van Heddeghem et al., 2014 forthcoming).

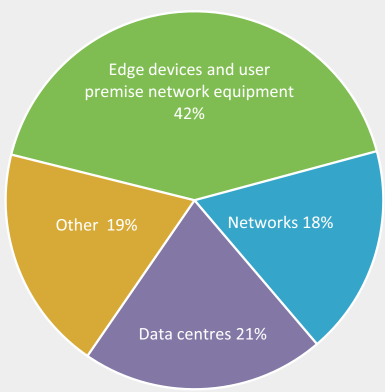
Figure 2.2 Global electricity consumption of networks, PCs and data centres



Note: does not include other network-enabled devices apart from PCs (PCs include desktop computers and laptops).
Source: Van Heddeghem et al., 2014 forthcoming.

Key point *Global energy demand of networks is growing at more than triple the rate of overall energy demand.*

Figure 2.3 Share of ICT electricity demand by ICT sub-segment in 2013



Source: unless otherwise noted, all tables and figures in this chapter derive from IEA data and analysis.

Key point *Edge devices and user premise network equipment account for the bulk of current ICT electricity demand.*

1 The energy performance of personal computers is improving. For example, the average performance of notebooks appears to be steadily improving with data showing a 10% decrease in average annual consumption for 2007 to 2008; consumption of the best-performing notebooks in the United States and European Union fell by 8% per year from 2008 to 2011 (4E IA, 2012a). Increases in energy demand are due to increased deployment and changes in usage patterns.

Edge devices (such as set-top boxes, games consoles and printers) and user premise network equipment (such as modems and routers), i.e. the aggregate of electronics located in homes and offices, constitute more than 40% of ICT electricity demand.

A single network-enabled games console continuously drawing up to 190 watts (W) per hour may not seem like much to worry about, but the scale of deployment for network-enabled devices makes the cumulative effect quite staggering. By 2013, the global population of network-enabled devices had already reached 14 billion – two for every person on the planet. In 2013, network-enabled devices used more than 615 TWh – surpassing the electricity production of Germany (611 TWh in 2012).

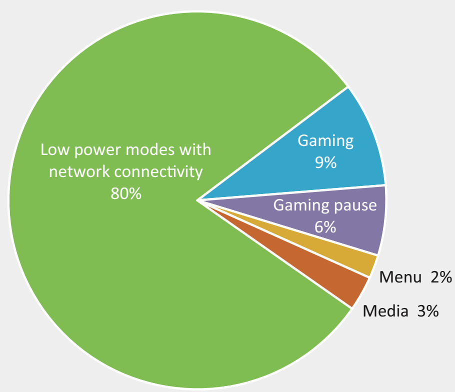
With a projected increase to 50 billion devices by 2020 (OECD, 2012), the amount of wasted energy becomes substantial. By 2025, without any radical efforts to improve energy efficiency, these devices are projected to consume close to 1 140 TWh, surpassing the current electricity production of Russia and accounting for 6% of total final global electricity consumption.

Energy Efficiency Opportunities

The savings potentials from mainstreaming energy efficiency solutions across all components of ICT-based systems – network-enabled devices, networking equipment, and network infrastructure – are considerable and grow as these systems expand and connectivity spreads.

The solution is not to pull the plug on connectivity. Some devices, particularly network equipment that has the primary function of transmitting data, need to be on continuously. The challenge is more about ensuring that network-enabled devices do not use excessive amounts of energy unnecessarily.

Figure 2.4 Example of annual energy consumption using a typical duty cycle of a 2010 games console model



Note: a 2010 games console model with a low-power active mode in which the console appears to be in standby but remains connected. The console uses 10 W of power per hour in standby mode, which accounts for 80% of the annual energy consumption using a typical duty cycle.
Source: NRDC, 2013.

Key point *Some network-enabled devices are using up to 80% of their electricity demand to maintain connectivity.*

Technologies and solutions: powering down and power scaling

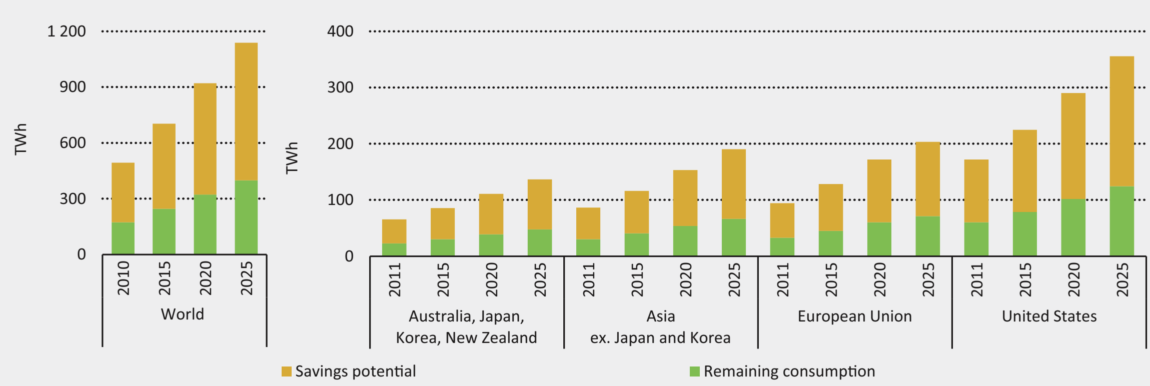
The ICT sector is designed to be on all the time, operating with maximum capacity and speed: no break time, and no loss of service; electricity demand does not change with changes in traffic volumes (Auer et al., 2011). This design principle is crucial for the core components of networks. But a large number of devices that are becoming network-enabled – for example, those offering entertainment or comfort features – do not need to be on all the time. In fact, global electricity demand of network-enabled edge devices and network equipment could be slashed by 65% by implementing BATs – resulting in savings of almost 740 TWh per year by 2025 and corresponding to 4% of current global total final electricity consumption.

Solutions already exist that enable such devices to maintain connectivity when needed but to "power down" (i.e. reduce their energy draw) when not in use or not engaged in sending or receiving important messages. Other solutions ensure that devices can stay connected continuously, but with far lower energy consumption. This can be done by, for example, shutting down those parts of the device not needed when the equipment is not communicating.

Even devices that need to be connected all the time can be designed to maintain connectivity for less energy. The principle of power scaling is to match the energy demand of such devices to the actual work performed; rather than needing to draw large quantities of power just to maintain capacity, they would have the capacity to use less power when less data is being transmitted. One option is to reduce the processing rate of a device when its workload is low.

Some solutions can be embedded in devices; others require changes in how networks or other devices on the network function. While some solutions incur extra costs, many just require use of technology standards that enable power management and more energy efficient device behaviour.

Figure 2.5 **Global network-enabled device electricity consumption and savings potential**



Notes: domestically and professionally used network-enabled equipment, connected to external or internal networks. Savings potential estimated on the difference between the BAT and the average device on the market.
Source: Bio Intelligence Service, 2013.

Key point *Early action to improve energy efficiency of devices leads to greater savings over time, even as the number of devices in use rises steeply.*

Mainstreaming energy efficiency in the ICT sector is not a one-off activity – it requires sustained effort by multiple stakeholders. Policy makers play an important role in facilitating the development and uptake of solutions, and in creating market demand for more efficient devices and systems.

Market Creation

While energy efficiency in ICTs and networks is gaining attention, some areas require policies to accelerate progress and create a demand for energy efficient solutions.

Where energy efficiency contributes to an improved bottom line, industry itself often drives the development and implementation of energy efficient solutions. This is true, for example, in optimising energy use in data centres. For portable devices that rely on batteries, strong consumer demand for lightweight devices with long battery life encourages manufacturers to incorporate design criteria that support energy efficiency.

Box 2.1 From standby to network standby

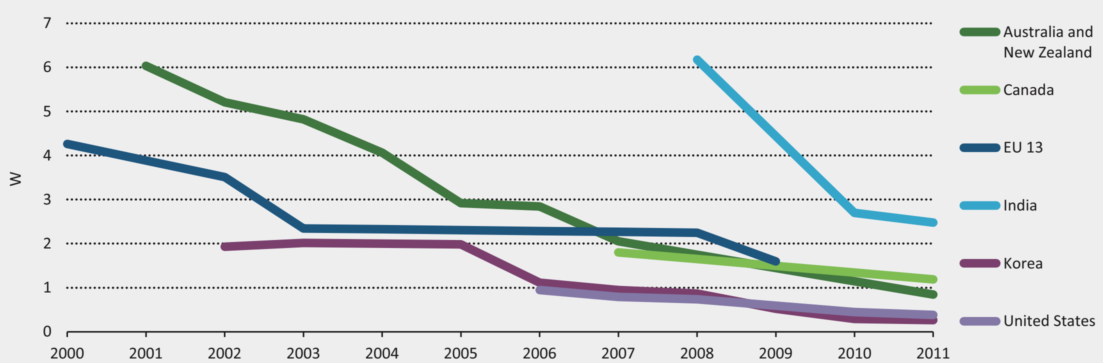
Standby power refers to the electricity consumed by appliances while not performing their primary functions. There are two general types of secondary functions for stand-alone devices (i.e. not network connected) that use energy in low power modes:

- the ability to be activated via a remote control and quicker start-up;
- features provided for convenience such as a clock display.

The issue of standby energy consumption is aptly illustrated by the case of the microwave oven. Heating food (the primary function) requires 100 times more power than running the clock displayed on most microwave ovens. But most microwave ovens are in standby mode(s) more than 99% of the time; over their life cycle, more energy is used to run the clock display than to cook food.

Standby power was first recognised as an area of significant energy waste in 1986. Experts estimate that standby energy now accounts for 1% to 2% of global electricity consumption and approximately 10% of residential electricity use (Energy Efficient Strategies, 2011). In 1999, the IEA proposed that all countries harmonise energy policies to reduce standby power use to no more than 1 W per hour. Widespread uptake of this initiative has had a clear impact in driving down energy consumption of televisions (other appliances show similar trends).

Figure 2.6 Average standby power of TVs



Notes: EU 13 includes data from Austria, Belgium, the Czech Republic, Denmark, France, Germany, Greece, Hungary, Italy, Latvia, Portugal, Romania and the United Kingdom. TVs covered include: cathode ray tube, liquid crystal display and plasma.
Source: 4E IA, 2012b.

Key point *In a relatively short time, policy intervention has been instrumental in pushing standby power of TVs to 1 W or less in multiple countries and regions.*

In fact, portable devices by far surpass devices that are mains-connected (i.e. devices that need to be plugged into electricity sockets) in terms of energy efficiency, including standby power consumption. High-efficiency mobile devices can maintain a network connection at 50 mW, whereas some set-top boxes use up to 40 W for that purpose. There are no technical barriers to implementing a similar emphasis on integrated energy efficiency and power management solutions in other network-enabled devices. What is lacking is the same level of drivers for efficiency.

This creates a strong case for policy intervention to support and foster the development and implementation of energy efficient solutions for the mains-connected devices that account for a large share of this energy demand. Concerted, international efforts such as those that were initiated as part of the IEA 1-Watt Plan of 1999 are needed, with recognition that technologies have advanced rapidly and tackling network standby will be more complex.

To date, policy initiatives for low-power modes for network standby have been limited, but progress is under way. Both Korea and the European Union have established minimum energy performance requirements to reduce standby energy consumption in network-enabled devices. The European policy (the most far-reaching to date) is estimated to achieve savings of approximately 49 TWh per year by 2025 (European Commission, 2013).

Voluntary endorsement programmes, such as ENERGY STAR and industry-led initiatives, also play an important role in fostering the uptake of energy efficient solutions. Rule-making to consider efficiency standards for set-top boxes spurred the US set-top industry to launch its voluntary agreement in 2013. The agreement engaged 15 industry-leading, multi-channel video providers and device manufacturers that deliver service to more than 90 million US households and is expected to result in annual residential electricity savings of USD 1.5 billion. Rule-making considerations have also promoted focus on energy efficiency in games consoles.

In May 2013, the Swiss Federal Office of Energy, together with leading service providers, launched a large awareness campaign on how customers can optimise the energy performance of modems, routers and set-top boxes (the country has more than 3 million modems and 2 million set-top boxes). The initiative aims to slash annual energy consumption of these devices from 500 gigawatt hours (GWh) per year to 320 GWh per year. The resulting savings of 180 GWh represents enough electricity supply to power 40 000 households (Brüniger, 2013).

These examples should spur other countries to follow suit and start addressing energy wasted by network-enabled devices. Without policy interventions, it is expected that:

- Energy efficiency will continue to be a low priority in device design.
- The value chain will lack incentives to develop energy-saving solutions.
- The rate of energy efficiency improvements will be slow.

Where policies and implementation vary considerably among countries, there is a risk that devices that do not comply with legislation in one jurisdiction will be sold in countries lacking legislation or with weaker requirements – i.e. inefficient devices will dominate in markets lacking interventions.

The Way Forward

International dialogue and alignment in this area will reduce the resources needed to develop policy responses. Ultimately, aligned approaches will reduce costs and unnecessary constraints on industry by avoiding situations in which globally traded devices must comply with a multitude of diverse regulatory approaches and procedures.

Building on the success of the 1-Watt Standby Plan, the IEA proposes a Digital Energy Efficiency Plan. This plan aims to initiate an ongoing process to enable the necessary research, stakeholder dialogue and information sharing that will enable policy makers to ensure that energy efficiency considerations are a core consideration in moving towards increasingly digitalised societies.

The IEA has developed a set of Guiding Principles to ensure that networks and network-enabled devices are designed with energy efficiency in mind. Leading industry associations have already adopted elements of the IEA guidelines, but further work is needed to mainstream energy efficiency in the design of ICT systems and devices.

Box 2.2 IEA Guiding Principles for Energy Efficient Networks and Network-Enabled Devices

The IEA Guiding Principles for Energy Efficient Networks and Network-Enabled Devices (IEA, 2007) sets out broad principles that support low(er) energy consumption in networks and network-enabled systems, focusing on both hardware and technology and on policy.

Five principles for hardware and technology design:

- Devices should support effective power management.
- A network function should not stop power management internally.
- A network function should not stop power management in other devices on the network.
- Devices should cope with legacy equipment on the network (that may have poor behaviour or lack suitable energy management features).
- Devices should scale power requirements in proportion to the service being provided.

Four principles for energy policy:

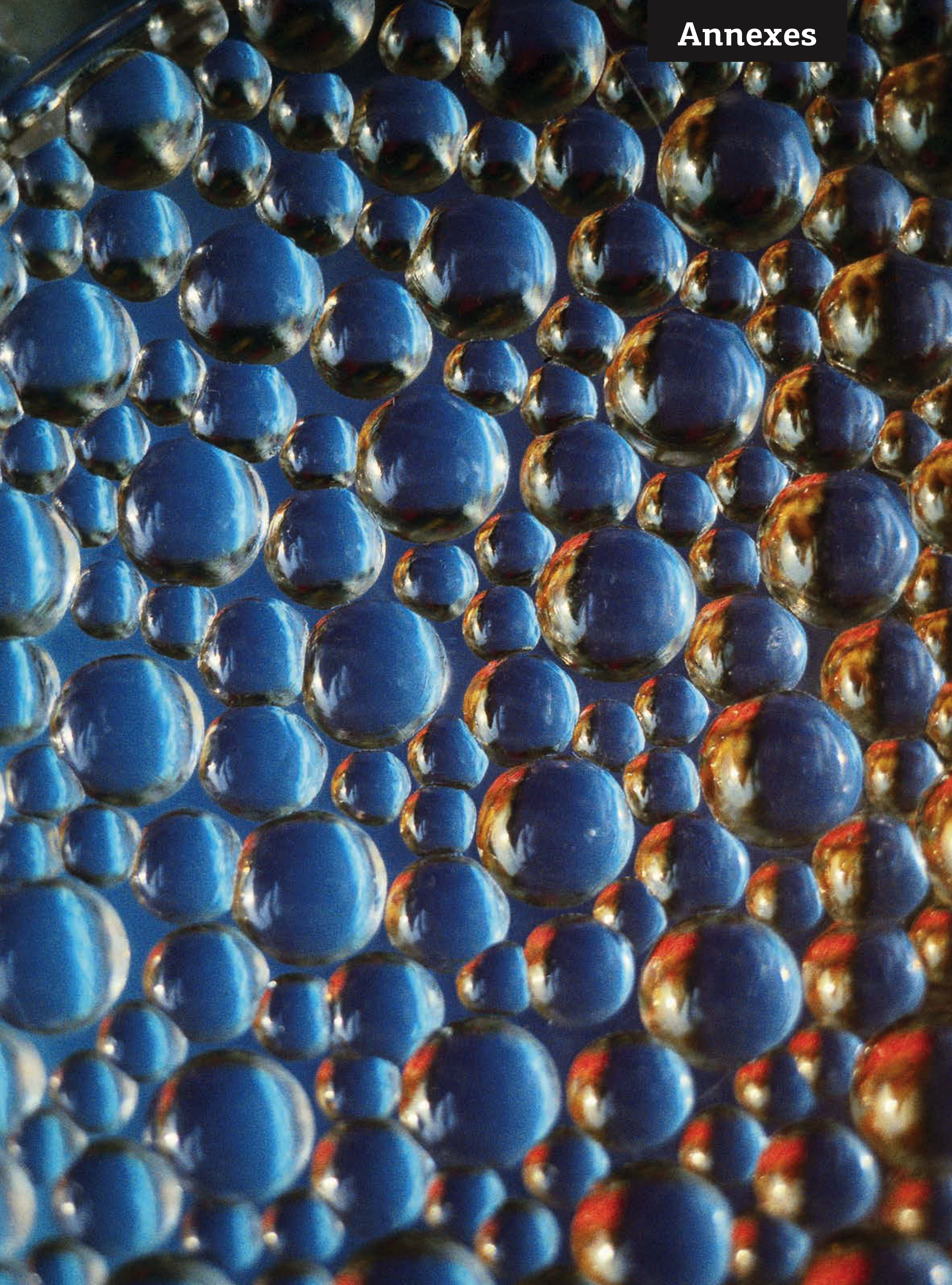
- Require power management to automatically enter low-power modes.
- Put reasonable power limits on low-power modes.
- Encourage network-enabled devices to minimise their total energy consumption, using industry-wide protocols for power management in networks.
- Keep performance requirements generic; require specific hardware or software technologies only after careful consideration.

As part of the Digital Energy Efficiency Plan, the IEA recommends that governments take three broad steps to stimulate implementation of the IEA Guiding Principles.

- Develop policies with clear and measurable energy efficiency objectives to promote power management in network-enabled devices.
- Intensify international co-operation to develop technical foundations for policy making, including the development of energy efficiency metrics and test procedures.
- Work towards establishing or supporting international initiatives to promote energy efficiency in the broader context of digital economies.

Considering the rapidly growing share of network power consumption, energy efficiency in a digital context needs to become an integrated part of the agenda of IEA member countries as well as key international initiative such as the Clean Energy Ministerial (CEM) and the G20.

CEM ministers are encouraged to enable and endorse a collective global approach to addressing network standby, by expanding the activities of the Super Efficient Appliance Deployment (SEAD) and related initiatives and adding their respective country's expertise and effort to international co-operation on network power energy efficiency solutions.



Acronyms, Abbreviations and Units

Acronyms

APEC	Asia Pacific Economic Cooperation
ASEAN	Association of Southeast Asian Nations
BAT	best available technologies
BEV	battery-electric vehicle
BF	blast furnace
BOF	basic oxygen furnace
BPT	best practice technologies
BRT	bus rapid transit
CAGR	compound annual growth rate
CCGT	combined cycle gas turbine
CCS	carbon capture and storage
CDQ	coke-dry quenching
CEM	Clean Energy Ministerial
CEPI	Confederation of European Paper Industries
CFL	compact fluorescent lamp
CHP	combined heat and power
COG	coke oven gas
CSP	concentrated solar power
DES	deep eutectic solvents
DH	district heating
DHC	district heating and cooling
DRI	direct reduced iron
EAF	electric arc furnace
EMEC	European Marine Energy Centre
EnMS	energy management systems
EOR	enhanced oil recovery
EPA	Environmental Protection Agency
ESCII	Energy Sector Carbon Intensity Index
ETP	Energy Technology Perspectives
EU	European Union
EUR	euro
EV	electric vehicle
EVI	Electric Vehicles Initiative
FiT	feed-in tariffs
FTA	Free Trade Agreement
GBP	Great Britain pound
GEF	Global Environment Facility
GHG	greenhouse gas
GSEP	Global Superior Energy Performance Partnership
HDV	heavy-duty vehicle
HEV	hybrid-electric vehicle
HVAC	heating, ventilation and air-conditioning
HVC	high-value chemicals
ICAO	International Civil Aviation Organization

ICE	internal combustion engine
ICT	information and communication technologies
IEA	International Energy Agency
IGCC	integrated gasification combined cycle
IIL	inefficient incandescent lamps
IP	internet protocol
IPEEC	International Partnership for Energy Efficiency Co-operation
ISGAN	International Smart Grid Action Network
ISO	International Organisation for Standardisation
JPY	Japan Yen
LED	light-emitting diode
LEED	Leadership in Energy and Environmental Design
LIS	Low Impact Steel
LNG	liquefied natural gas
low-e	low-emissivity
MEPS	Minimum Energy Performance Standards
NEA	Nuclear Energy Agency
NEDO	New Energy and Industrial Technology Development Organization
NOAK	Nth of a Kind
OCGT	open-cycle gas turbine
OECD	Organisation for Economic Co-operation and Development
OHF	open-hearth furnaces
PC	personal computers
PHEV	plug-in hybrid-electric vehicle
PLDV	passenger light-duty vehicle
PMU	phasor measurement units
PPP	purchasing power parity
PTC	production tax credit
PV	photovoltaic
R&D	research and development
RD&D	research, development and demonstration
RDD&D	research, development, demonstration and deployment
SEAD	Super-Efficient Equipment and Appliance Deployment
SIRFN	Smart Grid International Research Facility Network
ULCOS	Ultra-Low Carbon Dioxide Steelmaking
USD	United States dollar
WAMPAC	wide-area monitoring, protection and control
WHR	waste heat recovery

Abbreviations

2DS	ETP2014 2°C Scenario
4DS	ETP2012 4°C Scenario
6DS	ETP2012 6°C Scenario
CO_2	carbon dioxide
NO_x	nitrogen oxide
SO_2	sulfur dioxide

Units of measure

bcm	billion cubic metres
EB	Exabyte
EJ	exajoule
G	gramme
GB	gigabyte
GJ	gigajoule
Gt	gigatonne
GW	gigawatt
GWh	gigawatt-hour
km	kilometre
kW	kilowatt
kWh	kilowatt-hour
m^2	square metre
Mbtu	1 000 British termal units
Mt	megatonne
MW	megawatt
mW	milliwatt
PJ	petajoule
pkm	passenger-kilometre
TJ	terajoule
tkm	tonne-kilometre
toe	tonne of oil equivalent
TWh	terawatt-hour
W	watt

Technology Overview Notes

Figures and data that appear in this report can be downloaded from www.iea.org/etp/tracking. Enhanced interactive data visualisations are also available for the figures marked with the "more online" ribbon.
Unless otherwise noted, data in this report derives from IEA statistics and analysis. The notes below provide additional sources and details related to data and methodologies.

Renewable Power (page 20)

Figures 1.1, 1.2: source: data for 2000-2018 from IEA (2013), *Medium Term Renewable Energy Market Report*, OECD/IEA, Paris.

Figure 1.5: source: Bloomberg New Energy Finance database, 2014.

Figure 1.8: data in USD 2012 prices and PPP. Bioenergy and biofuels includes solid biofuels used for heat and power and liquid biofuels used for transport. Other renewables refers to techniques, processes, equipment, and systems related to renewable energy and not limited to a specific technology or fuel source as well as technologies used for monitoring and measuring renewable energy.

Nuclear Power (page 26)

Figure 1.9: source: historic data from IAEA, PRIS Database. Projections from Nuclear Energy Agency (2012), *The Role of Nuclear Energy in a Low-Carbon Energy Future*, OECD/NEA, Paris.

Figure 1.10: 2DS numbers are required average yearly capacity additions: 12 GW/year in the decade to 2020, and 23 GW/year between 2020 and 2030.
Source: historic data from IAEA, PRIS Database.

Figure 1.11: construction span from first concrete to grid connection. Gen III construction spans starting in 2011 are estimated. Grid connection for projects under construction is estimated based on recent public information.
Source: realised grid connection data from IAEA PRIS database; OECD/NEA.

Natural Gas-Fired Power (page 28)

Figure 1.12: NBP = National Balancing Point (United Kingdom), representative of European gas prices.
Sources: Henry Hub: Intercontinental Exchange; NBP: GasTerra; Japan LNG: Japan Customs.

Figure 1.13: oil-fired power generation is negligible in Germany and the United States (<1%), but represents 15% in Japan (2011).

Figure 1.14: the capacity factor represents the full load hours a plant was operated as a percentage over a whole year (8 760 hours).

Coal-Fired Power (page 30)

Figure 1.15: other renewables includes geothermal, solar, wind, ocean, biofuels and waste.

Figure 1.16: source: 2011-2018 projections from IEA (2013), *Medium Term Coal Market Report*, OECD/IEA, Paris.

Figure 1.17: source: Platts database.

Carbon Capture and Storage (page 32)

Figure 1.18: large-scale projects are defined in accordance with the definitions of the Global CCS Institute: projects involving the capture, transport and storage of CO_2 at a scale of at least 800 000 tonnes of CO_2 annually for a coal-based power plant, or at least 400 000 tonnes of CO_2 annually for other emission-intensive industrial facilities (including natural gas-based power generation). Advanced stage of planning has been defined as projects that have reached at least the Define stage in accordance with the Global CCS Institute's Asset Lifecycle Model. Projects which do not have sufficient clarity at the end of 2013 over the support needed to become operational by 2020 have not been included. Projects included are those undertaking monitoring sufficient to provide confidence that injected CO_2 is permanently contained, which is assumed to be the case for all projects becoming operational after 2014.
Source: GCCSI (2014), *The global status of CCS: February 2014*, Global CCS Institute, Melbourne, Australia; IEA analysis.

Figure 1.19: the CCS patent database was constructed using a combination of keywords and patent classification codes to retrieve CCS-related patents in the United States, European and Japanese patent offices. Patents were sought for their pertinence to a range of practices including inter alia CO_2 capture from flue gases, CO_2 capture from industrial processes, natural gas clean-up, CO_2 enhanced oil recovery, CO_2 storage site management, CO_2 stream clean-up and oxyfuel power generation. The results were examined by subject matter experts to remove as many irrelevant patents as possible. Duplicates and triplicates (i.e., patents appearing in more than one patent office) were consolidated into single patents for the computation of these statistics.
Source: Science-Metrix Inc.

Figure 1.20: data in USD 2012 prices and PPP.

Industry (page 34)

Figure 1.21: the paper and paperboard category includes a wide variety of products with a range of BAT energy intensity values. Because of this variety, no overall energy intensity related to BAT is included.
Sources: IEA (2009), *Energy Technology Transitions for Industry*, IEA/OECD, Paris; Worrell, E., L. Price, M. Neelis, C. Galitsky and Z. Nan (2008), *World Best Practice Energy Intensity Values for Selected Industrial Sectors*, Lawrence Berkeley National Laboratory.

Figure 1.23: industrial energy use per unit of industrial value added in USD 2005 prices and PPP.

Chemicals and Petrochemicals (page 36)

Figure 1.26: 2025 data are 2DS targets. BPT values: steam cracking, naphtha based = 12.0 GJ/t; ammonia, coal based = 19.7 GJ/t; ammonia, oil based = 15.1 GJ/t; ammonia, gas based = 7.3 GJ/t; methanol, coal based = 12.8 GJ/t; methanol, gas based = 8.5 GJ/t. All energy intensities exclude energy associated with feedstocks (Source: IEA (2009), *Energy Technology Transitions for Industry*, IEA/OECD, Paris). Methanol production is mainly based on gas in OECD-member countries. A shift toward biomass-based methanol increases the level of energy intensity while reducing CO_2 footprint.

Iron and Steel (page 38)

Figure 1.28: depending on the specific status of the relevant process or plant, not all the indicated energy savings potentials may be relevant or able to be cumulatively tapped. "Other" refers to all countries and regions not included individually. BF = blast furnace; OHF =

open-hearth furnace; BOF = basic oxygen furnace; COG = coke oven gas; CDQ = coke-dry quenching (also includes advanced dry quenching).

Figure 1.29: aggregated energy intensity includes energy use in blast furnaces and coke ovens. Comparisons of this indicator among countries and regions are limited, as there are considerable differences in the iron and steel sector, specifically structure and quality of iron ore. Global overall crude steel energy intensity increases slightly in the short-term (2015) driven by fast capacity growth in some regions, with local scrap availability being unable to follow that increase. BAT values: coke oven net energy use = 3.7 GJ/t coke; blast furnace net energy use = 10.4 GJ/t hot metal; DRI gas = 10.4 GJ/t DRI; DRI coal = 20.0 GJ/tDRI; scrap-based EAF = 350 kWh to 370 kWh (1.3 GJ/t steel).
Source: IEA (2007), *Tracking Industrial Energy Efficiency and CO_2 Emissions*, IEA/OECD, Paris.

Transport (page 40)

Figure 1.30: Well-to-wheel refers to the energy use and GHG emissions in the production of a fuel and its use in a vehicle. Well-to-wheel energy use and GHG emission estimates exclude the production and end of life disposal of the vehicle and fuel production/distribution facilities. As such, they provide a partial view of energy use and emissions resulting from a Life Cycle Assessment (LCA) of fuel and vehicle production, use and disposal. LCA is a broader concept, requiring more information that the well-to-wheel energy and GHG emissions estimates. LCA is used to account for all the environmental impact (not only energy and GHG, but also many kinds of pollutants and water requirements) resulting from the consumption of all the materials needed for the production process.

Figure 1.31: source: BRT Centre of Excellence, EMBARQ, IEA and SIBRT. Global BRTdata database www.brtdata.org

Figure 1.32: data calculated by multiplying average fuel price in a country with the average new vehicle fuel economy. Sources: IEA (2013), *Energy Prices and Taxes database*, OECD/IEA, Paris; Cuenot and Körner (2011), *International comparison of light-duty vehicle fuel economy: an update using 2010 and 2011 new registration data*, GFEI IEA Working Paper 8.

Electric and Hybrid Electric Vehicles (page 42)

Figure 1.33: source: Electric Vehicles Initiative and MarkLines Database.

Figure 1.34: source: MarkLines Database.

Figure 1.35: source: MarkLines Database.

Biofuels (page 44)

Figure 1.36: an 85% capacity utilisation is assumed to derive the capacity requirements for the 2DS. Utilisation rates of new projects can lie well below this level in the first year of production. Projections from IEA (2013), *Medium Term Oil Market Report*, OECD/IEA, Paris.

Figure 1.37: projections from IEA (2013), *Medium Term Oil Market Report*, OECD/IEA, Paris.

Figure 1.38: source for figure and textbox: Bloomberg New Energy Finance database, 2014.

Appliances and Equipment (page 50)

Figure 1.44: source: Super-Efficient Equipment and Appliance Deployment (SEAD) initiative, 2014.

Figure 1.45: ownership levels above 100% indicate more than one unit per household. For instance, 150% television ownership indicates an average of 1.5 televisions per household.

Missing bars do not indicate 0%; rather, data were not available for those indicators. Japan refrigerator data has not been updated since 2004.

Figure 1.46: source: adapted from US DOE (2012), *Solid-State Lighting Research and Development: Multi-Year Program Plan*, prepared for Lighting Research and Development Building Technologies Program, Office of Energy Efficiency & Renewable Energy, Washington, DC.

Co-generation and district heating and cooling (page 52)

Figure 1.47: According to IEA energy balance conventions, for auto-producer co-generation plants, only heat generation and fuel input for heat sold are considered, whereas the fuel input for heat used within the auto-producer's establishment is not included, but accounted for in the final energy demand in the appropriate consuming sector. Transmission and distribution losses are not included.

Figure 1.48: source: Euroheat & Power (2013), *District Heating and Cooling: Country by country 2013 survey*, Euroheat & Power, Brussels.

Figure 1.49: Russian data is from 2007.
Source: Euroheat & Power (2013), *District Heating and Cooling: Country by country 2013 survey*, Euroheat & Power, Brussels.

Smart Grids (page 54)

Figure 1.50: source: ISGAN (2014), "ISGAN Inventory Report, Annex 1, Task 2", *Smart Grid Project Catalogue: Part 1 by Project Main Application,* United States.

Figure 1.51: source: Navigant Research (2013), "Executive Summary: Smart Meters", *Smart Electric Meters, Advanced Metering Infrastructure, and meter Communications: Global Market Analysis and Forecasts*, United States.
Textbox source: ISGAN (2013), "ISGAN Annex 6 Discussion Paper", *Smarter & Stronger Power Transmission: Review of Feasible Technologies for Enhanced Capacity and Flexibility,* updates through professional correspondence; Swedish Transmission Institute, Sweden; Department of Electric Power Engineering, Norway.

Figure 1.52: investment includes transmission upgrades, substation automation, distribution automation, smart grid information and operations technology, and smart metering. Data are based on the best estimates available at the time of calculation. Annual revenues, shipments, and sales are based on end-of-year figures unless otherwise noted. All values are expressed in 2013 USD.
Source: Navigant Research (2013), "Executive Summary: Smart Grid Technologies", *Transmission upgrades, Substation Automation, Distribution Automation, Smart grid information technology and Smart Metering: Global market Analysis and Forecasts,* United States.

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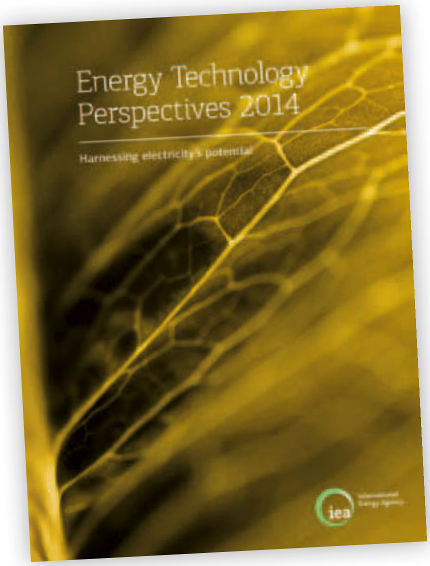

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Tracking Clean Energy Progress 2014

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The 22 countries that participate in the Clean Energy Ministerial (CEM) share a strong interest in the development and deployment of clean energy technologies. As these same countries represent more than 75% of global energy consumption, 80% of global CO_2 emissions and 75% of global GDP, they have the power to drive the transition to a cleaner energy system and, since CEM first convened in 2010, have taken steps toward this challenging goal. So how much progress has been made thus far?

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