Tracking Clean Energy Progress 2015

Energy Technology Perspectives 2015 Excerpt
IEA Input to the Clean Energy Ministerial

International Energy Agency
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INTERNATIONAL ENERGY AGENCY

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

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

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Table of Contents

Foreword

As the IEA looks to what is being heralded as a historic year for international cooperation on climate change mitigation, I wonder: will we be able to rise to the challenge? Drawing on the analysis of *Energy Technology Perspectives 2015* (*ETP 2015*) to survey today's energy landscape, I am as convinced as ever that the opportunities are there. Never has the promise of clean energy technology been so great. Yet, *ETP 2015* also highlights that never have the challenges surrounding deployment of the proper solutions been so daunting. We need to start thinking differently about what we can do to change the current sluggish pace towards sustainable change: we need to innovate!

ETP 2015 demonstrates that strategic action on clean energy technologies at national, regional and international levels has the capacity to move the world closer to shared goals for climate change mitigation while delivering benefits of enhanced energy security and sustainable economic development. Unfortunately, this report also shows that the current pace of action is falling short of the aim of limiting climate change to a global temperature rise of 2°C (in *ETP* modelling, the 2° Scenario or 2DS). Indeed, despite positive signs in many areas, for the first time since the IEA started monitoring clean energy progress, not one of the technology fields tracked is meeting its objectives. As a result, our ability to deliver a future in which temperatures rise modestly is at risk of being jeopardised, and the future that we are heading towards will be far more difficult unless we can take action now to radically change the global energy system.

ETP analysis shows that innovation needs strong support to be able to deliver on its promises. Indeed, inventions do not become innovations until they are deployed at scales sufficient to have an impact, and there are many non-technical barriers that can prevent very cost-effective solutions from playing their role. We must therefore adopt a systems perspective and recognise that technology innovation will only occur if the right policy signals and market and regulatory frameworks are in place to foster environments conducive to attracting the required levels of investments. International collaboration can provide the means to speed up innovation by sharing best practices and enabling a pooling of resources for solving common issues.

The theme of *ETP 2015*, "Mobilising Innovation to Accelerate Climate Action", not only reaffirms the need for government to stimulate energy technology innovation across production and consumption in all sectors, but also to recognise the impacts innovation can have on providing cost-effective means to achieve ambitious goals. This year's analysis highlights areas in which targeted action can deliver rapid impacts, for instance, by stimulating wider deployment of renewables such as wind and solar photovoltaics and by reducing emissions and improving efficiency in industry. It also demonstrates the importance of early action to enable longer-term benefits including the advancement of carbon capture and storage along the innovation pathway and boosting innovation capacity in emerging economies.

The timescale for this publication is 40 years. This also represents the IEA's history of supporting international technology co-operation through its energy technology network, which celebrates in 2015 four decades of progress in accelerating technology results through international collaboration. Through its broad range of energy technology initiatives, the IEA enables countries, businesses, industries, and international as well as non-governmental organisations to share research on breakthrough technologies, to fill existing research gaps, to build pilot plants and to carry out deployment or demonstration programmes across the energy sector. This quiet success story demonstrates that, through a common shared vision, stakeholders worldwide can take actions that will enable the transformation needed to support energy security, economic growth, and environmental protection.

We need more collaboration of this type if we are to transcend the shortcomings of our current energy system, which is unsustainable and, therefore, insecure. The climate negotiations set to take place in Paris later this year make it imperative that the messages of *ETP 2015* be heard by all stakeholders and turned into ambitious pledges for actions. This is the time to construct a clean energy future that works for everyone, and for our leaders to have the wisdom to seize the power of innovation to benefit from the best that technology offers.

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

Maria van der Hoeven
Executive Director
International Energy Agency

Key Findings

Market viability of some clean energy technologies is progressing, but the overall rate of deployment falls short of achieving the *ETP* 2°C Scenario (2DS).

- **The cost gap between electricity generated from renewables and that from fossil fuels is narrowing.** Some renewables are already competitive with new-built fossil fuel plants in various locations. In addition, long-term contracts with record low prices were signed for both onshore wind and utility-scale solar photovoltaic (PV) projects over the last year showing the significant improvement on cost of energy for some renewables.
- **Solar PV may even exceed 2DS targets with its strong growth in deployment and increasing competitiveness.** Improvement in the rate of onshore wind and hydropower deployment is needed to get back onto the 2DS trajectory. Meanwhile, progress has slowed in the development of bioenergy, offshore wind, geothermal power, solar thermal electricity (STE) and ocean energy. In addition to current policy frameworks further support is needed to overcome technology-specific barriers in order to meet 2DS targets.
- **Globally annual additions of renewable power capacity are expected to level off over the medium term.** Policy uncertainty and retroactive policy signals are the main barriers to deploying renewables in member countries of the Organisation for Economic Co-operation and Development (OECD). However, persistent economic and non-economic barriers remain challenging to deployment in OECD non-member economies. In particular, issues concerning financing, grid connection and integration are contributing to the slow-down in renewable power deployment and generation.

Key Numbers

2.6% annual increase in global energy demand between 2002 and 2012

4% annual increase in GDP since 2002

3.6% global annual increase in electricity demand between 2002 and 2012 › **2.3%** annual increase expected to 2025

Electricity from variable renewables › **2.8%** in 2012 — **12%** in 2025

7 billion global population in 2012, grew at a rate of **1.2%** per year between 2002 and 2012

- **Support for low-carbon heat is very limited compared with low-carbon electricity.** Both co-generation and the use of modern renewable energy for heat have grown in absolute terms, but their rate of growth is too slow; co-generation has plateaued as a share of global electricity generation. The strong potential of these technologies, particularly when combined with district heating and cooling (DHC), to support greater integration of locally available, renewable or surplus energy sources is not being tapped.
- **Electricity markets and market mechanisms need to reflect the true environmental costs of generation while also adapting to the production of variable and distributed clean energy generation.** Clear and strong market incentives that favour low-carbon technologies, either through the introduction of carbon prices or technology feed-in tariffs, are required to make clean energy technologies competitive in an era of continuing low coal prices. To secure investment and integration, market mechanisms need to be accompanied with clear policy goals that build certainty.

Limited data availability and poor data consistency on energy use constrain capacity to undertake the targeted analysis required to identify underlying trends and the most appropriate policy options.

- **High-quality, timely, comparable and detailed data and indicators are vital to establishing, monitoring and maintaining (or adapting) sound policies.** Promoting the development of metrics for evaluating the penetration of clean energy technologies, costs and benefits, requires both national data collection and international data co-ordination. Filling existing data gaps, many of which are highlighted in this report, is vital to improving reporting of data and the quality of official statistics.

Thermal demand accounted for **44%** of final energy in 2012

29% of emissions

87 **USD/MWh** for solar PV electricity, a record low price for contracts signed in 2014

56% increase in solar PV electricity generation in 2012

42 **EUR/tCO$_2$** carbon price to effect short-term coal-to-gas switching in Europe

6.3 **EUR/tCO$_2$** average carbon price in 2014 in Europe

The deployment of clean fossil and nuclear technologies is constrained by complacency in exploiting existing opportunities.

- **Low-priced coal was the fastest-growing fossil fuel in 2013, and coal-fired generation increased in all regions.** Newer coal plants can perform to a relatively high standard. But where coal-fired capacity is expanding, in emerging economies for example, less efficient, subcritical units dominate, primarily due to the absence of minimum efficiency policies.
- **Natural gas-fired power, a cleaner and more flexible generation fuel than coal, slowed markedly on global markets in 2013-14, unable to compete against low coal prices.** Weakened electricity demand and coal oversupply (leading to low coal prices) are undermining natural gas use for electricity generation. Technical developments to improve the flexibility of gas fired-power plants are continuing apace, establishing a long-term competitive advantage over the traditional base-load plants.
- **On the nuclear side, 2014 saw the highest number of reactors under construction in more than 25 years.** But the increase in global capacity and the rate of grid connections are still too low to meet 2DS targets in 2025. Overall, there appears to be a plateauing of growth in OECD countries, though some newcomer countries (including Turkey and Poland) are preparing for new build. Much stronger growth is expected in OECD non-member economies, with China having particularly ambitious plans.

New clean energy technologies can transform energy markets providing new economic opportunities.

- **Smart grids can provide enhanced monitoring, control and directionality to grid operators.** Deployment of some sub-categories of smart-grid technologies

TOTAL ELECTRICITY GENERATION IN 2012

11% NUCLEAR

21% RENEWABLE

40% COAL-FIRED

250 **USD billion** invested in new renewable capacity in 2014

only 50 countries have support measures for renewable heat

more than 130 have policies supporting renewable electricity has grown quickly in early adopter markets, although not entirely smoothly, with cost overruns and regulatory uncertainty the main barriers to greater deployment. Significantly, in OECD non-member economies, the ability of smart grids to facilitate grid stabilisation and security of electricity supply is driving the technology deployment, rather than integration of renewables. This signals progress in the maturity of the concept and technology.

- **Energy storage can provide valuable services to energy systems while also facilitating flexible electricity systems and reducing waste thermal energy.** Development in battery technology is currently driven by transport demand for electric vehicles (EVs). But significant numbers of large-scale batteries have been deployed for use in frequency regulation and to help integrate a rising share of variable renewables.
- **A significant milestone for carbon capture and storage (CCS) was reached with the opening of the first commercial-scale coal-fired power plant (CFPP) with CO_2 capture in October 2014.** Further projects are being built in the United States, Canada, Australia, Saudi Arabia and the United Arab Emirates. The number of projects in development, however, is lower than required to meet the 2DS targets. Given the importance of CCS in a low-carbon future, there will need to be a substantial increase in investment in research and development (R&D), storage resources, and projects now to ensure it is widely available in the coming decades.
- **Increased use of hydrogen is seeing renewed interest, given its ability to provide multiple energy services.** Between 2008 and 2013, the global market of fuel cells (FCs) grew by almost 400%, with more than 80% of FCs used in stationary applications such as FC micro co-generation, backup and remote power systems. In terms of transport, some manufacturers have announced pre-commercial market introduction of fuel cell electric vehicles (FCEVs) at prices of around USD 60 000.
- **EVs are continuing to grow in the passenger light-duty vehicle (PLDV) market, with more EV models released by vehicle manufacturers.** Relative slowdowns in deployment and in government spending make it unlikely, however, that ambitious 2DS targets will be achieved. EVs also have significant potential to contribute to cleaner and more fuel-diverse vehicles in both light-duty freight and collective transport modes, but progress in these modes is negligible.

Primary energy consumption
22 MWh
per person in 2012

36%
USED FOR ELECTRICITY GENERATION

4.5 tCO_2
EMISSIONS PER PERSON IN 2012

142 GW
current electricity storage capacity

12 USD billion
INVESTED IN LARGE-SCALE CCS PROJECTS SINCE 2005

15 USD billion
invested in smart grids projects in 2013

Strong actions linked to stated targets need to be pushed forward to achieve the clean energy potential.

- **Cleaner use of coal can be achieved by strengthening bilateral or multilateral co-operation.** The recent agreement between China and the United States to address their carbon emissions reflects positive actions by both countries and sets a strong precedent for other countries in the lead-up to COP 21. However, CFPP capacity is continuing to expand, and existing policies and best practices do not yet ensure strategic siting of CFPPs, deployment of the most efficient technologies, or CCS-readiness or CCS.
- **In energy-intensive industries, deployment of best available technologies (BATs) and energy- saving measures, and demonstration of innovative low-carbon processes, have been relatively slow over the last decade and need to accelerate to match stated ambitions.** This is partly due to inertia in capacity stock turnover, fluctuation of raw material availability, and demands for return on investment for refurbishment projects. Resource limitations also affect investments in research, development, demonstration and deployment (RDD&D), and process constraints that make innovative technology developments rare and timeframes for commercialisation of such technologies long. Finding new pathways for public-private collaboration and co-operation, as well as more effective support mechanisms, will be critical to meeting short-term milestones and climate targets through 2025.
- **Buildings energy demand continues to grow rapidly; in fact, the growth rate would need to be halved to achieve 2DS targets, meaning that each year the gap grows larger.** While ambitious targets have been set for the buildings sector, few examples exist of successful large-scale measures. Given the relatively long life of buildings, overcoming the large inertia in the building stock is critical. Both the rate and the depth of energy efficiency renovations need to scale up from the current low level of activity.
- **Fuel efficiency standards have proven to be an effective method of improving vehicle fleet efficiency; expanding the application of these standards beyond PLDVs is now necessary.** As the PLDV market in OECD non-member economies is now bigger than that in OECD member countries – and continuing to grow – policy measures to improve fuel economy of new PLDVs need to be introduced in OECD

GLOBAL ENERGY DEMAND IN 2012

82% FOSSIL FUELS

13% RENEWABLES

29% COAL

REDUCTIONS TO MEET 2DS IN 2025
relative to the current trajectory

13% industry energy demand

25% transport CO_2 emissions

80% REDUCTION OF THERMAL LOADS IN NEW BUILDINGS POSSIBLE WITH EFFICIENT BUILDING ENVELOPES non-member regions. Even though over two-thirds of freight transport is by road, fuel efficiency standards for medium- and heavy-duty vehicles remain quite limited and must be expanded. An overarching strategy of Avoid, Shift and Improve is required to stabilise transport energy demand in the next decade, and for CO_2 emissions to start showing a net decrease.

- **International transport, often excluded from analysis of the transport sector, needs significant co-operation to render policy measures effective.** The energy efficiency targets of both the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO) are broadly consistent with 2DS objectives, but will need to be complemented with actions impacting activity levels and with fuel switching, especially towards biofuels. Market-based instruments such as emissions trading have direct effects on transport activity in the aviation and shipping sectors; they can serve to internalise the social costs these transport sectors generate through local pollutant and greenhouse gas (GHG) emissions.

Reframing climate goals through energy metrics can help highlight various drivers for low-carbon technology deployment and support ambitious, yet realistic, targets.

- **The near-term focus and monitoring of energy sector metrics can provide a greater insight into emissions reduction measures than GHG emissions inventories alone.** International climate agreements have typically focused on GHG emissions and measures. Alternative metrics, which can be framed around energy efficiency, new investment in clean power generation, and even advances in RDD&D, can help to identify opportunities for actions with both short- and long-term impacts.
- **Energy sector decarbonisation needs to be tracked, with electricity decarbonisation of particular importance and interest.** Tracking both technology- and sector-specific indicators is useful to get a clear picture of opportunities and bottlenecks in advancing decarbonising the energy system as a whole. The transition to low-carbon economies needs to be carefully managed, for the provision of secure, affordable energy is critical for economic growth and social development. A fuller understanding of the opportunities to promote synergies among energy, environmental and climate policies is also needed.

EMISSIONS REDUCTIONS POTENTIAL BY 2025

15 $GtCO_2$ IN INDUSTRY

13 $GtCO_2$ IN TRANSPORT

7 $GtCO_2$ IN BUILDINGS

52% OF EMISSIONS REDUCTIONS TO 2025 CAN BE DELIVERED BY END-USE ENERGY EFFICIENCY

Table I.1 Summary of progress

	Status against 2DS targets in 2025	Policy recommendations
Renewable power ↗	Renewable power is increasingly at risk of falling short of ETP 2DS target, despite the growing competitiveness of a portfolio of renewable technologies.	■ Policies that enable a predictable and reliable long-term market are imperative to mitigate the risks associated with capital-intensive investment in renewables. ■ Regulatory frameworks that support cost-effective remuneration are needed, to avoid high economic incentives and the possibility of retroactive steps. ■ Developing markets should follow well-established best practices to avoid problems with integration.
Nuclear power ~	Conservative estimates put installed capacity at 24% below the 2DS target for 2025, with policy and financing uncertainties contributing to nuclear being off track.	■ Electricity market incentives that promote all types of low-carbon solutions are required to provide financing certainty for investments in nuclear power. ■ Policy recognition of the security of supply, reliability and predictability that nuclear power offers.
Gas-fired power ~	Despite improved flexibility of gas-fired power plants, renewable energy and low coal prices make the situation for gas power challenging.	■ Electricity market incentives such as carbon prices and other regulatory mandates are necessary for natural gas to compete with low-cost coal in the power sector. ■ Policy makers and manufacturers need to tailor solutions by application and location in order to maximise the advantage available from natural gas-fired power technologies.
Coal-fired power ~	The continuing trend of year-on-year growth in coal-fired power needs to be reversed to meet 2DS targets.	■ Policy incentives such as carbon pricing and regulation are imperative to control pollution and limit generation from inefficient units. ■ New coal power units should achieve best available efficiency and, if not initially installed, should be CCS-ready to have the potential to reduce the impact of coal use
CCS ↗	While progress is being made, CCS deployment is not on track to meet 2DS targets.	■ Financial and policy commitment to CCS demonstration and deployment are needed, to help mitigate the investment risk and long lead time required to discover and develop viable storage sites. ■ Policy incentives such as carbon pricing and regulation are required as currently CO_2 for use in enhanced oil recovery (EOR) remains the only commercial driver for carbon capture projects.
Industry ~	Despite progress in energy efficiency energy use must be cut 13% and direct CO_2 emissions 18% by 2025 compared with current trends. Demonstration activities of innovative low-carbon industrial technologies need to be accelerated to meet 2DS targets.	■ Focus on improving energy efficiency, switching to lower-carbon and alternative fuels, and deploying BATs to the greatest extent possible in all sub-sectors. Instruments such as stable, long-term CO_2 pricing mechanisms and the removal of fuel subsidies should be implemented to properly incentivise energy efficiency. ■ Support mechanisms to reduce investment risk and to accelerate demonstration and deployment of innovative technologies, as well as co-operative frameworks for international collaboration and technology transfer which manage intellectual property and competitive advantage concerns. Regional and sectorial disparities illustrate the need for co-ordinated efforts.

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

Recent trends: ↘ Negative developments ~ Limited developments ↗ Positive developments

Table I.1 Summary of progress (continued)

	Status against 2DS targets in 2025	Policy recommendations
Iron and steel (~)	Steady growth in crude steel production, particularly in emerging economies, puts more pressure on the need to limit annual growth in energy use to 1.1% through 2025 (half of the increase in 2012), along with direct CO_2 emissions.	■ Improve energy efficiency, phase out outdated technologies, switch to low-carbon fuel based processes (e.g. gas-based DRI) and recycle more steel to increase scrap availability, while addressing the challenges of slow capacity stock turnover, high abatement costs, fluctuation in raw material availability, carbon leakage and industrial competitiveness. ■ Support research, development, demonstration and deployment (RDD&D) programmes that will bring new technologies to commercial maturity and accelerate their diffusion to meet the 2DS.
Cement (~)	Energy use must decline by 3% through 2025, despite cement production growth of 17%. Compared with current trajectory, direct CO_2 emissions need to be reduced by 12%.	■ Incentivise improvements in thermal energy intensity, clinker substitution and switching to low-carbon fuel mixes to capture potential improvements in energy use and emissions. ■ Demonstrate CCS in the short term to enable direct emissions reduction from cement manufacturing in the longer term, through globally co-ordinated efforts.
Transport (~)	Meeting the transport 2DS targets requires a reversal of current trends, for both annual energy use and CO_2 emissions.	■ Policy instruments are required to rationalise travel choices, shifting part of the passenger transport activity to collective transport modes, particularly in areas of high urban density. Including economic instruments such as fuel taxation, road charging (e.g. associated with the usage of freight transport vehicles on the road network), congestion charging and parking fees. ■ Remove fuel subsidies to incentivise switching to fuel-efficient vehicles.
Fuel economy (↗)	OECD PLDV efficiency improvement rates of 3% per year have not been matched by the larger and growing non-OECD market, leading to a global annual average improvement of 1.8%, almost half the rate required to meet 2DS targets.	■ Replicate the success in improving the average fuel economy of the PDLV fleet in the light commercial and medium- and heavy-duty vehicle fleets to drive efficiency improvements in the road freight sector. ■ Promote switching from larger, more powerful PLDVs towards smaller and/or less powerful vehicles. ■ Introduce a global realistic test cycle and better monitoring of the real on-road fuel economy.
Electric and hybrid-electric vehicles (↗)	Annual average passenger electric vehicle sales growth rates of 50% are short of the 80% needed to meet 2DS targets.	■ Continuing RD&D, infrastructure roll-out and government incentives are required to support the development of passenger electric vehicles (EVs), particularly to increase vehicle range and reduce battery costs. ■ Promote EVs for transport modes other than passenger transport vehicles. ■ Explore the potential that electric mobility offers from changes in traditional vehicle ownership patterns to multi-modal travel and behavioural changes from enhanced use of information and communication technologies (ICTs).

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

Recent trends: ↘ Negative developments ~ Limited developments ↗ Positive developments

Table I.1 Summary of progress (continued)

	Status against 2DS targets in 2025	Policy recommendations
Buildings (~)	Year-on-year growth of buildings energy demand is incompatible with 2DS targets, which require constrained growth between now and 2025, despite a predicted increase in population.	■ Governments need to promote deep energy renovation during normal refurbishment, only incentivising very high-performing buildings and components. ■ To achieve near-zero-energy buildings (NZEBs), building codes for insulation and windows with lower U values, along with mandatory air sealing, will be essential. ■ All governments – especially in emerging economies – need to make more effort to develop, promote and enforce more stringent building codes.
Building envelopes (~)	The potential to save energy in buildings by 75%-80% compared with existing buildings through advanced building envelope materials and construction techniques is not being realised.	■ Policies that promote awareness, education and financial incentives for very high-performing products and systems are necessary to increase adoption of the most efficient building envelope materials and construction. ■ Labelling and minimum performance standards for building components need to be enforced to accelerate the deployment of best available technologies. ■ International co-operation is needed to help establish commodity-based advanced building materials and products in emerging markets.
Appliances and equipment (~)	To meet 2DS targets the annual growth of electricity consumption in the buildings sector needs to halve, relative to growth in the last decade.	■ Appliance minimum energy performance standards (MEPS) need to be extended to more countries and appliances, particularly for digital and network-connected appliances. Monitoring and evaluation of the standards and their impact are also needed. ■ Stringent standards and enforcement are required to eliminate inefficient appliances from the market.
Co-generation and district heating and cooling (~)	The benefits of co-generation and district heating and cooling (DHC) systems, both through their direct energy efficiency, and through the increased flexibility that they provide to the electricity and thermal grids, have not been fully captured.	■ Strategic planning of local, regional and national heating and cooling should be developed to identify cost-effective opportunities to efficiently develop co-generation and expand DHC networks. ■ Policy measures are needed to facilitate investment in modernising and improving existing DHC networks and make them more energy efficient. ■ Policies should be implemented to mitigate high up-front costs and inflexible business structures, and address the lack of long-term visibility on regulatory frameworks that also limit co-generation and DHC.
Renewable heat (~)	Modern renewable heat deserves greater attention by policy makers, and should be included in low-carbon energy strategies that are based on a detailed local appraisal of both potentials and barriers.	■ Policy measures to raise awareness and tackle non-economic barriers can be a very cost-efficient way to tap into the potential of renewable heat given the maturity of many modern renewable heating technologies. ■ Success of targets and support policies in a number of regions need to be replicated.

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

Recent trends: ↘ Negative developments ~ Limited developments ↗ Positive developments

Table I.1 Summary of progress (continued)

	Status against 2DS targets in 2025	Policy recommendations
Smart grids ~	The transition of smart grids from a perceived exclusive enabling function for renewable and distributed generation to the function of grid stabilisation and security of electricity supply signals the maturity of the concept and technology.	■ Regulation that enables cost-reflective investment in advanced distribution network technologies is required for sustained market development. ■ Market mechanisms are necessary to ensure that customers and suppliers share the smart-grid costs and benefits. ■ Support the development of international standards to accelerate RDD&D.
Energy storage ↗	Storage can contribute to meeting the 2DS by providing flexibility to the electricity system and reducing wasted thermal energy.	■ Policies are required to support market development of energy storage and the regulatory environment needs to adapt to recognise and compensate storage for the variety of energy solutions it provides to both the electricity and thermal energy systems.
Hydrogen ~	Hydrogen has the potential to contribute to meeting the 2DS as a flexible near-zero-emissions energy carrier with potential applications across all end-use sectors.	■ Targeted investment in RD&D for both stationary and transportation applications, as well as energy system integration, is needed to establish the role of hydrogen technologies in a broader energy system. ■ Support the development of international standards for hydrogen storage production and delivery.

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

Recent trends: ↘ Negative developments ~ Limited developments ↗ Positive developments

Tracking Progress: How and Against What?

Tracking Clean Energy Progress 2015 (TCEP 2015) examines whether current policy is effectively driving efforts to achieve a more sustainable and secure global energy system. Published annually, *TCEP* highlights how the overall deployment picture is evolving. For each technology and sector, *TCEP* identifies key policy and technology measures that energy ministers and their governments can take to scale up deployment, while also demonstrating the potential to save energy and reduce emissions.

TCEP 2015 uses interim 2025 benchmarks set out in the 2DS, as modelled in *ETP 2015*, to assess whether technologies, energy savings and emissions reduction measures are on track to achieve the 2DS by 2050. As in previous *TCEP* reports, there is an evaluation of whether a technology or sector is on track, needs improvement or is not on track to meet 2DS targets. Where possible this "traffic light" evaluation is quantitative.

The report is divided into 19 technology or sector sections, and uses graphical overviews[1] to summarise the data behind the key findings. This year's edition contains a special feature on metrics to support national action on energy sector decarbonisation, which is particularly relevant given that a new agreement will be negotiated in 2015 under the United Nations Framework Convention on Climate Change (UNFCCC).

***TCEP* focuses on whether the actions needed to decarbonise the energy sector over the ten years to 2025 are progressing.** It also uncovers areas that need additional stimulus. *TCEP 2015* introduces a second qualitative evaluation of progress, which reflects whether the rate of technology deployment, cost reductions, policy changes and other necessary measures have been positive, negative or limited. This evaluation is based on progress or activity in the last year or last tracking period.

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.1). For each technology or sector, *TCEP* examines recent trends, tracks progress and recommends further action.

Recent trends are assessed with reference to the three *TCEP* measures that are essential to the success of individual technologies:

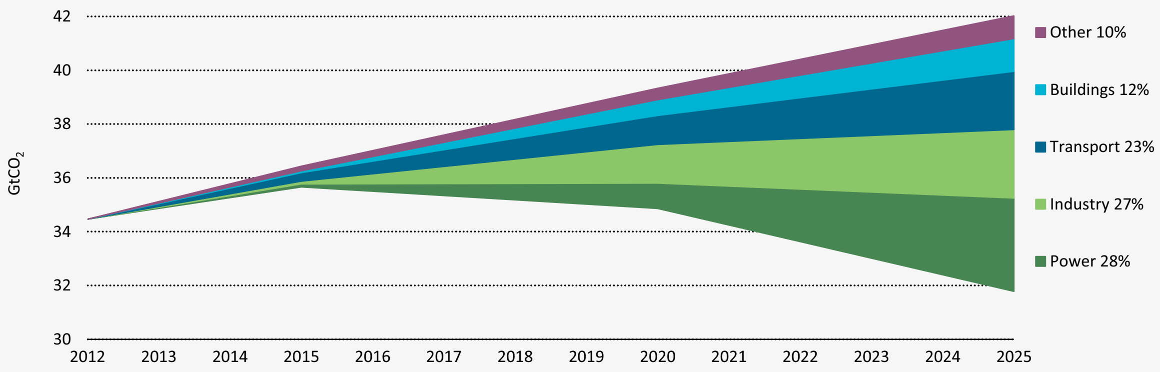
- **Technology penetration.** What is the current rate of technology deployment? What share of the overall energy mix does the technology represent?
- **Market creation.** What mechanisms are in place to enable and encourage technology deployment, including government policies and regulations? What is the level of private-sector investment? What efforts are being made to increase 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 is the level of public investment for technology research, development and demonstration (RD&D)?

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

Tracking progress: For each technology or sector, the progress towards meeting the 2DS is evaluated.

Recommended actions: Policy measures, practical steps and other actions required to overcome barriers to the 2DS are identified.

Figure I.1 Sector contributions to emissions reductions



Key point *Reduction efforts are needed on both the supply and end-use sides; focusing on only one does not deliver the 2DS.*

Box I.1 *ETP 2015* **scenarios**

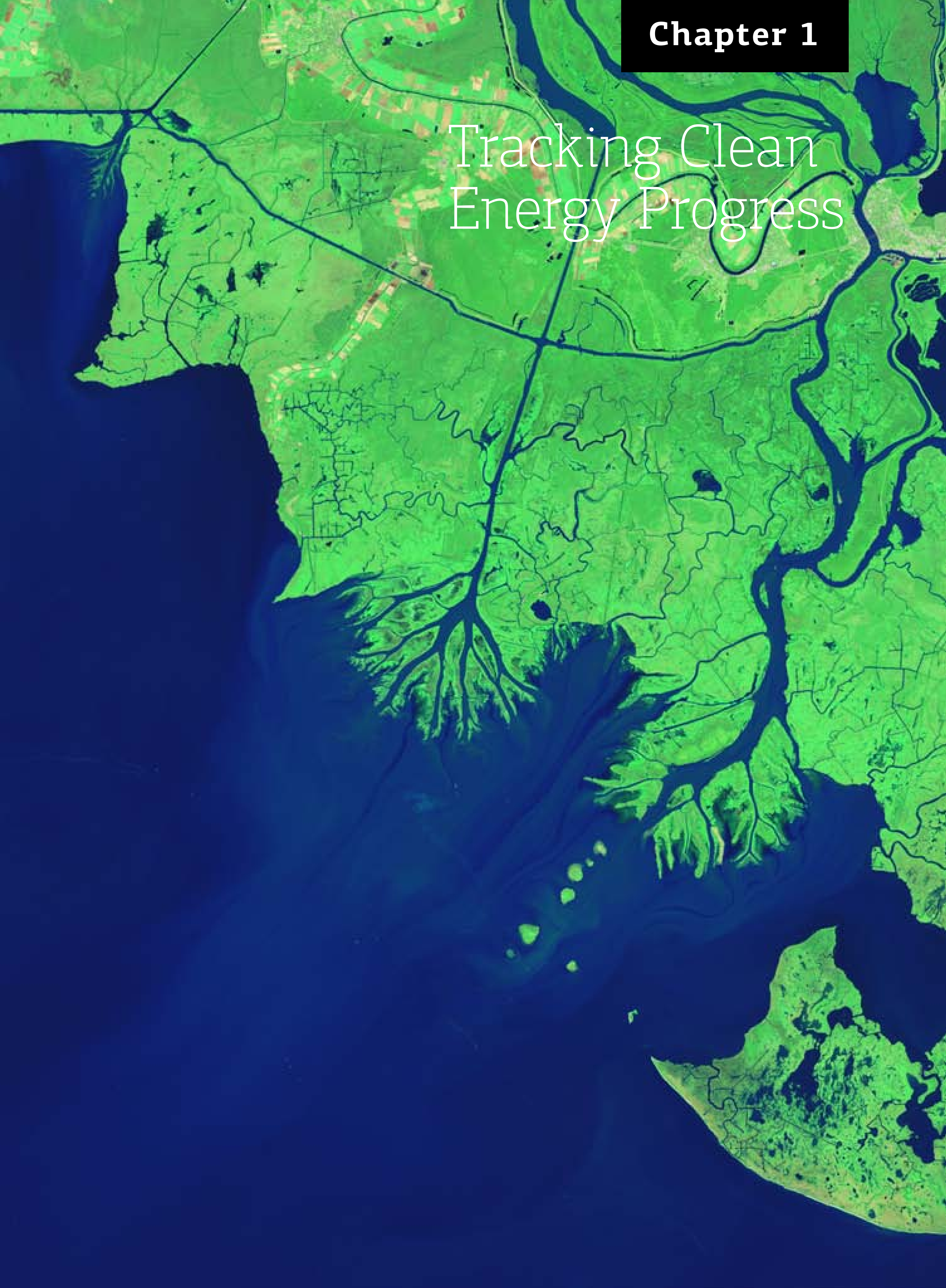
The **6°C Scenario (6DS)** is largely an extension of current trends. By 2050, primary energy use grows by almost two-thirds (compared with 2012) and total GHG emissions rise even more. In the absence of efforts to stabilise atmospheric concentration of GHGs, average global temperature rise above pre-industrial levels is projected to reach almost 5.5°C in the long term (by 2500) and almost 4°C by the end of this century. Already, a 4°C increase within this century is likely to stimulate severe impacts, such as sea level rise, reduced crop yields, stressed water resources or diseases outbreaks in new areas (World Bank, 2014). The 6DS is broadly consistent with the *World Energy Outlook* (*WEO*) Current Policy Scenario through 2040.

The **4°C Scenario (4DS)** takes into account recent pledges made by countries to limit emissions and step up efforts to improve energy efficiency, which helps limit long-term temperature rise to 4°C (by 2500). The 4DS is, in many respects, already an ambitious scenario that requires significant changes in policy and technologies compared with the 6DS. This long-term target also requires significant additional cuts in emissions in the period after 2050; yet with average temperature likely to rise by almost 3°C by 2100, it still carries the significant hazard of bringing forth drastic climate impacts. The 4DS is broadly consistent with the *WEO* New Policies Scenario.

The **2°C Scenario (2DS)** is the main focus of *ETP 2015*. It lays out the pathway to deploy an energy system and emissions trajectory consistent with what recent climate science research indicates would give at least a 50% chance of limiting average global temperature increase to 2°C. The 2DS sets the target of cutting energy- and process-related CO_2 emissions by almost 60% by 2050 (compared with 2012) and ensuring they continue to decline thereafter. It identifies changes that help ensure a secure and affordable energy system in the long run, while also emphasising that transforming the energy sector is vital but not solely capable of meeting the ultimate goal. Substantial effort must also be made to reduce CO_2 and GHG emissions in non-energy sectors. The 2DS is broadly consistent with the *WEO* 450 Scenario (referring to pollutant levels of 450 parts per million in the atmosphere).

Chapter 1

Tracking Clean Energy Progress



Renewable power

● Improvement needed
↗ Positive developments

Renewable power generation continues to progress, but is not fully on track to meet the 2DS. Renewable electricity generation is expected to grow by 45% between 2013 and 2020, reaching 7 310 terawatt hours (TWh). With annual capacity additions expected to level off, however, renewable power is increasingly at risk of falling short of the 2DS generation target of 10 225 TWh by 2025, mainly because of slow economic growth, policy uncertainty in OECD member countries and persistent economic and non-economic barriers in OECD non-member economies.

Recent trends

In 2014, global renewable electricity generation rose by an estimated 7% (350 TWh) and accounted for more than 22% of the overall generation. OECD non-member economies continued to dominate global renewable generation, with their share increasing to around 55%. China remained the largest market, accounting for an estimated 23% of overall renewable electricity generation in 2014.

In 2014, cumulative installed renewable capacity increased further. Onshore wind additions recovered and are back on track; over 45 gigawatts (GW) of new capacity was installed globally, as the market in the United States picked up. China remained the largest annual onshore wind market globally with a record number of installations in 2014 of around 20 GW. Additions in China were significantly higher than the annual deployment in 2013 as developers rushed to finish projects before the feed-in tariff was cut by between 3% and 4%. The United States added close to 5 GW, followed by Germany (4.3 GW), Brazil (2.7 GW), and India (2.3 GW).

Solar photovoltaic (PV) capacity grew by an estimated 40 GW in 2014, slightly more than the previous year. Strong expansions in Asia continued, particularly in China (10 GW) and Japan (9 GW). Asia installed close to 50% of new solar PV capacity. Growth in the United States was higher than the previous year, with around 6.5 GW installed. Annual growth in OECD Europe was led by Germany and the United Kingdom (UK), each installing around 2 GW.

Hydropower additions decreased slightly, as China had commissioned large capacity earlier than expected, in 2013. Offshore wind additions in Europe decreased slightly to 1.5 GW due to grid connection delays. Asia's large offshore wind potential remained largely untapped. Two large solar thermal electricity (STE) plants were partially operational in the United States (Ivanpah, 333 MW; and Crescent Dunes, 100 MW), but several other STE projects faced financing challenges. In 2014, geothermal additions increased as large projects were commissioned in Indonesia, Kenya, Turkey and the United States.

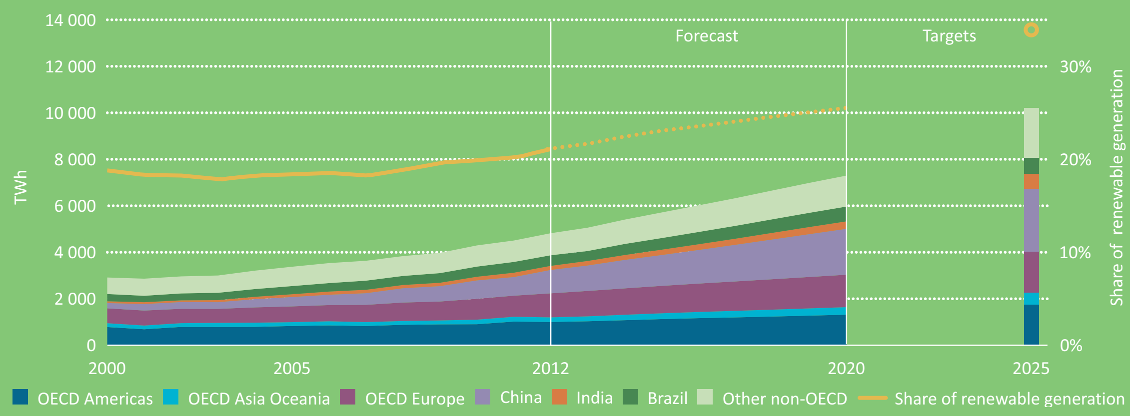
Early estimates indicate that total investment in new renewable capacity reached around USD 250 billion in 2014, with solar PV attracting the majority of investment, followed by onshore wind. According to Bloomberg New Energy Finance (BNEF, 2015), the financing of new projects showed an upward trend over the last year for utility-scale solar PV and offshore wind projects, signalling a positive outlook.

Although renewables are still more expensive in general than conventional power generating technologies, the gap has narrowed significantly over the last decade. In some countries, some renewables are competitive with new-built fossil fuel generation.

Similarly, utility-scale solar PV installations are already competitive in some places. In Chile and Mexico, two utility-scale solar PV plants are operational on the spot market. In Texas, a solar plant became partially operational without a power purchase agreement (PPA) for the first time. More projects are under construction and expected to be online in 2015.

In locations with good irradiation levels and high electricity spot prices, PPAs with record low prices were signed over the last year. In Brazil, developers signed PPA contracts for 1 GW of capacity averaging USD 87 per megawatt hour (MWh) to deliver power by 2017. In the United Arab Emirates, projects submitted bids as

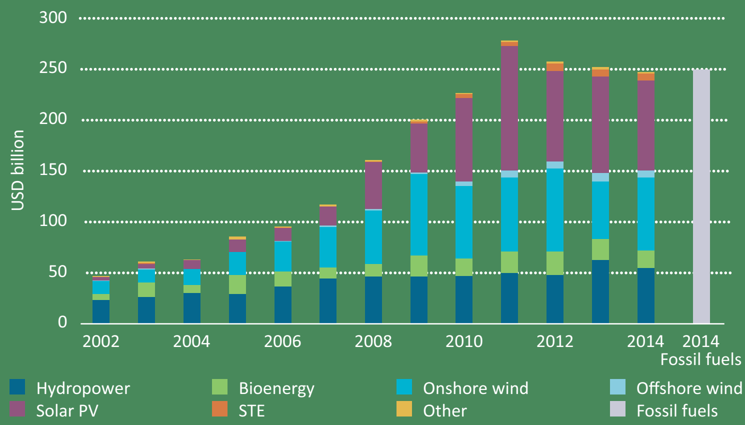
1.1 Renewable power generation by region



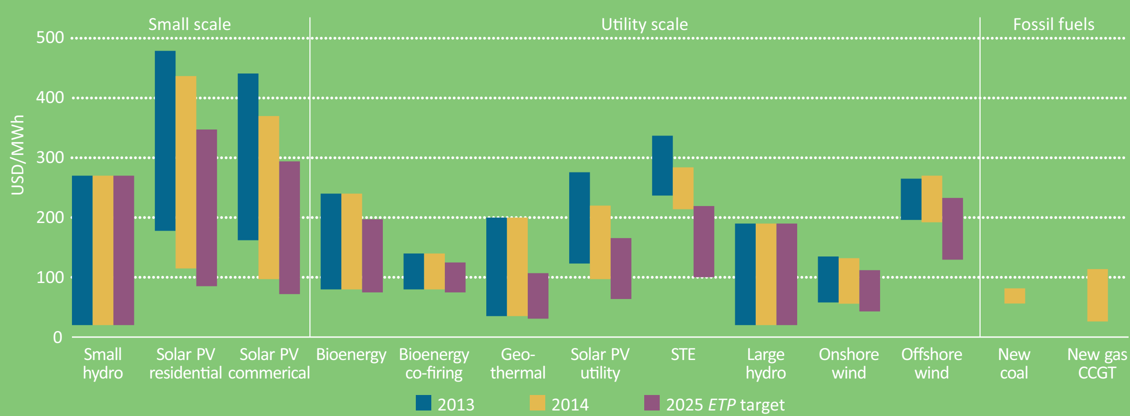
23%

OF GLOBAL RENEWABLE GENERATION CAME FROM CHINA, THE LARGEST MARKET IN 2014

1.2 Renewable capacity investment



1.3 Levelised cost of electricity



For sources and notes see page 82

low as USD 59/MWh. Developers in El Salvador, Panama and Uruguay signed PPAs or offered bids ranging from USD 90/MWh to USD 140/MWh.

Over the past year, growth in both residential and commercial distributed solar PV sectors was robust in countries where the levelised cost of energy (LCOE) of systems fell below the variable portion of retail electricity prices. In the absence of remuneration of excess electricity, the share of self-use, the overall cost of the project and financing are important factors for a profitable investment. In addition, if there is a good match between demand and generation, higher shares of self-consumption mean less stress on the grid. In Australia, Germany, Italy and the Netherlands, where retail electricity prices are high, some projects with good financing are already profitable depending on the share of self-consumption. The increase of distributed solar PV generation has posed challenges to the fair allocation of fixed-grid costs, which need to be addressed.

In Japan, booming solar PV market deployment has been driven by generous feed-in tariffs, which have raised concerns over the overall cost associated with this deployment. It has also posed integration challenges because developers have proposed PV projects in locations where land is cheap but demand is low and grid capacity is limited. In some provinces, utilities have refused to connect projects where the grid is already highly congested. Grid integration was also a challenge in South Africa, where some solar PV and wind projects could not get a timely grid connection. This contributed to delays in the third and fourth rounds of renewable tenders.

Over the past year, onshore wind continued to improve its competitive position. New turbine technology with larger rotor diameters has unlocked more low and medium wind resource sites, increasing the number of bankable projects, especially in Europe and the United States. In the interior region of the United States, PPAs were signed as low as USD 20/MWh (around USD 43/MWh including production tax credit, or PTC). In Brazil, PPA prices further increased from USD 47/MWh to USD 54/MWh, mainly due to the new grid connection rule where developers are responsible for all associated costs. In Uruguay, the first projects with PPAs – signed in 2011 – ranging from USD 50/MWh to USD 65/MWh came online over the past year.

Offshore wind costs remained high over the past year. This pushed some countries to lower their targets or delay projects. Germany lowered its 2020 offshore wind capacity target from 10 GW to 6.5 GW, while Denmark delayed auctioning a 600 megawatt (MW) project. By contrast, some countries in Asia – China, Japan and Korea – increased their support to boost the offshore industry. However, more time is needed to see how this affects actual deployment. Costs also remained high for ocean energy, with only a few demonstration projects in operation globally. Two of the largest ocean energy companies announced that they would not invest further in developing ocean technology.

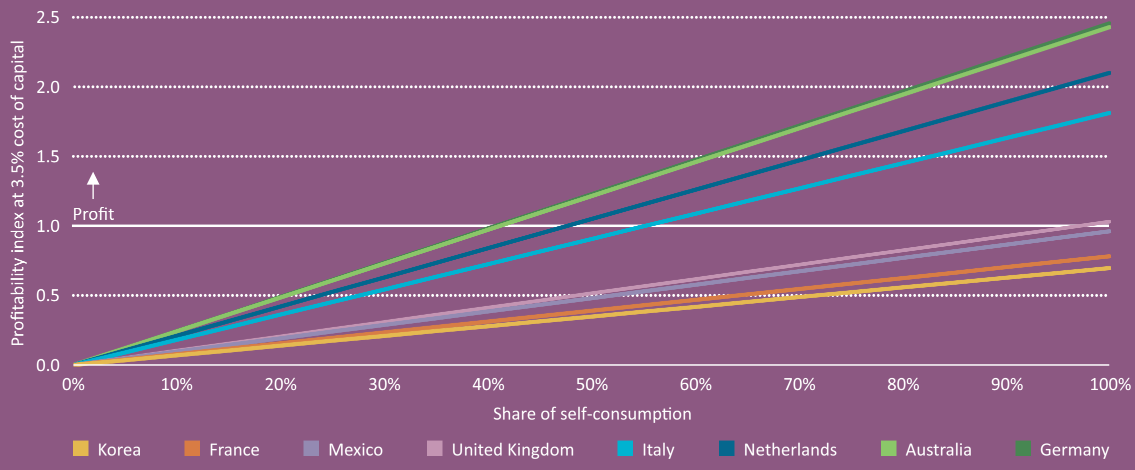
Policy remains vital to the competitiveness and deployment of renewable energy technologies. In 2014, policy signals were mixed. Although ambitious new renewable energy targets were announced in China and India, policy uncertainty and retroactive changes elsewhere posed challenges for renewables. In October 2014, European Union (EU) leaders committed to reduce GHGs by at least 40% and increase energy efficiency and renewables by at least 27% by 2030. Both of these targets are binding, but only at the EU level. Furthermore, the governance around the new policy to achieve the targets remains unclear, creating uncertainty for renewable energy investments.

In addition to policy uncertainty at the EU level, some countries in Europe introduced retroactive measures harming renewable deployment. Spain finalised the new retroactive remuneration scheme that ended feed-in tariff payments and replaced them with annual payments based on a calculation of a fixed “reasonable annual return” of 7.4%. Bulgaria cut solar PV feed-in tariffs retroactively, assuming that the country had already met its 2020 renewable energy target. In Romania, the government decided to halve the number of certificates provided to both wind and solar PV. Retroactive policy changes were also introduced in Italy for solar PV installations larger than 200 kilowatts (kW).

In the United States (US), policy volatility persisted. In December 2014, the PTC for onshore wind projects was extended for just a few days through the end of 2014. Meanwhile, the US Environmental Protection Agency (US EPA) announced its new Clean Energy Plan. The details and implementation of the plan are expected by June 2015, and its impact on renewable deployment remains to be seen.

Mexico launched a major energy market reform, which included liberalising the electricity market. Neutral green certificates were introduced to promote clean electricity. Rules and implementation of this policy remain uncertain while investors are currently in wait-and-see mode.

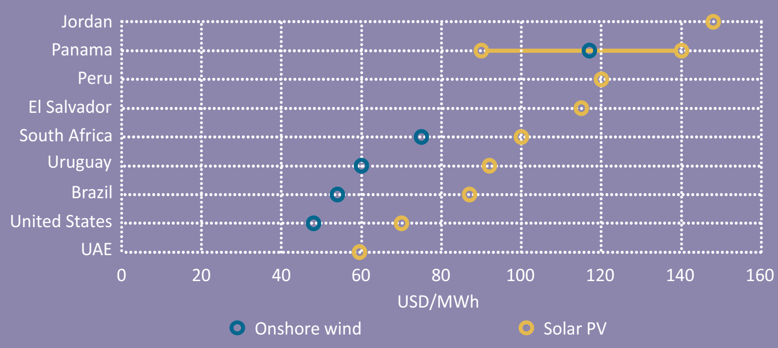
1.4 Profitability index of a residential PV system



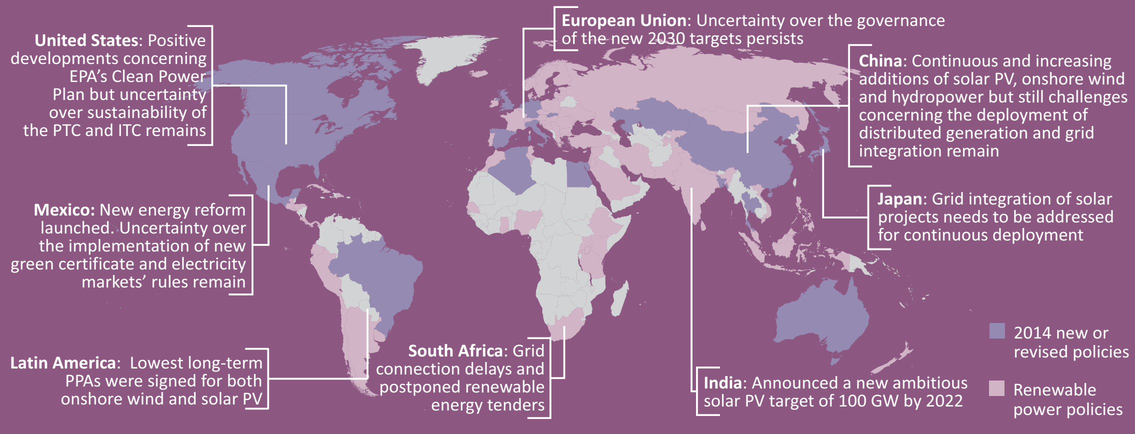
Key developments

Record-low long-term remuneration contract prices for onshore wind and solar PV were achieved in 2014. In some countries, renewables were the preferred option to new-built fossil fuel generation.

1.5 Wind and solar PV tender results or offered bids



1.6 Renewable power policies



For sources and notes see page 82

Tracking progress

Despite the growing competitiveness of a portfolio of renewable technologies, the growth of additional annual capacity is slowing down due to sluggish economic growth, policy uncertainty in OECD member countries, and persistent economic and non-economic barriers in OECD non-member economies. Thus, for the first time the *TCEP* evaluation is that renewable power improvement is needed to meet the targets of the *ETP 2015* 2DS scenario.

Renewable electricity generation is expected to grow by 45% between 2013 and 2020, reaching 7 310 TWh, and is currently at risk of falling short of the 2DS target of 7 537 TWh. If current trends continue, the shortfall will increase even further by 2025, when the 2DS target is 10 225 TWh. This result is subject to strong regional differences across technologies and regions.

Hydropower deployment needs improvement to reach its 2DS generation target. Over the medium term, new additions of hydropower capacity are expected to fall in OECD member countries, mainly due to decreasing resource availability. In OECD non-member economies, new additions are expected to be strong, but environmental concerns and lack of financing pose challenges to large-scale projects. Deployment trends in China and global precipitation levels may change this picture by 2025.

For onshore wind, the second-largest renewable technology, improvement is needed in capacity growth rates to meet 2DS targets. Policy uncertainty in OECD member countries is expected to affect deployment over the medium term, including doubts over governance of the European Union's 2030 climate change goals and the extension of the production tax credit in the United States. In OECD non-member economies, onshore wind is expected to grow, especially in China, Brazil and India. However, integrating large amounts of new onshore wind power remains a challenge, especially in China.

Solar PV is the only technology on track to meet its 2DS power generation target by 2025. Its capacity is forecast to grow by 18% annually between 2014 and 2020. This growth should be stable in OECD member countries, with decreasing annual additions in Europe and strong expansion in Chile, Japan and Mexico. In OECD non-member economies, growth of solar PV should spread geographically. Deployment trends in China are strong with improving economics and growing distributed generation opportunities. If these medium-term trends continue, solar PV could even surpass its 2025 target.

Offshore wind, geothermal, STE, bioenergy and ocean power are not on track due to technology-specific challenges. For offshore wind, OECD member countries, particularly in Europe, are expected to lead deployment over the medium term. Some countries and companies have announced ambitious targets to decrease costs by 2020, but grid delays and financing challenges have often made it difficult to realise similar ambitions. OECD countries could reach their 2DS targets if those challenges are addressed. Deployment is falling behind in OECD non-member economies, however, especially in China, as investment costs remain high and technological challenges persist.

Total investment costs remain high for STE, slowing the pace of deployment. The potential for electricity generation from geothermal energy is largely untapped. Pre-development risks remain high and only a handful of countries have introduced policies to address those risks. For bioenergy, sustainability challenges and long-term policy uncertainty have been decreasing the bankability of large projects, particularly in OECD member countries. Ocean power is still at the demonstration stage, with only small projects deployed.

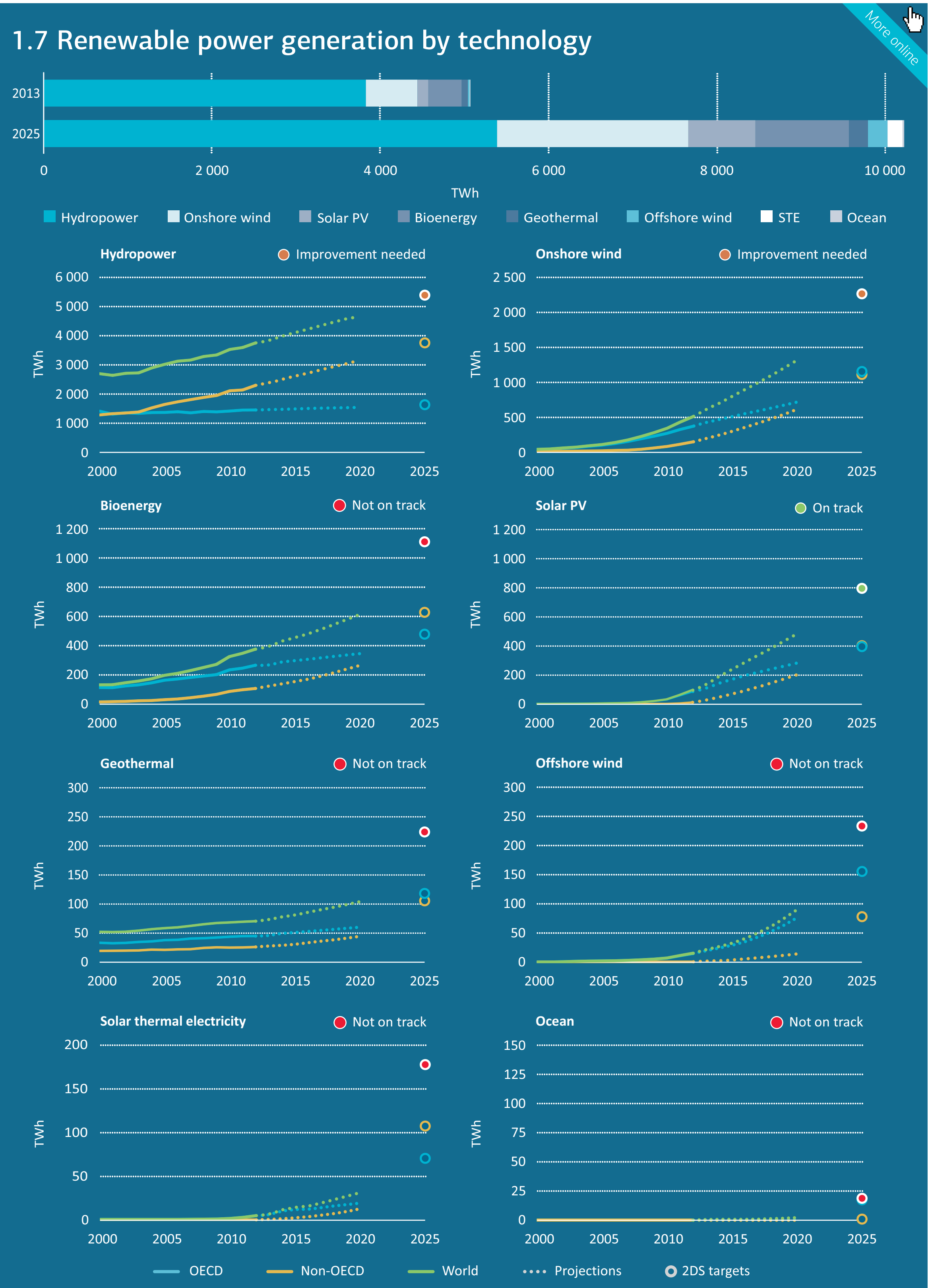
Recommended actions

Despite a portfolio of renewables becoming more competitive in a wider set of circumstances, policies remain vital to stimulating investment in renewables. Many renewables no longer need high economic incentives, but they do need long-term policies that provide a predictable and reliable market and regulatory framework compatible with societal goals.

Given their capital-intensive nature, renewables require a market context that ensures a reasonable and predictable return. Financing costs play a large role in determining generation costs for capital-intensive renewables. Policy and regulatory uncertainties create higher risk premiums, which directly undermine the competitiveness of renewables, so policy risk is an important barrier to deployment.

Policy makers should focus on cost efficiency to prevent over-remuneration of some technologies, but changes must be predictable and retroactive changes must be avoided at all times. Countries beginning to deploy variable power plants should implement well-established best practices to avoid integration challenges. Markets with high variable renewable penetration should take advantage of their existing flexibility assets, and consider other flexibility mechanisms to optimise the balancing of their overall energy system.

1.7 Renewable power generation by technology



For sources and notes see page 82

Nuclear power

Not on track
~ Limited developments

Global nuclear generation increased slightly between 2012 and 2013, but remains about 10% lower than in 2010. At the beginning of 2014, 72 reactors were under construction, the highest number for more than 25 years. But in 2014 there were only three construction starts (down from ten in 2013), and five grid connections (representing 5 GW, up from 4 GW in 2013).

Recent trends

The European Commission approved the United Kingdom's Contracts for Difference scheme for the construction of the Hinkley Point C nuclear power plant, paving the way for further new-build projects in the United Kingdom and other European countries in the coming decade. In Japan, all operable reactors have remained idle pending safety reviews. The Nuclear Regulation Authority has approved restarting the two units of the Sendai plant, as well as Takahama units 3 and 4. These restarts could be effective in the first half of 2015. Construction of the Akkuyu nuclear power plant in Turkey, the country's first, is expected to start in 2015 (under the build-own-operate model offered by Russia). In Poland, the first nuclear power plant could be under construction before 2020 if a suitable financing model is found. Hungary secured a loan from Russia for two new units, which also could be under construction before 2020. A new energy plan developed by the government of the Republic of Korea calls for the construction of nine new reactors by 2023. In the United States, besides the five units under construction, there remains interest in long-term operation of the existing fleet. The Nuclear Regulatory Commission has resumed licence renewals for nuclear power plants after a two-year hiatus; currently 74 reactors are licensed to operate up to 60 years, and applications are being reviewed for an additional 19 units. However, as many as six to ten merchant units could be shut down due to unfavourable economics despite receiving licences. Vermont Yankee, for example, shut down in December 2014 after 42 years of operation.

Developments in other OECD countries in 2014 could reduce nuclear generating capacity. France's lower house of parliament voted to reduce the share of nuclear power generation from 75% to 50% by 2025. In Sweden, where nuclear power accounts for more than 40% of generation, the short-lived coalition government proposed replacing the country's nuclear power plants with renewable technologies. Among OECD non-member economies, South Africa signed several agreements with countries that possess nuclear technology, in preparation for tenders that aim at securing up to 9.6 GW by 2030. China moved ahead with planning and construction of nuclear power plants, and development of its own Generation III technologies, such as the Hualong-1 design. It is also considering investments in projects in Argentina, Romania and the United Kingdom. In the United Arab Emirates, construction started on the third unit of the four-unit Barakah plant, which will provide 5.6 GW by 2020. Belarus is constructing its first two units with technical and financial support from Russia.

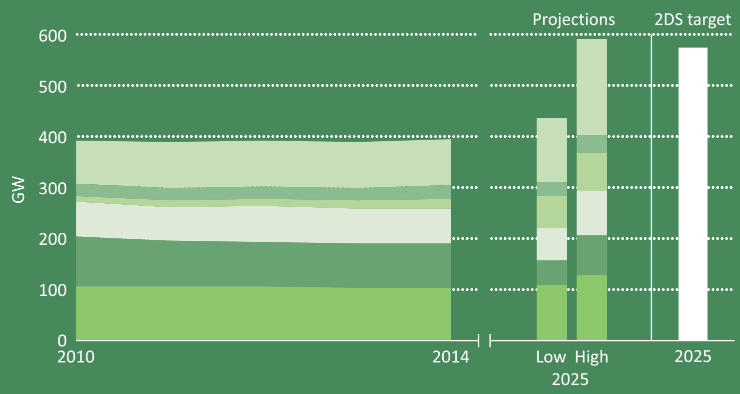
Tracking progress

According to the recently published "Red Book" from the Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA), gross installed capacity currently at 396 GW is projected to reach 438 GW to 593 GW by 2025; in the 2DS, global nuclear capacity would need to reach 585 GW by that time. The range of projections is wide because policies concerning climate change mitigation are still unclear, the existing fleet will be in operation for a long time, financing is uncertain and China's new-build programme beyond 2020 has yet to be clarified, in particular with respect to inland power plants.

Recommended actions

Recent geopolitical events, and the realisation that swift action is needed to reduce GHG emissions and air pollution from fossil-based generation, have highlighted the potential of nuclear power to increase energy security, diversify fuel supply and lower emissions. This awareness has yet to be translated into policy support for long-term operation of the existing fleet and construction of new plants, particularly in Europe. There is a need to introduce market incentives to favour all low-carbon technologies, through carbon taxes or electricity market arrangements, or both, and to recognise the vital contribution that nuclear energy can make.

1.8 Installed gross nuclear capacity

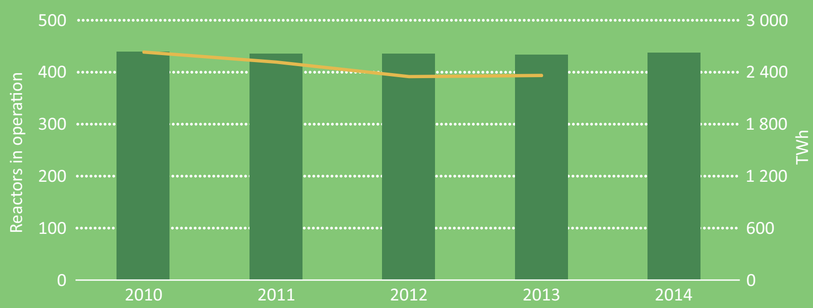


5
GW CAPACITY INCREASE IN 2014 TO A TOTAL OF
438
OPERATIONAL REACTORS

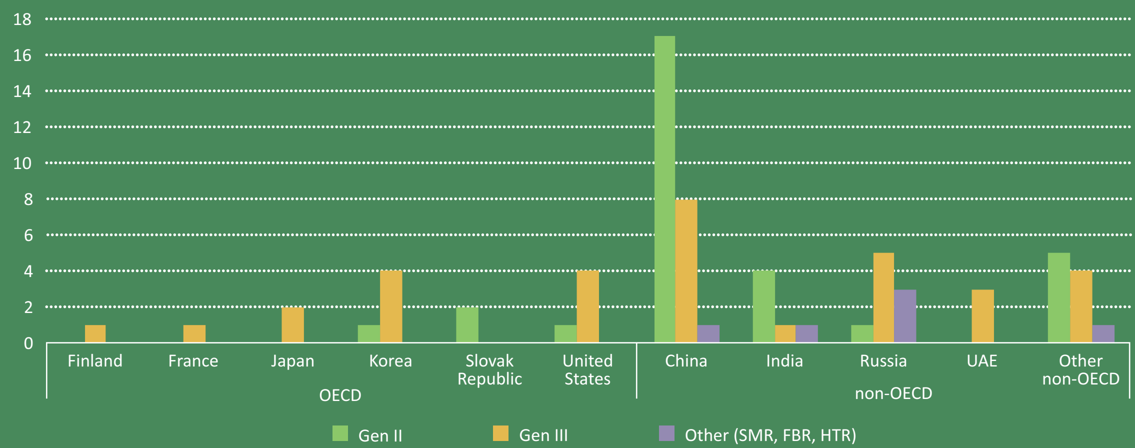
Construction trends

47% of all reactors under construction are third-generation nuclear, 44% are second-generation and 9% other

1.9 Operable reactors and electricity production



1.10 Reactors under construction



For sources and notes see page 82

Natural gas-fired power

Improvement needed

~ Limited developments

Natural gas-fired power generation accounted for 22% of total global power generation in 2012 (5 104 TWh). While this share is projected to decrease, generation is likely to continue to grow over the next two decades, playing a major role in reducing the carbon intensity of power generation globally.

Recent trends

Global natural gas demand slowed markedly in 2013, increasing at an average of just 0.8%, compared with 1.8% in both 2011 and 2012. The power sector accounted for the bulk of the weakness in OECD member country demand. Gas-fired generation dropped sharply in 2013, as electricity consumption fell in the United States and Europe. In the United States, a rebound in gas prices allowed coal generation to regain market share. In Europe, under pressure from renewable technologies and coal, gas-fired generation fell for a third consecutive year in 2013, to stand some 30% below its 2010 level.

For 2014, gas demand in the OECD power sector is poised to move less dramatically than during the previous two years. Gas use for electricity generation in the United States remained broadly flat in 2014 until October, with the impact of further moderate gas price gains offset by growing electricity demand. In some European countries, including Spain and the United Kingdom, gas consumption in the power sector was showing smaller year-on-year reductions in 2014. In the United Kingdom in particular, the sharp fall in gas prices made gas more attractive than coal. In OECD non-member economies, growth in gas consumption was also considerably slower than usual in 2013 and, outside China, it barely increased. And many countries face gas shortages, particularly in Africa and the Middle East, as the costs of development of new fields are higher than subsidised domestic prices.

Liquefaction capacity stood at roughly 400 billion cubic metres (bcm) globally at the end of 2013, with an additional 150 bcm under construction. The next wave of liquefied natural gas (LNG) supplies will be dominated by Australia and the United States. Governments remain divided on shale gas exploration policy, and geological uncertainty is high. In China, the original 2020 shale gas production target of 60 bcm to 100 bcm has recently been downgraded to 30 bcm. In India, the government inaugurated a shale gas policy in late 2013 and the first wells have been drilled, but commercial production is some time away. In Europe, a handful of countries have banned hydraulic fracturing (fracking) while others are issuing exploration licences. So far, test drilling has shown less favourable conditions than in the United States, and local opposition remains strong in many places. The plunge in oil prices during 2014 – and associated oil-linked gas prices – adds a further obstacle.

High cycle efficiency that includes quick start-up time, low turndown ratio, good ramping capabilities and part-load behaviour are now major gas turbine design parameters. Although reciprocating gas engines are unable to match the efficiencies of state-of-the-art combined-cycle gas turbines (CCGTs), they are becoming increasingly attractive. They are robust, offer flexible operation, accept a wide range of fuels, are effective for co-generation[1] and can be stacked to match the capacity required.

Tracking progress

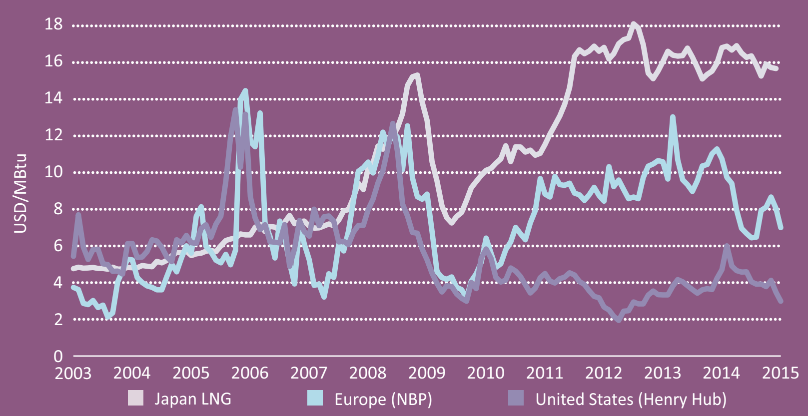
Natural gas-fired power is needed in the 2DS to provide grid flexibility to support the integration of variable renewables and as a lower-carbon alternative to coal-fired generation. While natural gas-fired electricity generation increases in meeting 2DS projections over the next decade, its share would fall by 1 to 2 percentage points by 2025. In fact, growth in gas-fired generation over the period falls to less than 2% annually from the 5.2% annual average growth observed over the last decade.

Recommended actions

As regional differences in the energy mix and in gas prices widen, policy makers and manufacturers need to remain responsive to market demands, including operational flexibility, high efficiency through the load range and fuel flexibility. In co-generation mode, improvements in thermal storage technology would allow a CCGT to operate more flexibly. As designs are improved, the choice between CCGTs, open-cycle gas turbines (OCGTs) and stacked reciprocating engines will depend on each project's application and location.

1 Co-generation refers to the combined production of heat and power.

1.11 Natural gas spot prices

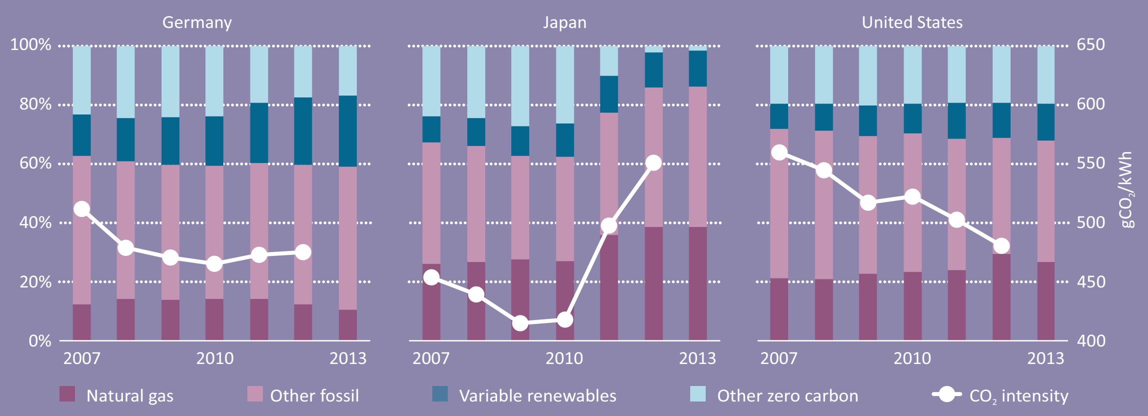


Coal-to-gas or gas-to-coal?

Natural gas continues to struggle against cheap coal in the power sector

Divergent trends in coal-to-gas switching are continuing in different regional markets

1.12 Power generation mix and related CO_2 intensity



EU CO_2 PRICE

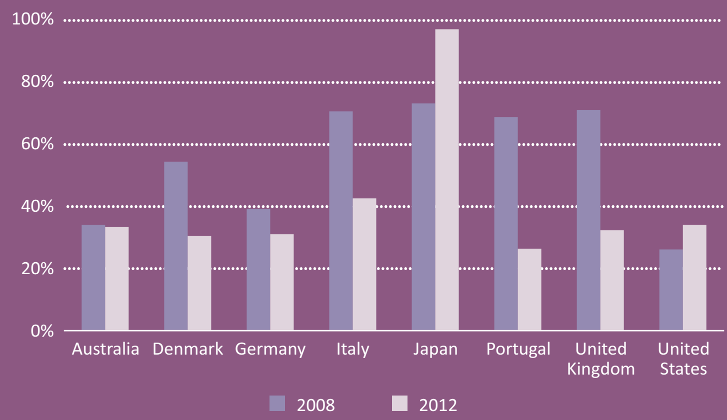
42 €/tCO_2

FOR SHORT-TERM COAL-TO-GAS GENERATION SWITCH

20 €/tCO_2

LONG-TERM CAPACITY INVESTMENT SWITCH

1.13 Natural gas-fired power capacity factors



For sources and notes see page 82

Coal-fired power

Not on track

~ Limited developments

Global coal-fired power generation continued its year-on-year growth in 2012. A decline in OECD member countries was more than compensated for by growth in OECD non-member economies. Indications for 2013 show growth in both OECD member and non-member economies.

Recent trends

Coal remains the fastest-growing fossil fuel, outpacing the growth of oil and gas in 2012. Although growth in demand for coal slowed, it still accounted for almost 30% of global primary energy consumption and more than 40% of electricity generated. In 2012, despite its weaker economic growth, China's share of global coal energy demand rose above 50%. In 2013, China was the largest coal consumer, followed by the United States and India, as in 2012; combined, these countries accounted for more than 70% of global coal demand. At the same time, the growth in generation from coal in OECD non-member economies in 2012 was 2.9% – the lowest in a decade.

In 2013, a combination of factors led to an increase in coal-fired generation. The weather was more severe than in 2012, gas prices were generally higher, and coal prices were lower, as a result of coal oversupply in world markets. In Japan, where coal-fired generation has increased to compensate for nuclear capacity taken off line after the Fukushima Daiichi accident in 2011, two new coal plants have led to higher coal consumption.

While there was a net increase in new coal plant capacity in OECD non-member economies of almost 80 GW in 2012, there was a net decrease in OECD countries of 14 GW. In the United Kingdom, 2 GW net coal generating capacity was retired in 2012 and 4.6 GW in 2013. In the United States, 10 GW net was retired in 2012 and 6 GW in 2013. Retirements in OECD countries were offset by a wave of new-build coal-fired units in Europe, for which financial investment decisions had been made when a set of particularly favourable circumstances came together around 2007-08. In Germany, for example, 2.7 GW of coal capacity came on line in 2012, followed by 5.6 GW in 2013. This wave of plants is unlikely to influence the more general trend of declining coal-fired generation in Europe.

In 2012, a net 53 GW of new coal plants was constructed in China, and more than ten times that capacity added over the last ten years. Unless plants are constructed for co-generation, China's policy is to build only supercritical or ultra-supercritical units, and permission to build new units is often granted at the expense of retiring some ageing capacity. In India, where 21 GW of new capacity came on line in 2012, building less-efficient subcritical units predominates. While India has a programme to build several supercritical ultra-mega power plants, policy measures to ensure that all new units have efficiencies consistent with supercritical or ultra-supercritical technology do not become effective until 2017. In Southeast Asia, where coal-fired capacity is also expanding, less-efficient subcritical units still dominate.

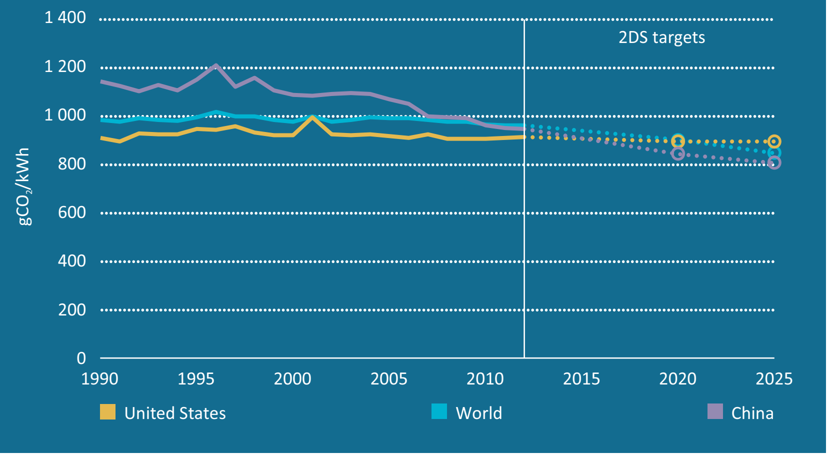
Tracking progress

While the annual average growth of CO_2 emissions from coal-fired electricity production from 2002 to 2012 was 3.7%, over the past five years this rate has halved. To meet the 2020 2DS targets, the growth in CO_2 must plateau and then fall. Given that China does not expect its emissions to plateau until closer to 2030 and given India's intentions to markedly expand coal consumption, the projected trajectory of emissions reduction from coal is not on track to meet 2DS projections.

Recommended actions

For CFPPs to be "future proofed" for operation in a low-carbon energy system, three principles need to be incorporated into their design. Wherever possible, CFPPs should offer the highest possible efficiency. CFPPs must be able to operate with sufficient flexibility to balance electricity supply and demand by compensating for variable supply from increasing renewable power. If not initially installed with CCS, CFPPs should be designed with future retrofit of CO_2 capture. Consideration given at an early stage may not only facilitate future retrofit of CCS but also reduce retrofit costs. It is vital that decisions on plant siting, which currently take into account needs such as fuel supply, cooling and grid connections, should also consider the future use of CCS by examining CO_2 transport connections and exploring access to large CO_2 storage capacity.

1.14 Coal-fired power generation CO_2 intensity

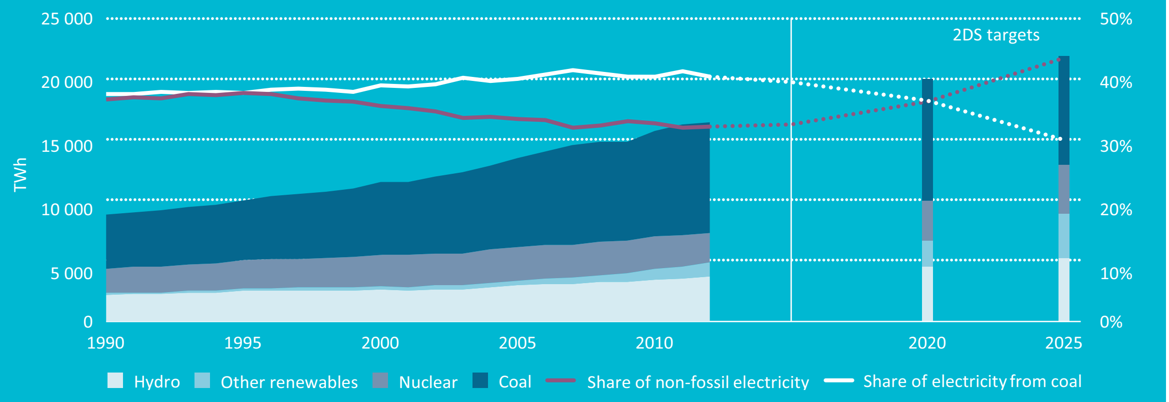


Key trends

Over the past 5 years the average annual increase in CO_2 emissions from coal-fired power generation has halved compared to the previous decade

Through a range of measures and practices, average annual fleet efficiencies continue to rise incrementally in both OECD countries and OECD non-member economies

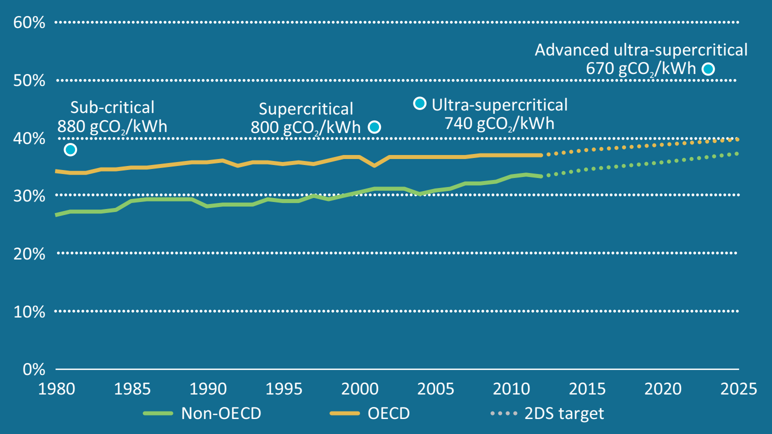
1.15 Coal and non-fossil power generation



40%

OF GLOBAL ELECTRICITY WAS GENERATED BY COAL IN 2012. THIS FALLS TO 30% BY 2025 IN THE 2DS

1.16 Average coal fleet efficiencies



For sources and notes see page 82

Carbon capture and storage

Not on track
Positive developments

Deployment of CCS passed a milestone in 2014 when CO_2 capture was demonstrated in a large-scale power plant for the first time. CCS investment needs to increase significantly, however, to ensure that enough projects are being developed to meet the 2DS.

Recent trends

In October 2014, SaskPower's Boundary Dam unit 3 in Canada became the world's first commercial electricity generating unit with full CO_2 capture. Around 1 million tonnes of CO_2 ($MtCO_2$) per year – 90% of CO_2 emissions from the unit – will be captured and stored underground through enhanced oil recovery (EOR). In Mississippi, construction of the Kemper Country energy facility continued, with the goal of commencing operations in 2016. And in Texas, the final investment decision was taken on the Petra Nova Carbon Capture project.

The three components of CCS – CO_2 capture, transport and storage – are now all being undertaken at commercial scale. By the end of 2014, 13 large-scale CO_2 capture projects were operating globally across five sectors, with the potential to capture up to 26 $MtCO_2$ per year. Over the past five years there has been a slow but steady increase in the number of CCS projects under construction. Final investment decisions were taken on two projects[2] in 2014, bringing the number of projects under construction to nine. A further 13 projects are in advanced stages of planning.

Of the 13 CO_2 projects operating, five store CO_2 with monitoring and verification focused on demonstrating storage permanence, while eight are using the captured CO_2 for EOR without storage-focused monitoring.

The demand for CO_2 for EOR in some places has created or strengthened the business case for carbon capture, enabling its demonstration. In the long term, however, all CO_2 storage, including for EOR, will need to be subject to monitoring and verification to account for the CO_2 stored.

The United States is leading the deployment of CO_2 capture, largely because of demand for CO_2 for EOR. Seven of the 13 projects in operation, and seven of the 22 in construction and development, are in the United States. To realise the 2DS CCS will have to increase markedly, particularly in OECD non-member economies which capture over half of the global total by 2025.

The USD 1 billion investment in the Petra Nova Carbon Capture project brings total global cumulative investment in large-scale CCS to USD 12 billion since 2005. OECD governments have made available USD 22 billion in support for large-scale projects, but much of this has not yet been spent.

Tracking progress

While CCS is making progress, it is well below the trajectory required to match the 2DS. At the end of 2014, 13 large-scale projects were capturing a total of 26 $MtCO_2$ per year, but only 5.6 Mt of the captured CO_2 is being stored with full monitoring and verification. The 35 projects currently in operation, under construction or in advanced planning have the potential to capture 63 $MtCO_2$ per year by 2025; however there remains a short window for additional projects to begin development in the coming years and be operating by 2025.

Recommended actions

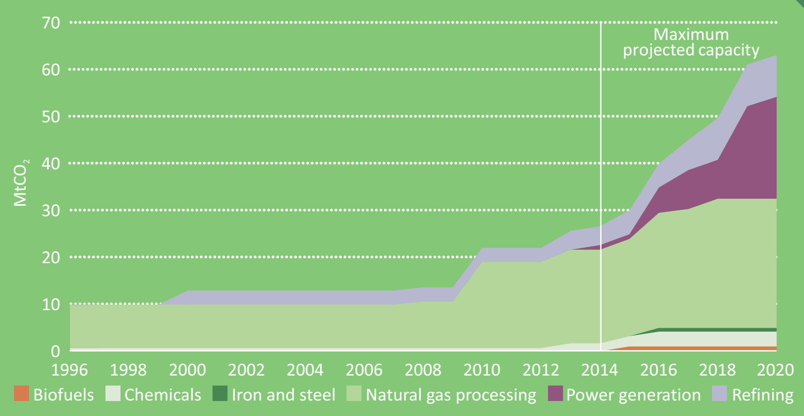
Governments and industry need to work together to ensure that final investment decisions are taken on as many as possible of the projects in development. It is vital to keep a consistent stream of projects moving through construction to build experience and foster growth in the industry.

To meet the 2DS, the rate of CO_2 being stored per year will need to increase by an order of magnitude. Governments should invest now in characterising storage resources and ensure that all CO_2 storage is appropriately monitored and verified.

Governments should identify opportunities where policies and local and commercial interests align to encourage CCS deployment, and introduce measures targeted at creating new and strengthening existing markets.

2 Petra Nova Carbon Capture project and the Abu Dhabi CCS Project.

1.17 Large-scale CO_2 capture projects



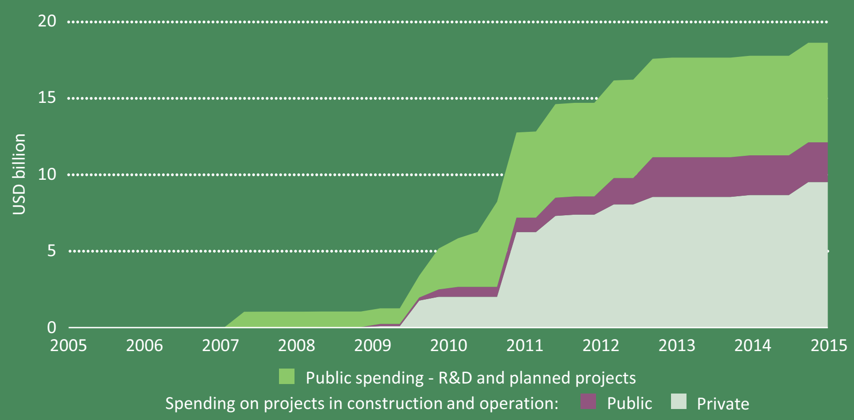
59%

OF GLOBAL CCS REQUIRED IN OECD NON-MEMBER ECONOMIES BY 2025 IN THE 2DS

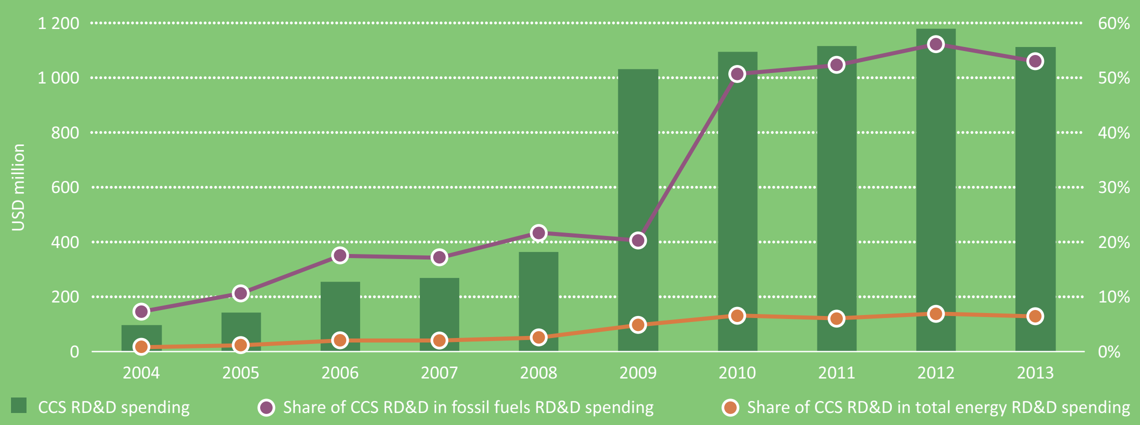
60

MILLION TONNES OF CO_2 STORED WITH MONITORING TO DATE

1.18 Cumulative spending on CCS projects



1.19 IEA public RD&D spending



For sources and notes see page 82

Industry

Improvement needed
~ Limited developments

Global industrial energy intensity in 2012 was 12% lower than in 2000, primarily due to the addition of efficient capacity. Industrial energy use continues to grow, however. To meet 2DS targets, by 2025 energy use must be reduced by 13% and direct CO_2 emissions by 18% compared with the current trajectory.

Recent trends

Energy use[3] fell between 2011 and 2012 in most OECD countries, mainly due to a slowdown in material production growth, but increased significantly in other parts of the world. Aggregated industrial energy intensity decreased by 13% in the United States and by 4% in China, but rose in other regions, including Russia and India. These changes can be attributed partially to efficiency shifts, though structural changes and price effects also play roles.

Direct industrial CO_2 emissions decreased by 6% globally in 2012, to 8 389 $MtCO_2$, despite a 1% increase in energy use. The global fuel mix in industry shifted towards electricity, biofuels and waste. In Africa, however, fossil fuels' share of total energy use grew from 52% to 59%. CO_2 emissions per unit of industrial energy use decreased in all major regions except Africa and the Middle East, including 8% decreases in developing Asia and in the European Union.

In addition to the up-front financial barriers to implementing best available technologies (BATs) in new capacity, the long technical and economic lifetimes of industrial facilities can contribute to "technology lock-in" and hinder the improvement of overall efficiency. In some regions, overcapacity in the energy-intensive industrial sectors is increasingly becoming a concern. For example, in China, capacity utilisation in five major sectors was at or below 75% in 2012.[4] In response, the State Council has reduced capacity additions in these sectors, and encouraged industry to eliminate outdated and inefficient capacity (Central Government of the People's Republic of China, 2013). To limit total industry emissions in the long term, CCS will be required.

Energy management systems continue to gain prominence across the industrial sector. The number of International Organization for Standardization (ISO) 50001-certified sites[5] is increasing, but the majority of these sites are in OECD countries (Peglau, R., 2014). It is difficult to track actual energy savings as a result of this certification, or sectoral distribution of these certifications, as there is little centralised reporting.

Tracking progress

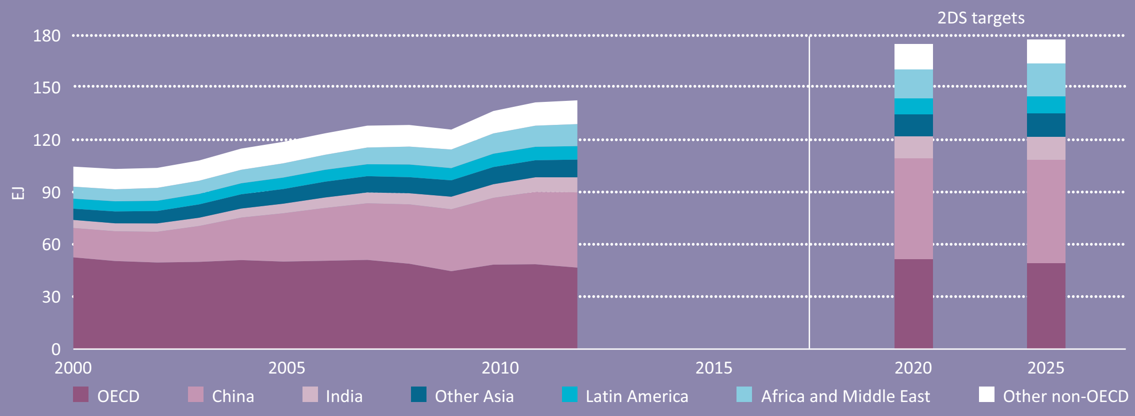
In 2012, industrial energy use increased slightly, reaching 143 exajoules (EJ), despite a decrease in overall industry energy intensity. To meet 2DS targets, energy use must be reduced by 0.9% per year and direct CO_2 emissions by 1.3% per year between now and 2025, compared with the current trajectory.

Recommended actions

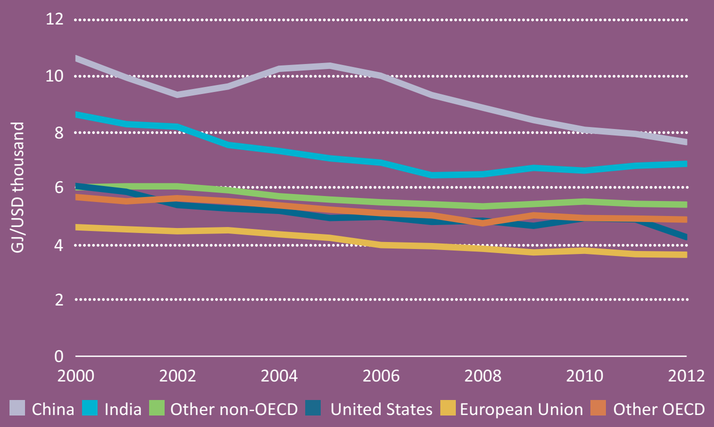
To reach the 2DS, government and industry need to join forces to promote BATs and best practices, as well as to demonstrate and deploy new technologies. Energy-intensive industry is particularly exposed to impacts on competitiveness. Carbon leakage – the transfer of production to jurisdictions with less-strict emissions standards – is also a concern. In addition, technical constraints can slow down the process of implementing new technologies. Policy frameworks and support mechanisms should take these issues into consideration by creating long-term policy and energy price stability, removing energy subsidies, and coordinating internationally to avoid carbon leakage while promoting technology transfer and capacity building for BATs.

3 Industry energy use data includes feedstock use in the chemicals and petrochemicals sector, and blast furnaces and coke ovens in the iron and steel sector.
4 The five major energy use sectors referred to by the State Council are iron and steel, cement, aluminium, plate glass, and shipping.
5 ISO 50001 is an international standard for energy management systems that supports more efficient energy use in all sectors.

1.20 Global industrial energy use



1.21 Aggregated industrial energy intensity



7 345

SITES ARE NOW ENERGY MANAGEMENT STANDARD ISO 50001 CERTIFIED IN 70 COUNTRIES (91% IN OECD)

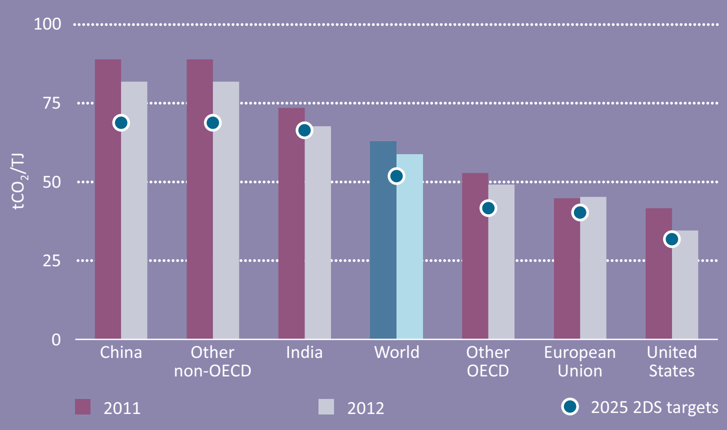
IN 2012 TOTAL INDUSTRIAL ENERGY USE INCREASED BY

1%

DIRECT CO_2 EMISSIONS DECREASED BY

6%

1.22 Aggregated industrial CO_2 intensity



For sources and notes see page 82

Iron and steel

● Improvement needed

~ Limited developments

The iron and steel sector has the second-largest energy consumption of all industrial sectors, (after chemicals and petrochemicals), accounting for 22% of total industrial energy use and 31% of industrial direct CO_2 emissions in 2012. The sector's energy use grew by 2.2% in 2012, partly because crude steel production rose by 1.4%. The 2DS requires growth in energy use of no more than 1.1% a year on average to 2025, even though crude steel production is expected to grow by almost 2% per year.

Recent trends

Global aggregated energy intensity in the iron and steel industry remained static. In 2012, the world average remained at 20.7 gigajoules per tonne (GJ/t), as in 2011, 5% lower than 2000 levels. The sector's energy intensity decreased by 1% to 14.3 GJ/t in OECD countries, but increased by 2% to 27.0 GJ/t in India, and by 5% to 25.4 GJ/t in other OECD non-member economies. Benefits of introducing more efficient production capacity have been offset by a decline in recycling as a share of total crude steel production, because the availability of scrap was unable to meet rapidly increasing crude steel demand. The steel industry in Europe has also been affected by overcapacity because of the recent slowdown in growth of demand (McKinsey and Company, 2013).

Production is expected to continue to grow steadily, so energy efficiency will need to be improved to meet the 2DS emissions target, through measures such as optimising the use of available energy embedded in process streams, deploying direct low-carbon process routes, and demonstrating and deploying innovative process technologies. The electric arc furnace (EAF) route, which is based on production from scrap and is less energy- and carbon-intensive than the basic oxygen furnace (BOF) method, represents 42% of crude steel production in 2025 in the 2DS, compared with 30% in 2012, though deployment is limited by scrap availability.

Several technologies that are at various stages of research, development, demonstration and deployment (RDD&D) focus on improving the energy and environmental performance of existing production routes, by enhancing process integration, optimising the use of process gas streams and facilitating carbon capture. However, progress is threatened by lack of resources and by economic and policy uncertainty. In the short term, the use of CO_2 capture in direct reduced iron (DRI) and smelting reduction processes could reduce emissions by 48 $MtCO_2$ by 2025 if coupled with permanent CO_2 storage.

Diffusion of ISO 14404, a standard on measurement of CO_2 emissions intensity in the iron and steel sector, has been increasing. The standard, adapted for both BOF and EAF, provides guidelines on measuring a steel plant's baseline emissions, allowing comparisons among plants and evaluation of the effects on emissions intensity of changes in operation or equipment. If widely adopted, such performance measurement or benchmarking programmes would also ensure that reported data are calculated on a similar basis.

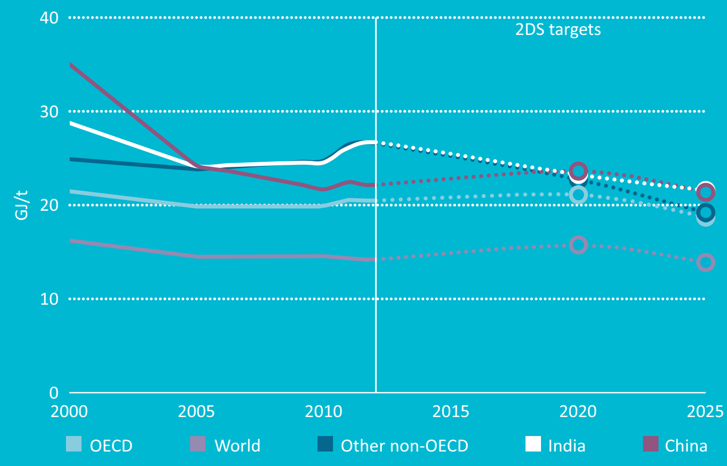
Tracking progress

Improvement is needed to put the iron and steel industry on a trajectory to meet 2DS targets. Overall growth in energy demand must be limited to 28% below the projected levels of current trends in the 2DS to 2025 (average annual growth of 1.1% per year), even though crude steel production is expected to grow by 25% from 2012 levels (average annual growth of 2% per year).

Recommended actions

Government and industry should promote the widespread application of BATs to help overcome the challenges of slow capacity stock turnover, high abatement costs, fluctuation in raw material availability, carbon leakage and industrial competitiveness, in both advanced and emerging economies. Private and public sector collaboration for development and deployment of innovative technologies to reduce CO_2 emissions from the iron and steel-making process is also critical.

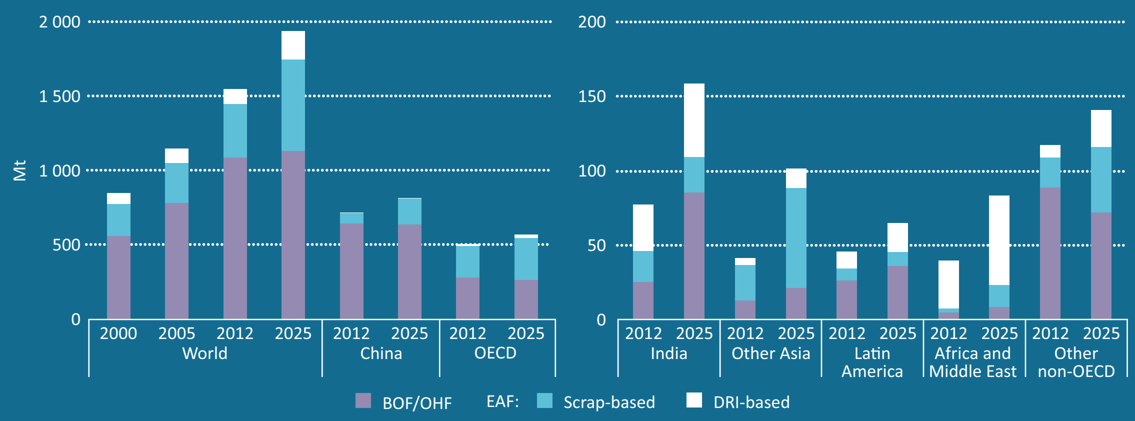
1.23 Aggregate energy intensity



30%

OF GLOBAL CRUDE STEEL PRODUCTION WAS BASED ON ELECTRIC ARC FURNACE IN 2012 (45% REQUIRED BY 2025 IN 2DS)

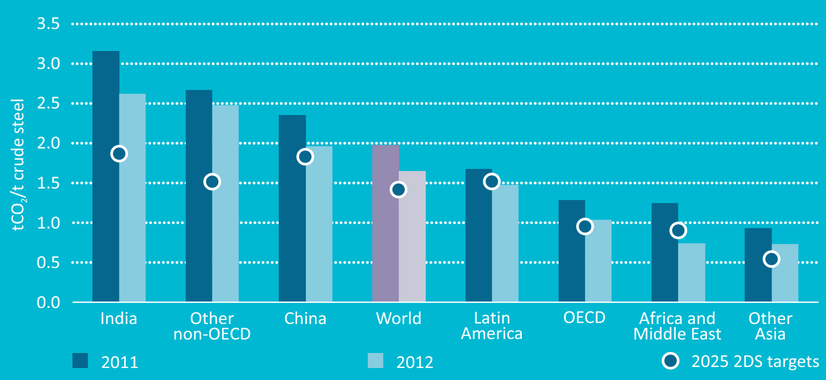
1.24 Crude steel production by process route



Recent developments

Limited availability of scrap, unable to keep up with crude steel demand, is constraining the deployment of more EAF

1.25 Direct CO_2 intensity



For sources and notes see page 82

Cement

Improvement needed
~ Limited developments

In 2012, the cement sector accounted for 8.5% of total industrial energy use and 34% of industrial direct CO_2 emissions. While the sector has made steady improvements in energy intensity, to meet the 2DS energy use must decline by 0.2% per year through to 2025, and CO_2 emissions must be 12% lower than projected levels based on current trends in 2025, despite production growth of 17%.

Recent trends

In 2012, energy use in the cement sector reached 11.1 EJ, an increase of 4.8% from 2011, while global cement production increased by 200 Mt (5.5%). The majority of the increases in production were in China (up 5% in 2012), India (up 13% in 2012) and other developing Asian countries, while in Europe production decreased by 10%.

Global average thermal energy intensity of clinker production stayed at 3.7 GJ/t clinker in 2012. There was widespread progress in reducing the electricity intensity of cement production. The global average fell by 2% to 96.3 kWh/t cement, going beyond projected improvements from *ETP 2014*. Globally, these trends are expected to continue as more capacity is shifted to BATs. Depending on local energy prices and context, the thermal intensity of dry-process kilns could be almost half that of wet-process kilns, offsetting the higher investment requirements of this type of kiln (additional USD 57 million/Mt clinker capacity).[6] Shifting capacity towards dry-process kilns with six-stage preheaters and precalciners (BAT), while improving efficiency, reduces thermal intensity to 3.1 GJ/t clinker by 2025 in the 2DS.

Improvements from technology switching will not reduce emissions enough to reach 2DS targets. Increased use of alternative fuels, waste heat recovery systems and clinker substitution can help reduce emissions in the short term, though the trade-offs between use of alternative fuels or materials and energy efficiency should be considered. Bringing CCS technologies to commercial scale in the short term, with construction beginning within a decade, is critical to reducing direct emissions from cement manufacturing in the longer term. Process emissions make up a large proportion of the CO_2 emitted in cement production, and these can be reduced only through innovative products and processes relying on different feedstocks, or through CCS. Different CO_2 capture technologies have been pilot-tested in the cement sector but not yet demonstrated at commercial scale. Though these technologies are still not commercially viable, the 2DS sees first projects coming on line in 2025, capturing 0.5 $MtCO_2$, followed by further deployment in 2030.

Tracking progress

Improvement is needed to meet the 2025 2DS targets, especially as cement production is expected to grow by 1.3% per year through to 2025. Overall energy consumption must decline by 0.2% per year on average and emissions by almost 1% per year. Therefore, improvements in energy intensity and fuel switching are required in the sector to meet the target.

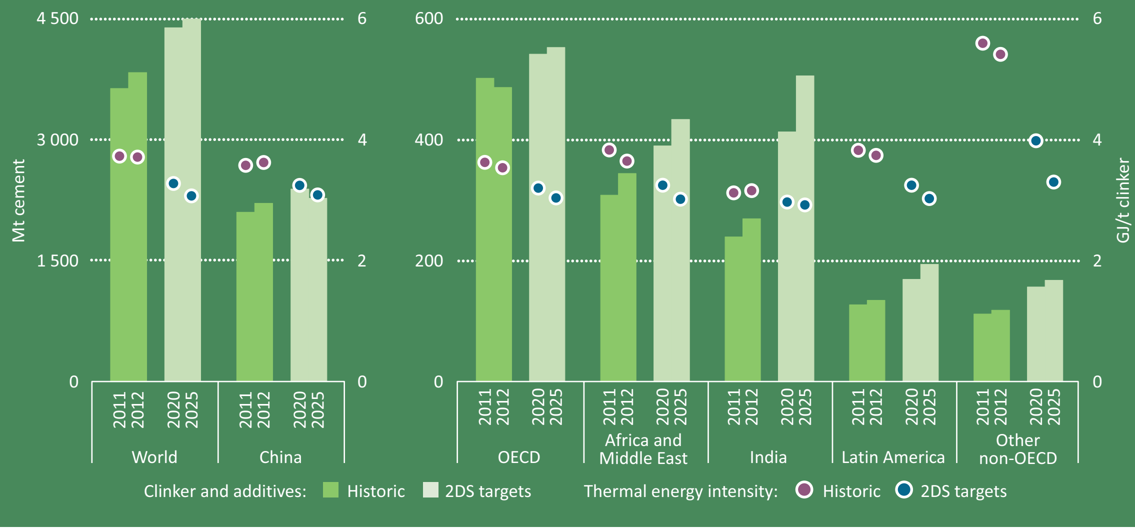
Recommended actions

Government and industry need to support RD&D programmes to bring to technical and commercial maturity new low-carbon technologies, as well as technologies that enable the use of low-quality feedstock, and to demonstrate and deploy emerging energy- and emissions-saving technologies, including CCS. Better data on cost and performance of CO_2 capture technologies will be critical for investment decisions, along with performance indicators for new products and processes, including advanced and low-carbon cement products. Simultaneously, strategies must be developed to address carbon leakage and industrial competitiveness concerns, while considering life-cycle approaches to emissions reduction.

Policies need to be developed to promote co-processing of alternative fuels, such as biofuels and waste, and to improve social acceptance of alternative fuels co-firing, particularly in regions where co-processing is currently low. Research is needed on operational health and safety risks of these alternative fuels.

6 Difference between capital expenditure on a typical wet-process kiln and on a dry-process kiln with four-stage preheater and precalciner.

1.26 Global production and thermal energy intensity



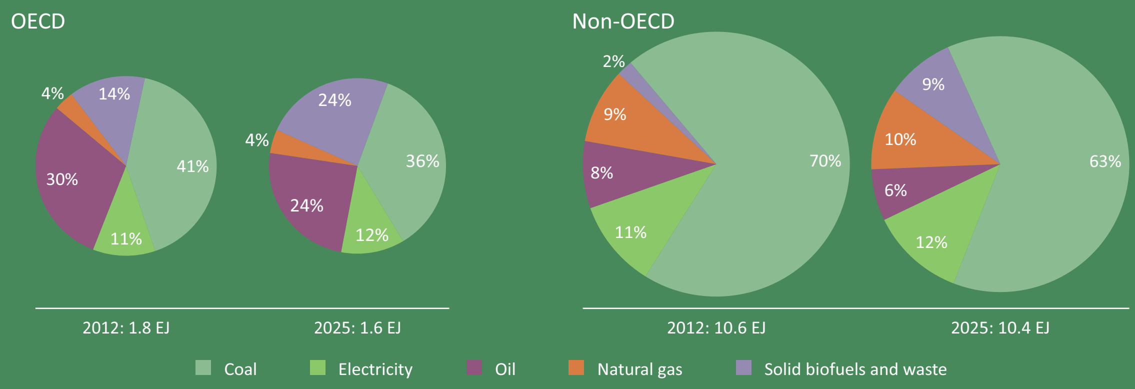
1.27 Key indicators in the cement sector

2DS low-demand variant	2011	2012	2020	2025
Cement production	3 635	3 836	4 394	4 506
Thermal energy intensity (GJ/t clinker)	3.7	3.7	3.3	3.1
Electricity intensity (kWh/t cement)	98.5	96.3	88.5	88.2
Share of alternative fuels and solid biofuels	5%	3%	8%	10%
Clinker to cement ratio	0.69	0.69	0.68	0.68
CO_2 intensity (tCO_2/t cement)	0.59	0.60	0.56	0.54

64%

OF CEMENT SECTOR DIRECT CO_2 EMISSIONS WERE PROCESS EMISSIONS IN 2012

1.28 Global energy consumption for cement production by fuel



For sources and notes see page 82

Transport

● Improvement needed
~ Limited developments

Global energy consumption by transport has grown by 2% per year since 2000 and accounted for 28% of overall energy consumption in 2012, or 105 EJ. Transport also led to emissions of 8.7 gigatonnes of CO_2 ($GtCO_2$)[7] in 2012. In the 2DS, transport energy demand needs to fall below 100 EJ by 2050, and CO_2 emissions from transport need to decline to 5.7 Gt.

Recent trends

Passenger transport accounts for nearly 60% of total transport energy demand, and 60% of this is in OECD member countries. Energy demand for freight transport was more evenly shared between OECD (47%) and OECD non-member economies (53%). Energy use in aviation remained close to 18% of the total needed for passenger transport across the past decade, both in OECD and OECD non-member economies.

Transport is the least diversified energy end use: oil products account for 93% of final energy consumption in 2012, followed by biofuels at 2%, a sixfold increase since 2000. Most of the natural gas used for transportation (about 2% of the total energy demand) is for pipeline transport, but natural gas use in other transport modes has experienced a tenfold increase since 2000, to more than 1% of total transport fuel use in 2012. The bulk of this growth took place in OECD non-member economies, representing 90% of the natural gas demand that was not used for pipeline transport.

In 2012 passenger cars accounted for 77% of passenger transport energy use in OECD member countries and 56% in OECD non-member economies; even though new vehicle registrations in OECD non-member economies now exceed those in OECD member countries (OICA, 2014), the vehicle fleet and the share of energy used by passenger cars in the non-OECD remained lower than in the OECD in 2012. Public transport modes (road and rail) represented 4% of the total transport energy demand in the OECD and 17% in the non-OECD. The lower energy intensity per passenger kilometre of public transport modes, however, translated into a higher share of transport activity (expressed in passenger kilometres): 15% in OECD and 52% in OECD non-member economies.

Road, the most energy-intensive freight transport mode besides aviation, represented 67% of the total energy used to move goods. Trucks consumed nearly three-quarters of this, with the remaining quarter mostly used by light commercial vehicles (LCVs). Trucking activity (in absolute terms) was more relevant in OECD non-member economies than in the OECD, while LCVs moved a comparable amount of goods in each of these regions. The second-most-important freight transport mode for energy demand (23%) is shipping, including both domestic and international navigation. Maritime transport takes the lion's share in this portion. Its low energy intensity, however, is such that maritime transport is by far the most relevant mode in terms of activity: 77% of total tonne kilometres in 2012. Rail freight is especially relevant in regions such as North America and continental Asia where long-distance water transport is not viable. Globally, it accounts for 4% of energy demand for freight transport and 13% of total tonne kilometres.

Tracking progress

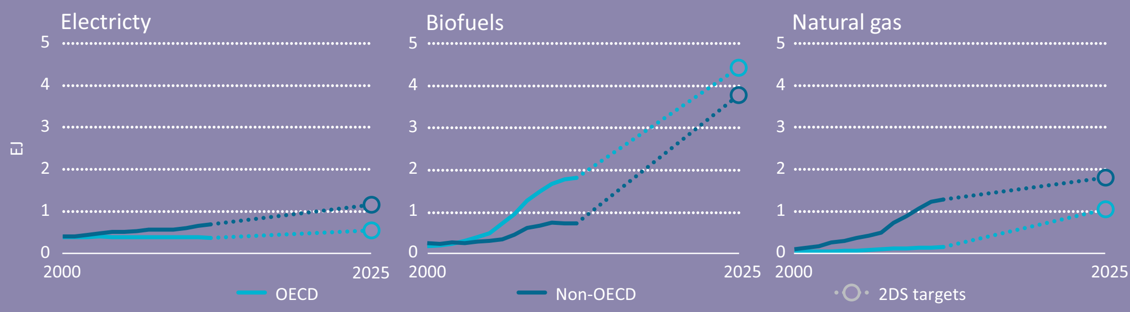
Transport energy and CO_2 emissions have increased by 28% since 2000, or 2% per year. The sector is not on track to meet 2DS targets. Stark changes to the trends of the last decade are required: energy demand needs to stabilise at least, while CO_2 emissions need to fall.

Recommended actions

Getting transportation on track to meet 2DS targets requires implementing a broad set of policies, summed up as "Avoid, Shift, Improve". These measures also enable reductions in air pollution, road fatalities and congestion, while improving passenger and freight transport access: avoiding unnecessary transport activity, for example by using land-use planning to favour compact urban forms, and ICTs to lower the need for traveling; shifting travel to energy-efficient modes, for example by providing adequate public transport infrastructure; improving the specific fuel consumption of vehicles (e.g. via fuel economy standards), their capacity to handle energy diversification (e.g. with incentives for multi-fuel vehicles), and the characteristics of fuels (e.g. with quality specifications to improve the carbon intensity of fuels).

7 Expressed on a well-to-wheel basis.

1.29 Alternative transport fuels

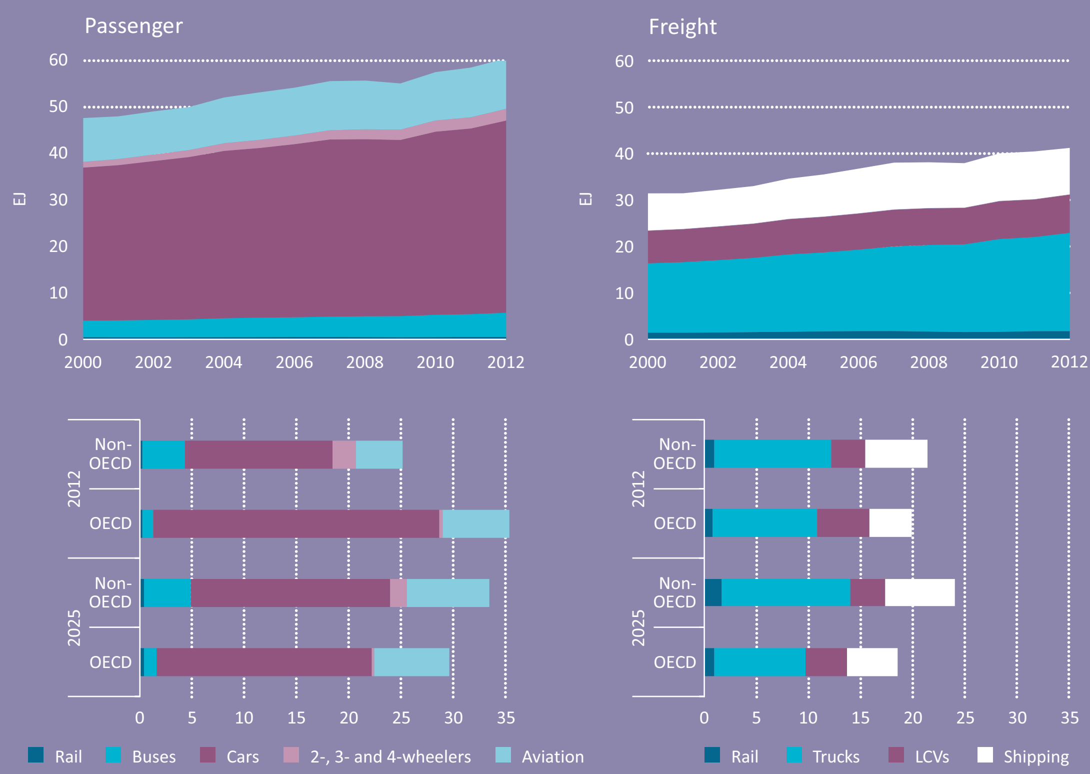


Once energy, infrastructure, congestion, environmental and health-related social costs are taken into account, public transport modes used for urban mobility deliver net savings compared to individual vehicles

50% of the cost of public transport systems of European cities is covered by subsidies

10% drop in the public transport mode share in total passenger kilometres in OECD non-member economies since 2000

1.30 Passenger and freight transport development



For sources and notes see page 82

Fuel economy

Improvement needed
Positive developments

To reach the 2DS target of halving specific fuel consumption of new conventional fuel PLDVs by 2030, global improvement rates of 3% per year have to be achieved. OECD countries have almost achieved this rate, partly due to strong policy measures, but progress has stagnated in OECD non-member economies because of a trend towards bigger, more powerful cars.

Recent trends

Many OECD markets, as well as large developing economies, have already introduced fuel economy regulations for road transport vehicles, in order to direct existing technological potential towards enabling fuel savings rather than enhancing vehicle performance. Several important and fast-growing markets in Asia, Latin America, the Middle East and Africa have not yet regulated fuel economy for transport vehicles, and the policy coverage is uneven across transport modes.

Almost all OECD member countries and China, the largest single-country market, have adopted policy measures to improve fuel economy of new PLDVs.[8] In 2012, the United States announced the extension to 2025 of the current regulatory framework, as well as a substantial improvement in average vehicle fuel economy targets. In the same year, Brazil implemented fiscal instruments promoting environmentally friendly innovations. Mexico introduced fuel economy standards in 2013. India and Saudi Arabia did so in 2014. Almost 80% of the global PLDV market is now regulated.

Fuel economy regulations have not been as widely adopted for heavy-duty vehicles as they have for PLDVs. Japan established the world's first fuel economy programme for medium- and heavy-duty vehicles in 2005 and will enforce it in 2015. China introduced heavy-duty fuel economy regulations in 2011, with a second phase starting in 2014/15. Canada and the United States introduced regulatory measures on heavy-duty road vehicles in 2014. Efforts are under way to develop similar regulations in the European Union, India, the Republic of Korea and Mexico.

Canada, the European Union, Japan, Mexico and the United States have also introduced fuel economy regulations for LCVs, building on their experience with PLDVs. China is the only country that has introduced fuel efficiency standards for motorcycles.

Tracking progress

For passenger cars, regions with regulations in place show annual improvement in fuel economy of around 2.6% since 2005. Non-regulated markets lag behind, mostly due to a shift of preference towards bigger and more powerful vehicles as consumers' personal income has increased. Globally, the average fuel economy of cars has improved by 2% per year since 2005, below the 3% per year needed to reach the 2DS efficiency target. Despite recent encouraging policy developments, further improvement is needed to meet the 2DS.

Recommended actions

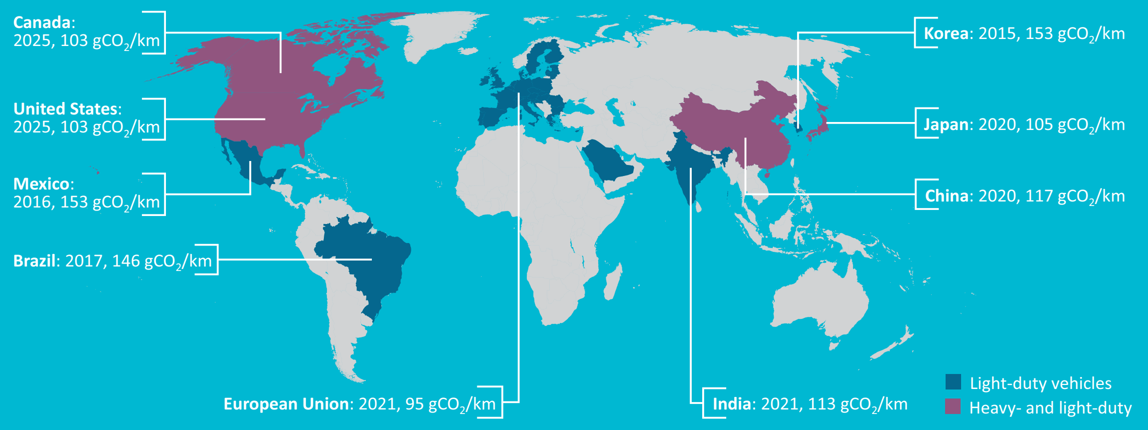
Governments need to enlarge the coverage of fuel economy regulations, and strengthen the stringency of those already introduced, to meet 2DS emissions reduction targets.

A widening gap between tested and real fuel economy could neutralise much of the improvement delivered under testing conditions. Despite recent progress with the development of the Worldwide Harmonised Light Vehicle Test Procedure (WLTP), the gap between testing conditions and on-road results needs to be reduced still further. Parallel efforts should aim to include elements related with usage patterns in fuel economy regulations, as the higher mileages of larger and more powerful vehicles can contribute to the gap between on-road fuel consumption averages and tested results.

8 Such as fuel economy standards, CO_2-based taxation, rebate or feebate systems (i.e. the combined use of taxation and subsidies to promote innovative technologies or support consumers and manufacturers opting for environmentally friendly vehicles) and labelling schemes.

1.31 New PLDV tested fuel economy

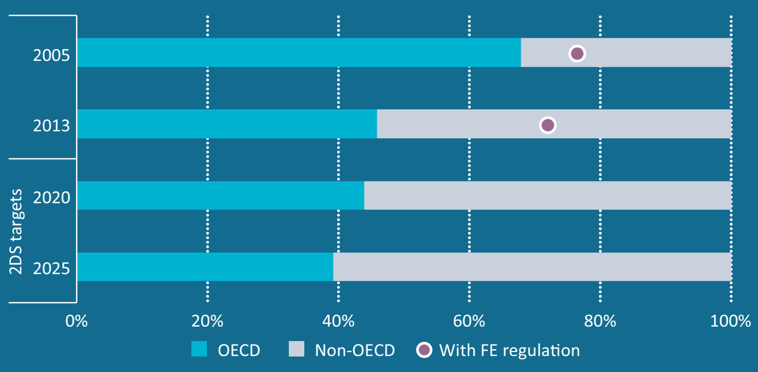
1.32 New vehicle fuel economy standards



30%

DISCREPANCY BETWEEN TESTED VEHICLE FUEL ECONOMY AND REAL ON-ROAD FUEL ECONOMY

1.33 Global PLDV market



For sources and notes see page 82

Electric vehicles

Improvement needed
Positive developments

Global sales of light-duty passenger electric vehicles (EVs)[9] grew about 50% from 2013 to 2014, a slowdown compared with previous years, but encouraging growth in absolute numbers starting from a small base. Sales of PHEVs grew 57% and BEVs grew 43% from 2013 to 2014. Battery costs continued to fall and vehicle range increased for several second-generation EV models, but greater government spending is needed to drive substantial deployment to meet ambitious 2DS targets.

Recent trends

While more EV models were released to the market, and global sales of PHEVs and BEVs grew from 2013 to 2014, there was otherwise a relative slowdown in government spending and EV deployment. Only in the Netherlands, Norway, Sweden, and the United States did sales of EVs exceed market shares of 1%. The cumulative global stock grew to about 665 000 EVs, impressive considering there were almost none on the road in 2009, but the Electric Vehicles Initiative (EVI) cumulative government target of 20 million EVs on the road by 2020 will be hard to achieve without much faster growth. After a slow start since the introduction of mass market EVs in 2010, sales of EVs in China finally took off, growing from around 13 000 in 2013 to more than 80 000 EVs in 2014.

EV charging infrastructure grew from around 46 000 slow chargers (Level 1 and 2) in 2012 to around 940 000 in 2014. The numbers of fast chargers (Level 3, CHAdeMo, and SuperCharger) grew from 1 900 to 15 000. Some car manufacturers began to sell vehicle-to-home systems, enabling customers to use vehicles to charge homes as well as vice versa; these are particularly suited to solar PV-powered homes.

EVI's 2015 update of its *Global EV Outlook* (IEA, 2015) shows battery costs continuing to decrease. However, battery costs have yet to achieve first-cost parity with equivalent internal combustion vehicles (versus lifetime-cost parity, already achieved for many models). More RD&D funding is needed to reach lower battery cost targets by 2020, which would increase the competitiveness of EVs not only on the basis of purchase cost but also by decreasing the cost of extending vehicle range.

Electric 2-wheelers make up the largest electrified vehicle fleet in the world, with over 230 million electric 2-wheelers in China alone. The total stock outside China is currently substantially smaller at approximately 5 million, but sales are increasing. Electric buses are increasingly being considered by cities as a way of reducing local air pollution; there are currently 46 000 electric buses worldwide, with 36 500 in China alone. Passenger vehicles have enjoyed trickle-down innovations from motorsports for years. In 2014 this extended to EVs with the launch of the all-electric racing series Formula E, which started in Beijing and will finish its inaugural circuit in London in 2015.

Tracking progress

Annual average growth of 80% in EV sales to 2025 is needed to meet 2DS targets, so improvement is needed, as growth is currently 50% per year. While there were many policy discussions in 2014 on vehicle electrification, few government actions were taken to support deployment. A slowdown in spending hampered progress, while incentives and infrastructure deployment remained otherwise unchanged.

Recommended actions

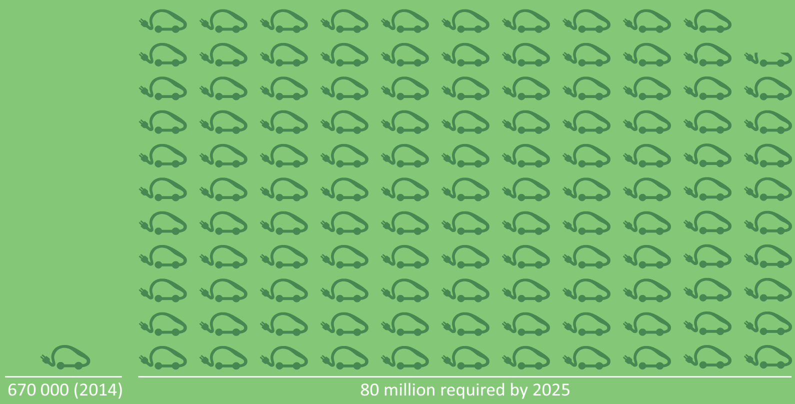
Support for RD&D continues to be crucial. To achieve 2DS deployment targets for 2020 and beyond, governments need to bolster RD&D to ensure EVs have longer driving range with less costly batteries.

Vehicle electrification needs to be considered from a broader perspective than just electric passenger vehicles, as increased usage can make a multi-modal approach viable – using ICT, for example, to integrate electric buses, 2-wheelers and rail with passenger cars.

Governments should support cities and regions to develop sustainable business models underpinning EV infrastructure.

9 Including plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs).

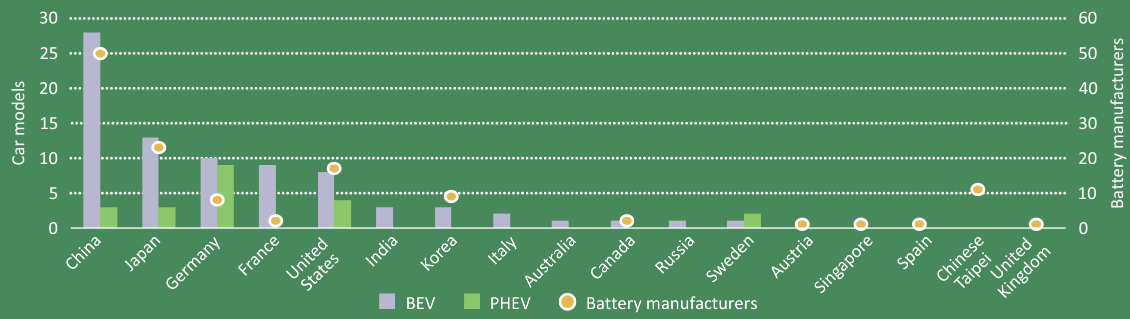
1.34 Global electric vehicles stock



4

COUNTRIES HAVE EV SALES SHARES OVER 1% OF TOTAL NEW CAR SALES

1.35 EV models available by country and lithium-ion battery manufacturers



OF EV SALES

91%

ARE BEVS IN NORWAY

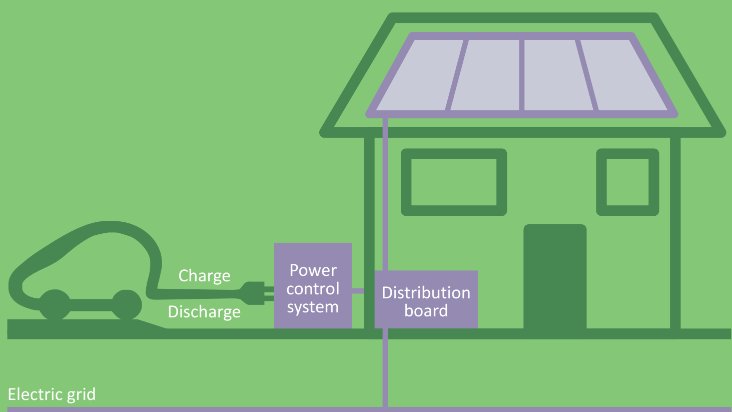
82%

ARE PHEVS IN THE NETHERLANDS

49%

ARE PHEVS IN THE UNITED STATES

1.36 Vehicle-to-home system



For sources and notes see page 82

Buildings energy efficiency

Not on track

~ Limited developments

Globally, buildings accounted for 32% (118.6 EJ) of final energy consumption in 2012, and 53% of global electricity consumption. Despite numerous studies highlighting untapped energy efficiency opportunities, that can reduce carbon emissions without increased life-cycle costs, progress has been inadequate to achieve 2DS targets by 2025.

Recent trends

Despite the continuing importance of energy efficiency in buildings, overall financial support and policy priority are widely believed to have peaked a few years ago, whereas a sustained effort is needed to overcome the major market barriers. Several developed countries have been pursuing zero-energy buildings (ZEB) for at least a decade. Outside the European Union, however, progress has been very slow, mostly because energy prices have remained low and RD&D has not yet resulted in widely available lower-cost technologies. Even in the European Union, where mandatory directives require member states to pursue NZEBs by 2020, many policy experts are sceptical that the ambitious target dates will be achieved (IEAi, 2014). The number of buildings achieving very low energy consumption or NZEBs is small. Actual performance or energy consumption is not being adequately tracked, and nor is NZEBs' share of new construction. Policy makers need to make energy efficient buildings a priority and take steps to improve progress, such as a major effort on public buildings.

The spread of mandatory building codes and more stringent energy requirements shows that progress continues in most of the world, but it is too slow. A lack of testing and rating protocols (for components and for whole buildings), poor product availability, low education and knowledge, and limited investment in advanced construction have prevented regulators from enacting and enforcing stringent building codes. The European Union, which has made the most progress, requires member countries to include cost optimality as a criterion when developing building codes. France, for example, has enacted a building code that limits space heating, water heating, cooling and lighting energy to 180 megajoules per square metre (50 kilowatt hours per square metre [kWh/m^2]) or less.[10] Implementation is just beginning, however, and researchers expect compliance to remain low for some time.

Deep energy renovation of at least 1% to 2% of existing buildings per year has been recommended as a key policy by stakeholders and the IEA for some time.[11] The technical and economic benefits have been demonstrated by case studies in a wide range of climates and regions. The European Union is the only region that seems to be pursuing this policy, and with a high space heating requirement, large gas demand, and recent concerns about gas supply security, it is possible this priority will be further elevated by policy makers. It does appear to be of higher interest in the United States for government buildings, but activity is limited to a few buildings from a research perspective rather than a deployment focus.

Tracking progress

Final energy consumption in buildings increased by 1.5% per year between 2000 and 2012. The rate has not declined despite recent reduced global economic growth. To achieve 2DS targets, it should not grow by more than 0.7% per year through to 2025. As global economic prosperity returns and the world's population grows by 1 billion people by 2025, however, there is a serious risk that buildings' energy consumption will continue to grow at a high rate (1.4% per year), reaching 142.7 EJ.

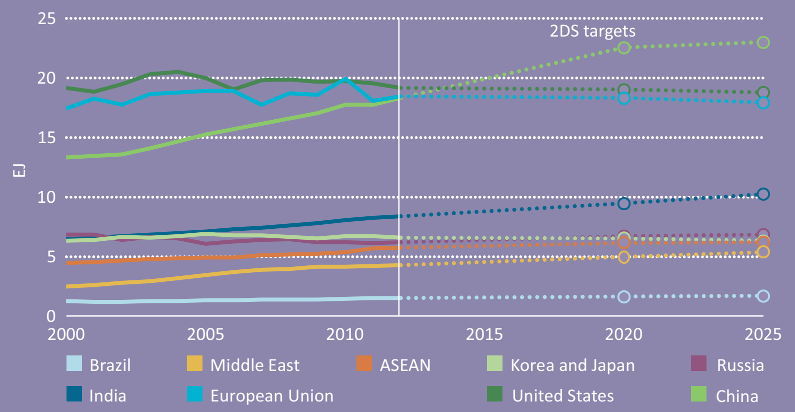
Recommended actions

IEA member countries should develop and promote deep energy renovation as part of normal refurbishment and limit financial incentives to very high-performance buildings (systems and components). The quality of energy performance certificates needs to improve in EU member countries, and the use of such certificates needs to spread to all regions of the world, with more effort to make them more effective (BPIE, 2014). All governments – especially in emerging economies – need to make greater efforts to develop, promote and enforce more stringent building codes, with the eventual goal of ZEBs.

10 The building code allows scaling based on building type and climatic region.

11 Where deep energy renovation or retrofit is defined as a reduction in energy consumption of at least 50% or to not more than 60 kWh/m^2 for building code loads (e.g. space conditioning, water heating and hardwired lighting), (GBPN, 2013).

1.37 Energy consumption in the buildings sector

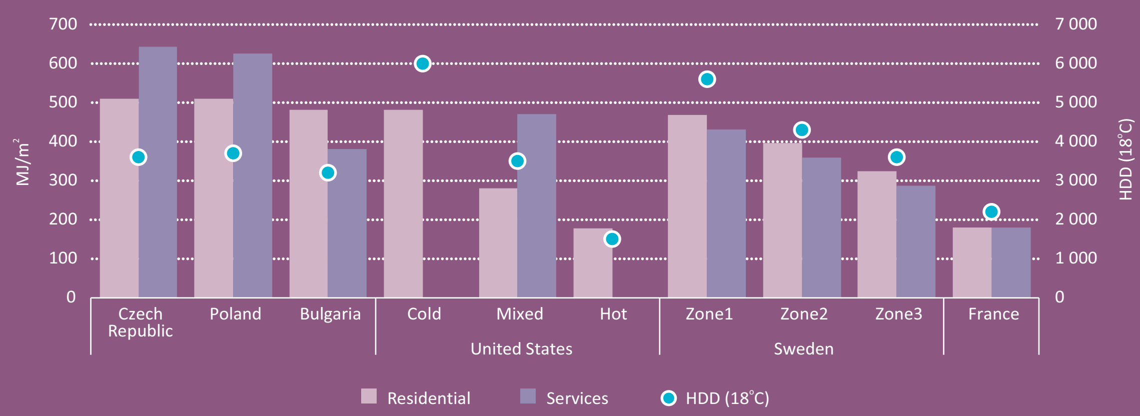


THE 2DS TARGET FOR 2025 ALLOWS FOR ENERGY DEMAND GROWTH BUT ONLY AT

50%

OF THE CURRENT GROWTH RATE

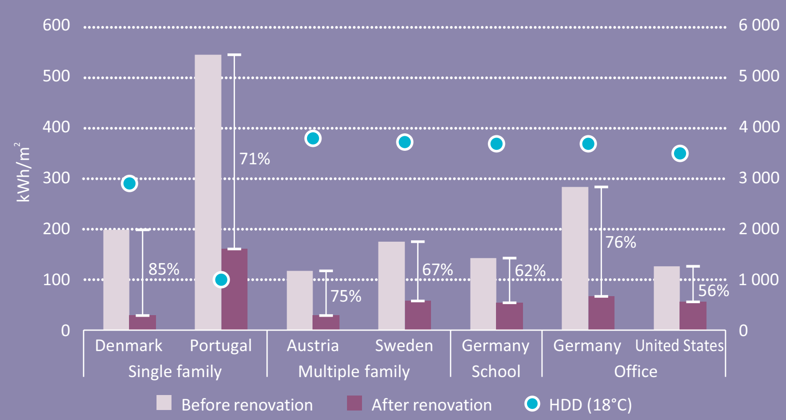
1.38 Building code energy intensity



Policy recommendation

To encourage investment in high-performance buildings, all countries should develop and promote building performance metrics that are compatible with financing organisations, including multiple benefits beyond energy efficiency

1.39 Deep renovation case studies



For sources and notes see page 82

Building envelopes

Not on track

~ Limited developments

Energy use by space heating, cooling and lighting, which represents 38% of global buildings energy consumption, could be reduced by more than half by ensuring that building envelopes are energy efficient. Advanced building envelope materials and integrated construction techniques enable the construction and renovation of buildings that consume little or no energy.

Recent trends

Windows are responsible for the highest heat loss in winter and highest heat gain in summer per unit area in the majority of buildings in the world. In moderate and cold climates, advanced windows can provide a positive net energy contribution when combined with highly insulating properties and dynamic solar control, and are viable today in places with high energy prices (IEA, 2013b). All areas of the world should require double-glazed, low-emissivity (low-e) coated windows (with climate "optimised" solar control) with low conductive frames. Cold climates should move to even higher-performing windows with low thermal transmittance (U values < 1.1 watts per square metres Kelvin [W/m^{2}K]) that effectively add a third low-e glazing or include vacuum glazing technology. Advanced windows offer systems benefits beyond efficiency, such as elimination of perimeter zone conditioning, improved comfort and reduction in equipment capacities. Progress in commercialising advanced windows has been too slow in all but a few EU countries; global market share is in the single digits. Voluntary energy efficiency labelling programmes in the United States (ENERGY STAR) and several EU countries (e.g. France and United Kingdom) specify criteria that are too weak for cold climates.[12]

If insulation is properly installed at optimal levels during planned building construction or renovation, it can be one of the most cost-effective energy efficiency measures. Insulation is available in most regions of the world and is usually installed in many high-profile buildings. It is typically installed at well below optimal levels, however, which are highly dependent upon local and regional conditions, including climate, cost of materials and energy prices. More effort is needed, including mandatory building codes, to ensure more widespread installation of higher levels of insulation (achieving low U values), which can also occur as independent retrofit measures.

Effective air sealing can reduce heating and cooling energy by 20% to 30% and needs to be implemented as part of any construction and renovation project. Air leakage rates are often determined as part of a quality energy audit or building performance rating and labelling activity. However, the vast majority of EU performance certificates do not require mandatory air leakage validated tests. While new construction in the most mature markets includes air sealing (low air leakage), the majority of existing buildings have high air leakage. More effort is needed globally to ensure that any building that will be heated or cooled is properly sealed. When sealing is done correctly, with controlled ventilation and advanced heat recovery, it can improve indoor air quality.

Tracking progress

Overall progress on efficient construction techniques – including optimal levels of insulation, well-insulated windows and proper air sealing – is too slow. Most regions of the world are not on track to realise the potential to reduce thermal loads in new buildings by 75% to 80% compared with loads in existing buildings.

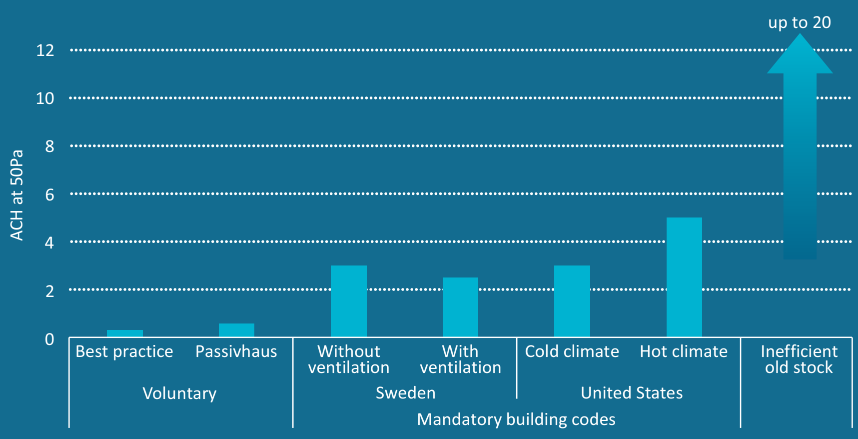
Recommended actions

More policy activity needs to be focused on advanced building envelope materials and construction techniques, including awareness, education, building material test and rating protocols, building codes and financial incentives for very high-performing products and systems. Promoting building codes for insulation and windows with lower U values, along with mandatory air sealing are critical. Greater effort is needed to help establish commodity-based advanced building materials and products in emerging markets. A key policy should be for governments to specify proper building material requirements and codes during construction and renovation of public buildings. Data quality and tracking of efficient building materials and products are essential to ensure that advanced construction develops globally.

12 New ENERGY STAR criteria effective January 2016 specify U values < 1.5 W/m^{2}K in cold climates, and France and the United Kingdom designate moderate performance windows being classified as A+ as part of its classification system. Many policy experts believe that A+ designations should be reserved for energy positive windows.

1.40 U values for walls and roofs

1.41 Air leakage rates



Key point

Beyond Canada, northern United States and north-western Europe, the majority of construction in the world uses sub-optimal products

For sources and notes see page 82

Appliances, lighting and equipment

Improvement needed
~ Limited developments

Energy demand continues to grow for appliances, lighting, and a large array of electrical and fossil fuel-powered equipment, despite significant progress on labelling and mandatory minimum energy performance standards (MEPS). Market penetration of major appliances has increased significantly in emerging markets, and plug loads from electrical devices and network usage continue to grow in all markets, resulting in energy consumption growth of over 50% from 2000 to 2012.

Recent trends

The number of energy performance standards and labels has grown significantly worldwide, with over 3 600 measures identified (EES, 2014). The geographical concentration of such programmes has gradually shifted from the United States and the European Union towards Asian and other countries; China has 100 separate measures. However, greater alignment and collaboration is needed on standards of globally traded products.

The Super-efficient Equipment and Appliance Deployment (SEAD) Initiative quantified the annual energy savings in 2025 from 81 performance standards promulgated in 12 participating economies between 2010 and 2013.[13] This analysis finds that MEPS are expected to save 2.4 EJ by 2025. A further 12 EJ could be saved by 2030 with more assertive MEPS (SEAD, forthcoming). The majority of standards are applicable to electrical appliances but also include fossil fuel-powered equipment such as boilers and water heaters. Energy savings from efficiency standards are expected to reduce OECD residential electricity consumption by nearly 10% compared to current trends in 2025. Further research is needed to evaluate the savings potential for standards in China and other developing countries.

Energy efficiency regulations for lighting products have moved sales away from inefficient incandescent lamps, but towards halogen lamps rather than more efficient compact fluorescent lamps (CFLs) or light-emitting diode (LED) lamps (4E IA, 2015). More assertive policies are needed to achieve large savings.

When MEPS are complemented by policies such as R&D, incentives, labelling, and educational programmes, the impact can be even more significant. For example, the European Union has promoted condensing boilers that are up to 17% more efficient than traditional boilers. Market conditioning has preceded MEPS that will come into force in September 2015. Japan has made significant progress in adopting heat pump water heaters (HPWHs) that use 75% to 50% less electricity than electric resistance technologies. As a result of R&D and incentives, sales in Japan are 20 to 40 times higher per capita than in the European Union and the United States. R&D has enabled the United States to bring the cost of HPWHs down to below USD 1 000; EU prices are typically over USD 3 000. Globally, around 25 million inefficient electric resistance storage water heaters continue to be sold each year. Overall, more integrated, comprehensive and stringent policies are needed for all product categories (IEA, 2013c).

Tracking progress

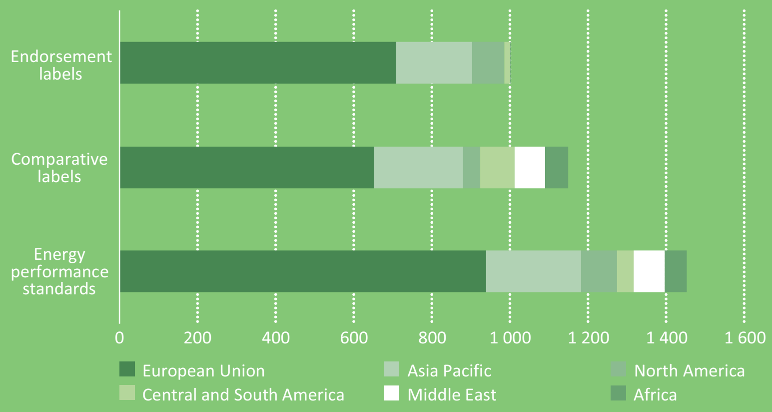
Despite recent progress in introducing MEPS, improvement is needed to meet 2DS targets. Electricity demand has increased by over 4% per year for the last decade, but this rate needs to fall to 1.2% in the 2DS.

Recommended actions

Much more effort is needed to promulgate more stringent MEPS globally, along with tracking and evaluation programmes, especially in emerging markets. Inefficient light bulbs, including halogens and electric resistance heaters, should be eliminated from the market and replaced with more efficient technology (e.g. CFLs, LEDs, HPWHs, heat pumps and solar thermal). IEA member countries need to transfer lessons learned to emerging markets, including capacity building related to analytical capability, stakeholder engagement, compliance monitoring and quality testing. More R&D and market conditioning is needed to bring down the cost of advanced technologies so they are commercially viable in areas with lower energy prices.

13 SEAD economies analysed include Australia, Brazil, Canada, the European Union, India, Indonesia, Japan, Korea, Mexico, Russia, South Africa and the United States. For more information on SEAD, see superefficient.org.

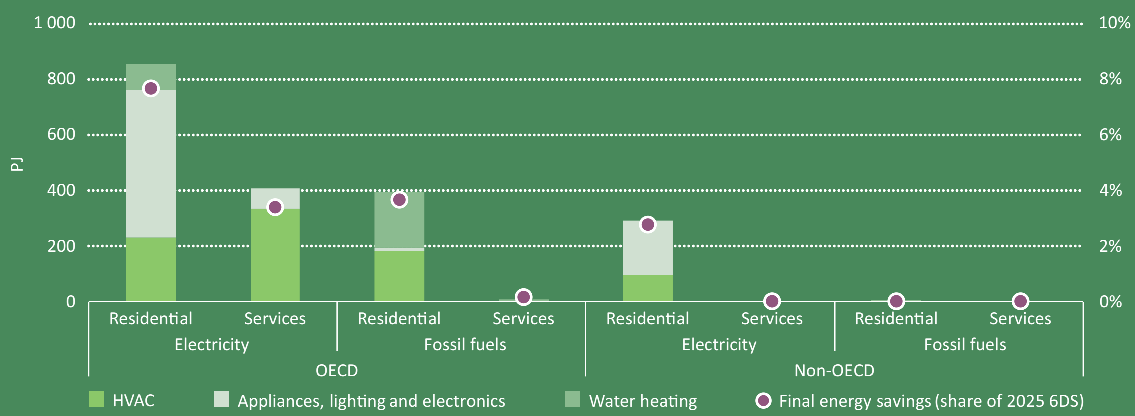
1.42 Appliance and equipment efficiency measures



80%

OF ENERGY CONSUMED BY SOME NETWORK-ENABLED DEVICES IS USED JUST TO MAINTAIN CONNECTIVITY

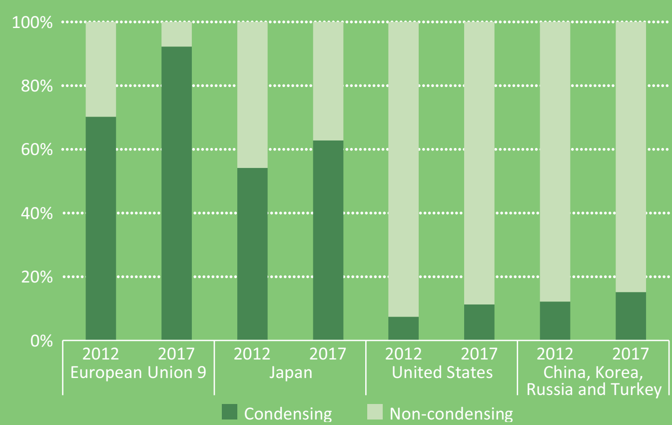
1.43 Mandatory appliance and equipment energy savings forecast



20%

INCREASE IN LIGHTING ENERGY CONSUMPTION BETWEEN 2000 AND 2012. IN THE 2DS TOTAL LIGHTING CONSUMPTION IN 2025 STABILISES AT JUST BELOW 2012 CONSUMPTION LEVELS.

1.44 Condensing boilers market share



For sources and notes see page 82

Co-generation and DHC

Improvement needed
~ Limited developments

Despite an absolute increase in co-generation, it has plateaued as a share of global electricity generation.[14] Efficient DHC systems have not been extensively deployed, despite their potential to help create a more integrated energy system.

Recent trends

Modern co-generation and DHC systems are highly efficient and increase the flexibility of electricity and thermal grids, but these benefits have not been fully captured. In 2012, co-generation of heat and power had a global average efficiency of 58%, compared with 37% overall for conventional thermal power generation.[15]

Co-generation deployment on a global level has plateaued in recent years, decreasing slightly to 9% of global electricity in 2012. In absolute terms, electricity production from co-generation has grown moderately, to just over 1 000 TWh per year in OECD countries and nearly the same level in OECD non-member economies. In absolute terms, production of heat from co-generation units has increased steadily, reaching over 6.5 EJ globally in 2012, or 44% of global commercial heat production, with most of the growth in OECD countries.

Modern district cooling (DC) networks can achieve efficiencies five to ten times higher than traditional electricity-driven cooling systems.[16] Data on progress in DHC is limited, but the district heating (DH) market is much more developed than the DC market. Both are more advanced in Europe, where more than 5 000 DH systems are in operation, supplying more than 10% of European heat demand in 2012 (556 TWh), and DC accounts for about 2% of cooling demand (3 TWh) (DHC+ Technology Platform, 2012).

Micro-co-generation, which can be beneficial for individual buildings where DHC is not economical, has also become more prevalent. Korea is targeting additional small-scale co-generation capacity of up to 2.7 GW by 2017, and Japan aims to have 1.4 million units installed by 2020 (IEA, 2013d, 2013e, 2013f).

Tracking progress

Greater deployment of efficient and cost-effective co-generation and DHC is needed. While absolute co-generation has increased, its global share of electricity generation has not changed significantly over the past decade. DH represented 10.8% of global heating energy use in 2012. Co-generation and modern DHC systems can help reduce primary energy demand and increase overall system efficiency, and should be part of an integrated approach to meeting 2DS targets across all sectors.

Recommended actions

Policy makers should enable co-generation and DHC to compete with other technologies by removing barriers to interconnection, facilitating interconnection standards, and rewarding efficient operation and use of low-carbon energy sources. They should also address the high up-front costs, inflexible business structures and lack of long-term visibility on regulatory frameworks that also limit co-generation and DHC.

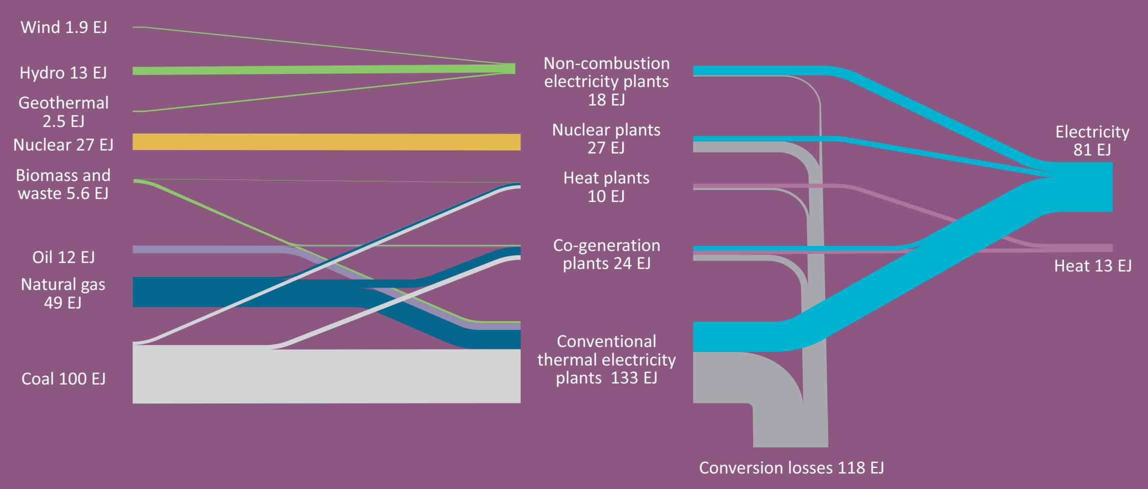
Strategic planning of local, regional and national heating and cooling should be developed to identify cost-effective opportunities to efficiently develop co-generation and expand DHC networks. Policy makers should also facilitate investment in modernising and improving existing DHC networks to make them more energy efficient.

14 Co-generation is also commonly referred to as combined heat and power (CHP). This report uses the term co-generation to refer to the simultaneous generation of heat and electricity.

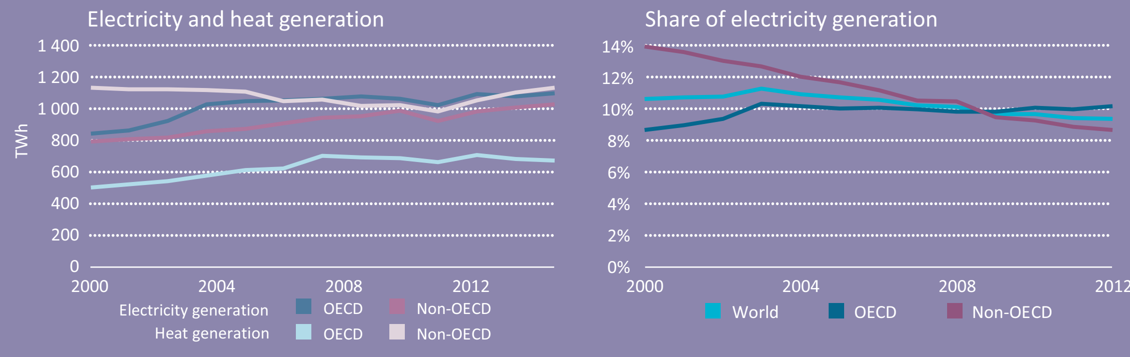
15 Where deep energy renovation or retrofit is defined as a reduction in energy consumption of at least 50% or to not more than 60 kWh/m^2 for building code loads (e.g. space conditioning, water heating and hardwired lighting), (GBPN, 2013).

16 Efficiency for a district cooling system refers to the ratio of final thermal energy provided to primary energy input for generation. These efficiencies can be especially high in the case of systems that use surplus heat and natural cooling sources as inputs.

1.45 Energy flows in global power and heat generation in 2012



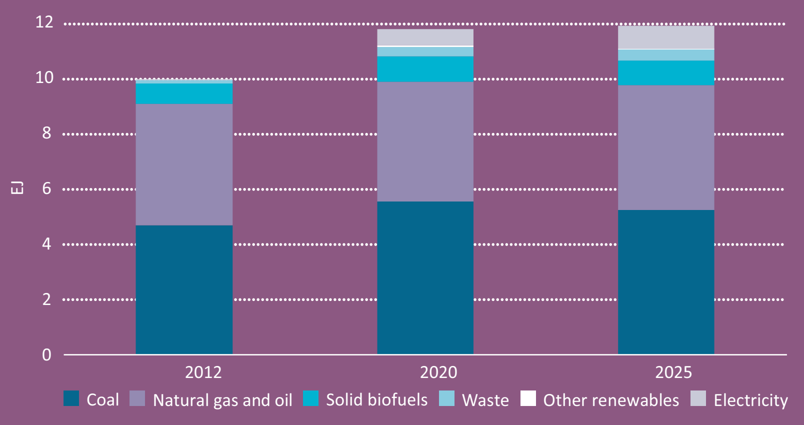
1.46 Co-generation trends



22%

INCREASE IN DISTRICT COOLING CAPACITY FROM 2007 TO 2011 (IN 9 COUNTRIES WHERE DATA WERE AVAILABLE)

1.47 District heating fuel mix



For sources and notes see page 82

Renewable heat

Improvement needed

~ Limited developments

Modern renewable energy use for heat, excluding the traditional use of biomass, continues to grow, albeit slowly. Growth is driven by support policies in key markets, and to an increasing extent by cost-competitiveness with fossil fuel use for heating. However, only around 50 countries have introduced support measures for renewable heat compared with more than 130 with policies supporting renewable electricity.

Recent trends

Renewable final energy use for heat (RE-FEH) accounted for about one-quarter (46 EJ) of world final energy use for heat (FEH) in 2013, with the largest part (32 EJ) still coming from traditional use of biomass in developing countries.[17] Modern renewable energy technologies, such as modern bioenergy, solar thermal and geothermal, accounted for 14.3 EJ of energy use for heat in 2013, up from 12.4 EJ in 2007, an average rise of 2.4% per year. In the buildings sector, modern RE-FEH increased from 4.5 EJ in 2007 to 5.9 EJ in 2013, and now provides 7% of the sector's total FEH. District heating has gained importance for distribution of renewable heat in a cost-efficient manner, and 6% (0.4 EJ) of modern renewable heat in buildings is now supplied through district heating networks.

Modern RE-FEH in buildings is expected to reach 8.3 EJ in 2020 or 9% of FEH in buildings, with China accounting for two-thirds (1.6 EJ) of this growth. If current trends continue, modern RE-FEH could reach around 11 EJ in 2025, but uncertainty over post-2020 policy frameworks in some regions, including the European Union, is likely to undermine growth. In general, the potential for renewable heat remains largely untapped, as many markets with favourable conditions do not have policies that would help overcome economic and non-economic barriers. Subsidies for fossil fuels are an additional challenge for the competitiveness of renewable heating technologies in several countries.

Developments have been slower in the industry sector, where RE-FEH grew by only 0.6% annually since 2007, reaching 7.7 EJ in 2013, roughly 10% of total FEH. Bioenergy accounts for 99% of the total RE-FEH, as solar thermal and geothermal energy remain concentrated in sectors with lower temperature heat requirements. In the absence of specific policy support, RE-FEH in industry is expected to grow only slightly faster at 1.6% per year from 7.7 EJ in 2013 to 8.7 EJ in 2020, almost entirely from a greater use of bioenergy. The share of modern renewable heat in total industrial energy use for heat is expected to decrease from 10% in 2013 to 9% in 2020, mainly because overall energy demand for heat in industry is likely to grow at more than 2% per year. Even if renewable energy use for heat in industry continues to grow along current trends – which is not guaranteed given the lack of policy support – its potential for use in industry would still remain largely untapped in 2025.

Tracking progress

Significant improvement is needed because modern renewable heat does not have significant deployment, yet it could contribute to meeting the 2DS by reducing fossil fuel usage and emissions associated with heat demand. Limited availability and consistency of data on energy use for heat in general and renewable heat in particular prevent a more detailed analysis of the heat sector. Reporting of data and quality of official statistics should be improved by filling existing data gaps (see IEA, 2014h).

Recommended actions

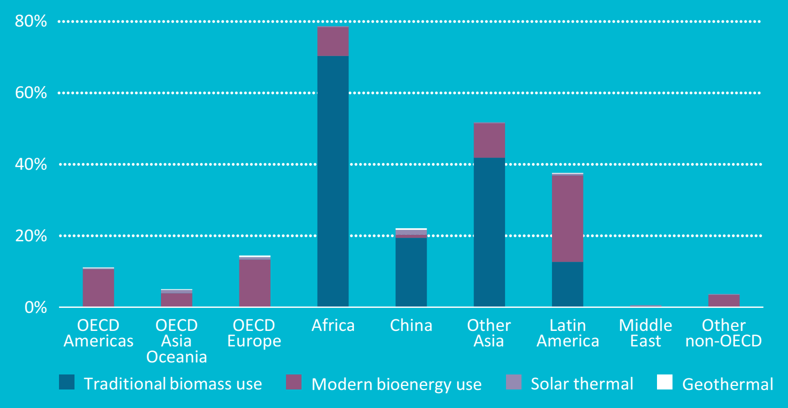
As many renewable heating technologies are already mature, policies should mainly focus on removing non-economic barriers that prevent the deployment of modern renewable heat.

Renewable heat needs to be delivered to consumers in an efficient way. District heating (and cooling) networks can play an important role in enabling enhanced use of renewable energy for heat in urban areas.

To enhance the use of RE-FEH production in industrial processes, further RD&D is needed that reduces costs of renewable heat technologies, including heat storage, so that they can meet the specific needs of different industries in a cost-efficient way.

17 Traditional biomass use refers to the use of fuelwood, animal dung and agricultural residues in simple stoves with very low combustion efficiencies. A decrease in the traditional use of biomass is desired as it is typically associated with indoor pollution and sustainability issues. *See Technology Overview* Notes page 85 for further explanation.

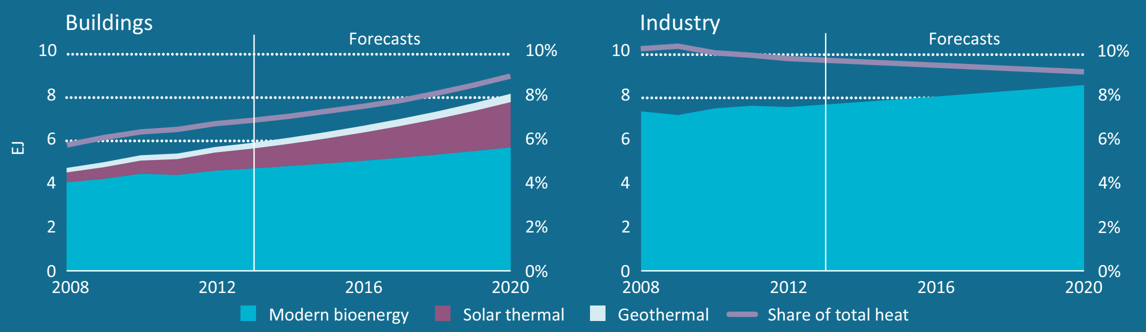
1.48 Share of renewable heat in total FEH



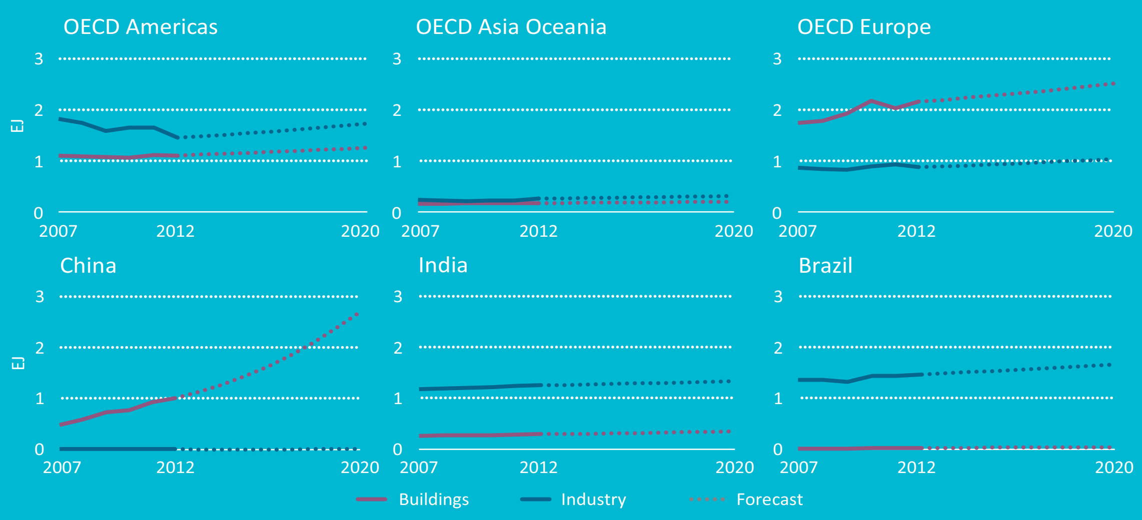
70%

OF GLOBAL RENEWABLE ENERGY USED FOR HEAT IN 2012 CAME FROM TRADITIONAL BIOMASS USE

1.49 Modern renewable energy use for heat by sector



1.50 Modern renewable energy use for heat by region



For sources and notes see page 82

Smart grids

● Improvement needed
~ Limited developments

Smart grids are a key enabling technology for achieving the cleaner energy systems envisaged in the 2DS. Despite false starts and cost overruns deployment of some sub-categories of smart grid technologies has grown quickly in early adopter markets. However, regulatory bottlenecks, and unrealistic expectations are preventing smart grid technologies from reaching the required levels.

Recent trends

As smart grids are involved in system integration, a wide range of factors is driving their development and deployment, not all directly related to clean energy technology. Revenue protection and assurance, as well as reduction of non-technical losses, are driving the adoption of smart meters in many jurisdictions. In many emerging economies, increased efficiency of grid management (including reducing the number and duration of service interruptions) and improved reliability and deferral of investment in reinforcing grid assets are also driving deployment and demonstration. Overall, evidence that some expectations were unrealistic has tempered initial enthusiasm surrounding smart grids – and yet benefits have been realised from advanced metering infrastructure and distribution automation. Distribution automation, in particular encompassing measures to enhance monitoring, control and directionality, is proving to be the fastest-growing technology sub-category. Global investments rose by 23% from 2013 levels, and inventive activity accelerated.

Last year China overtook the United States in annual investment in smart grid technologies. China has one of the world's highest rates of electricity service interruption; growth in smart grid investment reflects the increasing importance of revenue protection and system efficiency and reliability as drivers for these technologies, particularly in emerging economies. Smart meters are perhaps the easiest technology deployment to track: China dominated the meter market in 2013 by installing 62 million meters and now accounts for almost two-thirds of global installations. Deployment of smart grid technologies in the United States slowed significantly from 2013 to 2014 as stimulus funding lapsed, uncertainty persisted over clean energy policy and markets experienced some degree of saturation. In Europe, following rapid deployment in Spain and other initial markets, policy drivers are expected to push smart meter installations from the current 55 million per year to an estimated 180 million in 2020, led by France, Germany and the United Kingdom.

Beyond the deployment of advanced physical network infrastructure, investments in ICT solutions are expected to increase dramatically over the next five years. As changes in market arrangements allow demand response to benefit from wholesale and capacity market payments, ICT solutions showing the benefits of aggregating consumers at the distribution level are being piloted in Japan, Korea and the United States, with an aggregate consumer base of 6.5 million.

Tracking progress

Globally, annual smart grid investments reached USD 14.9 billion in 2013, 5% more than in 2012. The positive trends in distribution automation reflect the future "system of systems" vision for electricity networks envisaged in ETP 2014. As the replacement cycle of the first wave of smart meters begins, investment is expected to accelerate again. Data availability precludes a more complete picture of smart grid deployment.

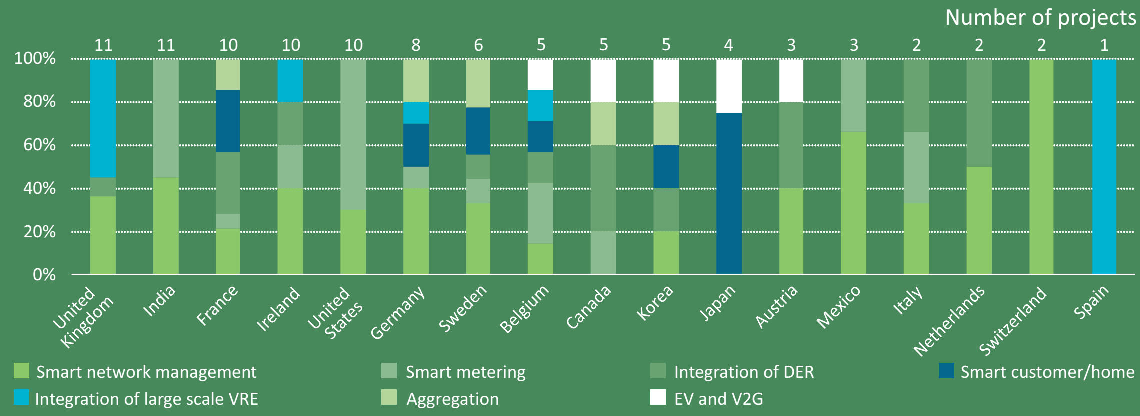
Recommended actions

Smart grid deployment strategies need to be centred on customers and business models. This calls for demonstrating and developing national strategies that articulate the benefits of smart grids to stakeholders.

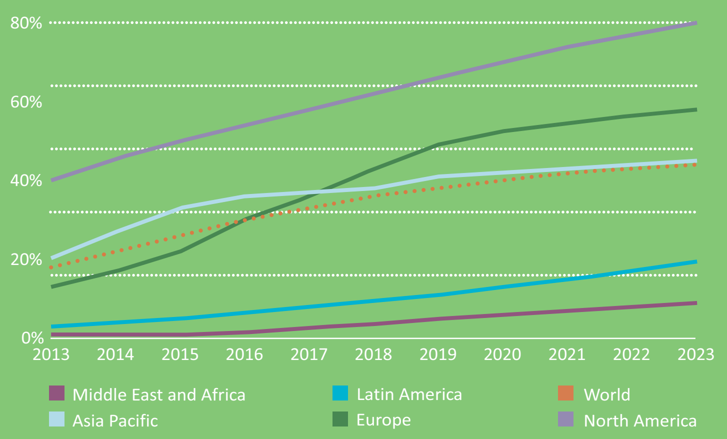
For system operators and utilities, key concerns are technology obsolescence, interoperable technology and system security. Consequently, transparent regulation that allows cost-reflective investment in advanced distribution network technologies will be required for sustained market development.

As electricity markets increase harmonisation of operation in several regions, international standards for underlying infrastructure need to be developed in parallel, in particular to accelerate RDD&D. Methodologies for quantifying the benefits of smart grids (e.g. reductions in duration or frequency of service interruptions) also need to be standardised.

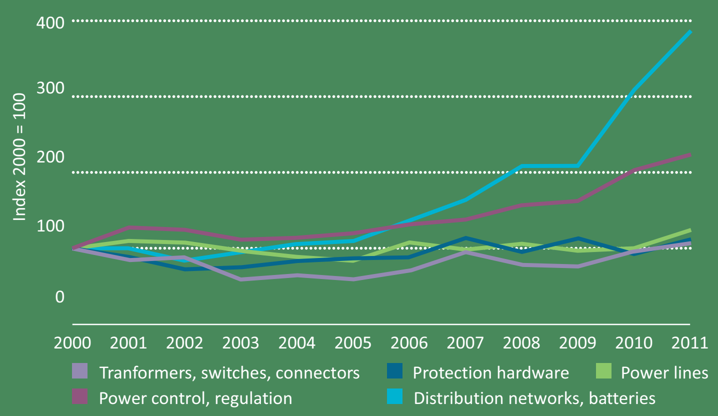
1.51 Sample projects by technology area



1.52 Smart meter penetration in key regions



1.53 Grid technology inventive activity



Deployment drivers

Emerging economies

1. Reliability
2. System efficiency
3. Revenue collection and assurance
4. Renewable power
5. Economic advantages
6. Generation adequacy

Developed economies

1. System efficiency
2. Renewable power
3. New products, services and markets
4. Customer choice and participation
5. Reliability improvements
6. Asset utilisation

For sources and notes see page 82

Energy storage

● Improvement needed
↗ Positive developments

Storage is expected to contribute to meeting 2DS targets by providing flexibility to the electricity system and reducing wasted thermal energy. The current outlook for energy storage is promising, but the high capital costs of storage technologies remain a barrier to wide deployment.

Recent trends

Large-scale energy storage capacity was over 145 GW in 2014, of which over 97% was accounted for by pumped hydro storage. While this total includes 2.4 GW of grid-connected thermal energy storage, the actual value is likely to be significantly higher, as thermal energy storage technologies not connected to networks are particularly difficult to capture in global statistics.

Rapid deployment of wind and solar PV energy in several countries has led to integration challenges and the need for more flexible resources, including storage. Between 2005 and 2014 there was a sharp increase in the deployment of large-scale batteries (from 120 MW to 690 MW) and thermal energy storage (from 250 MW to 2 420 MW).

Costs for large-scale batteries have shown impressive reductions, thanks in part to ambitious EV deployment programmes and greater demand for frequency regulation, spurred in some cases by variable renewables deployment. Large-scale batteries are particularly well suited to respond to additional demand for ancillary services. The cost of a lithium-ion battery for grid-scale storage for frequency regulation has shown the largest decline, falling more than three-quarters since 2008 to reach about USD 600/kWh in 2013 (Fernands, S., 2014). This cost reduction was accompanied by a 250% increase in the cycle life times of these batteries, from 2 000 cycles in 2008 to 5 000 in 2013.

As deployment of variable renewables continues to rise, the demand for energy storage technologies is also expected to grow. A wide range of forecasts exists for the deployment of large-scale battery energy storage over the next decade, from just over 11 GW (BNEF, 2014a) in 2020 to 40 GW (IHS, 2014) in 2022, while the potential manufacturing capacity that could be delivered is as high as 130 GW (AES Storage, 2014) in 2024.

Many governments have been supporting energy storage technologies through policies including funding for demonstration projects, subsidies for small-scale storage with PV and mandatory storage requirements for utilities. One such requirement introduced in California requires investor-owned utilities to procure 1 325 MW of energy storage by 2022. Recent action in the United States (FERC Orders 755 and 784) reveals how a market-based approach can accelerate deployment by allowing companies other than large utilities to sell ancillary services in the electricity market and by requiring operators to compensate for frequency regulation.

Tracking progress

Energy storage can contribute to meeting the 2DS, but high costs remain an obstacle to wider deployment, so improvement is needed. More work should be undertaken to improve the quality of statistics and fill existing data gaps.

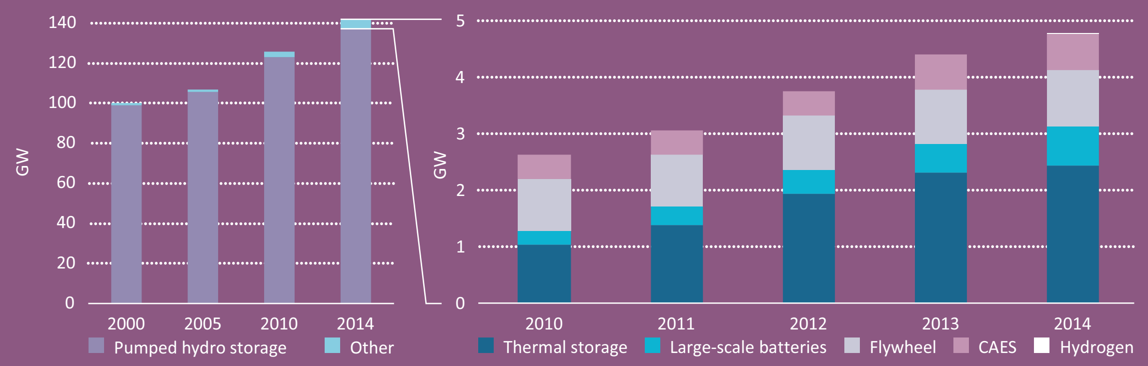
Recommended actions

Investments are required in R&D for early-stage energy storage technologies. Technology breakthroughs are needed in high-temperature thermal storage systems and scalable battery technologies, as well as in storage systems that optimise the performance of energy systems and facilitate the integration of renewable energy resources.

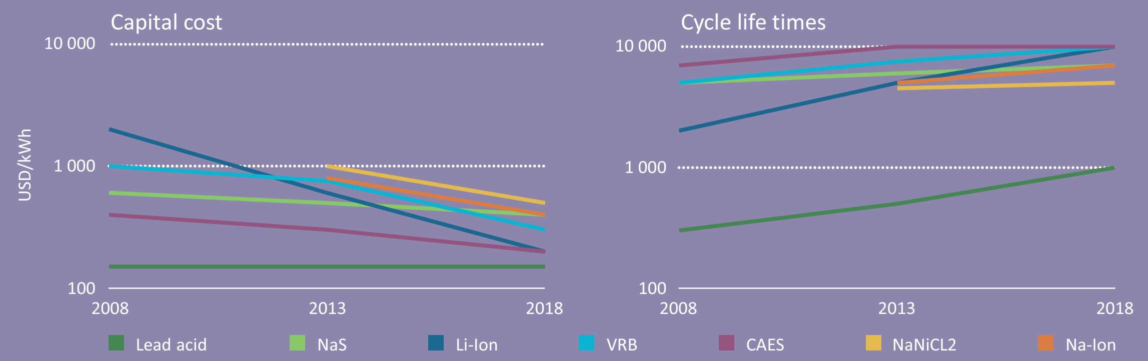
It is vital to develop marketplaces and regulatory environments that accelerate deployment of energy storage technologies. Price distortions need to be eliminated and benefits staking enabled to allow energy storage systems to be compensated for providing multiple services over their lifetime.

Policy makers need to support assessments of the value of energy storage in specific regions and energy markets. They should also promote the development and adoption of tools devoted to evaluating energy storage project proposals.

1.54 Installed capacity for grid connected storage



1.55 Grid-scale battery storage for frequency regulation



1.56 Thermal energy storage capacity

807

GW OF SOLAR THERMAL ENERGY INSTALLED GLOBALLY (566 IN CHINA, 155 IN THE EUROPEAN UNION)

31 780

ICE OR WATER STORAGE PLANTS IN JAPAN WITH A TOTAL CAPACITY OF 1.91 GW

THREE PIT-HEAT WATER STORAGES OF

13

GW INSTALLED IN DENMARK

550

UNDERGROUND THERMAL ENERGY STORAGE UNITS INSTALLED IN SWEDEN WITH A CAPACITY OF 290 MW. 100 UNITS IN BELGIUM WITH A CAPACITY OF 13.6 MW AND A 0.6 MW PLANT IN DENMARK

For sources and notes see page 82

Hydrogen and fuel cells

Improvement needed
~ Limited developments

Hydrogen is a flexible energy carrier with potential applications across all end-use sectors. It is one of only a few potential near-zero-emission energy carriers, along with electricity and biofuels. Hydrogen is most suitable for the storage of large quantities of energy over a long time, such as low-carbon electricity, or small quantities under restricted space and weight requirements, which makes it a promising fuel for low-carbon transport.

Recent trends

Around 8 GW of electrolysis capacity is installed worldwide, accounting for around 4% of global hydrogen production (Decourt et al., 2014). Alkaline electrolysers are the most mature technology and are already commercially available, while proton exchange membrane (PEM) and solid oxide electrolysers have higher potential for cost reductions and efficiency improvements. Electrolysers are highly modular systems, which makes the technology very flexible in terms of output capacity but also limits the effects of economies of scale, as even big electrolysers are based on identically sized cells and stacks.

According to the US DOE *2013 Fuel Cell Technologies Market Report* (US DOE, 2014a), between 2008 and 2013 the global market of fuel cells (FCs) grew by almost 400% (shipped units), with more than 170 MW of FC capacity added in 2013. Currently, more than 80% of FCs are used in stationary applications, such as FC micro co-generation, back-up and remote power systems. While the United States ranks first in terms of added FC power capacity, Japan ranks first in terms of delivered systems, due to the successful upscaling of the Japanese EneFarm micro FC co-generation system.

Globally, around 600 FCEVs are running in demonstration projects. Since driving performance of FCEVs is comparable to conventional cars and refuelling time is about the same, FCEVs can provide the mobility of conventional cars at potentially much lower carbon emissions. Some manufacturers have announced pre-commercial market introduction of FCEVs at prices of USD 60 000 to USD 100 000. Costs of the FC system are the main reason for high vehicle prices. According to the US DOE, costs of PEM FC systems for mobile applications could be significantly reduced if large-scale production processes were initiated and theoretic production costs materialised. Announced plans for FCEV market introduction range from a few thousand vehicles in the near future up to several hundred thousand by 2025.

Overcoming the "chicken and egg" problem is the biggest barrier for larger deployment: FCEVs require hydrogen stations. Currently, around 80 stations are in operation worldwide. Ambitious plans envisage the installation of around 800 hydrogen stations worldwide by 2020, clustered around early development centres and along main connecting corridors to refuel the first commercial generation of FCEVs.

Tracking progress

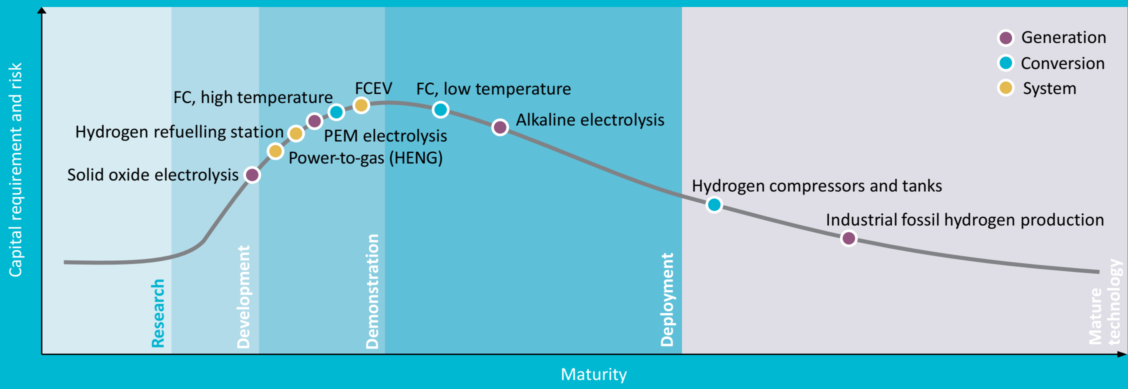
Although many hydrogen and FC technologies are still in the demonstration phase, some are close to early adoption, such as FCEVs and PEM electrolysers. FCEVs now have to demonstrate their economic viability as deployment grows beyond several hundred vehicles in demonstration projects and niche market applications such as materials handling.[18] Similarly, the use of PEM electrolysers at capacities of several megawatts, to generate hydrogen from otherwise curtailed low-carbon electricity, needs to be brought forward to finally prove the economic feasibility of large-scale and long-term energy storage systems and power-to-gas systems.

Recommended actions

To foster the uptake of hydrogen as an energy carrier, it is imperative to sustain RD&D, for transportation and stationary applications as well as for hydrogen storage, production and delivery. To accelerate deployment, codes and standards need to be developed and harmonised; policies and incentives such as fuel economy regulations and tax credits for low-carbon vehicles need to be strengthened; and refuelling and recharging infrastructure needs to be put in place. Further support is needed for research that quantifies benefits and challenges of energy system integration, to enable better understanding of the application of hydrogen technologies in a broader energy system context.

18 The largest part of FC units shipped in the transportation sector is currently composed of FC forklifts.

1.57 Maturity of hydrogen technologies and systems



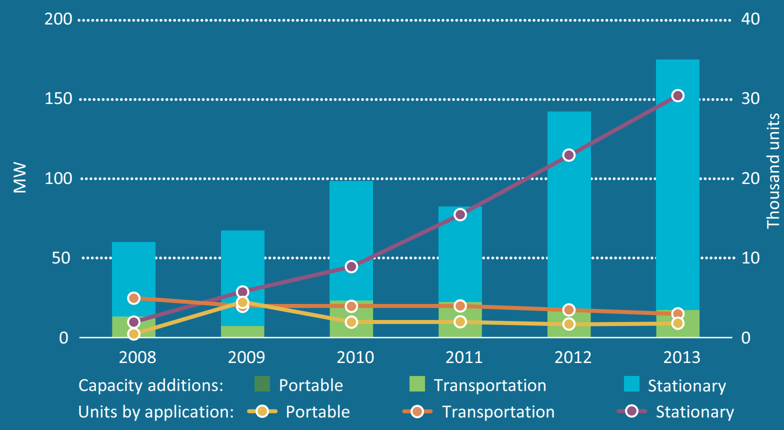
85

EXISTING HYDROGEN STATIONS IN EUROPE, JAPAN, KOREA AND CALIFORNIA

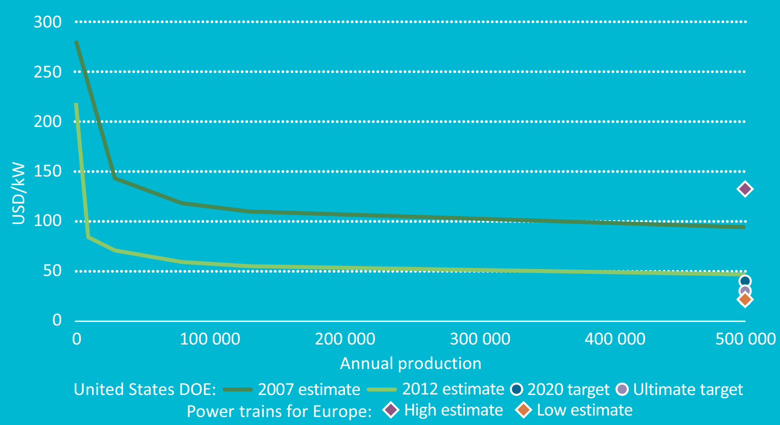
800

PLANNED TO 2020, ALMOST TEN TIMES THE EXISTING NUMBER OF STATIONS

1.58 Market development for fuel cells



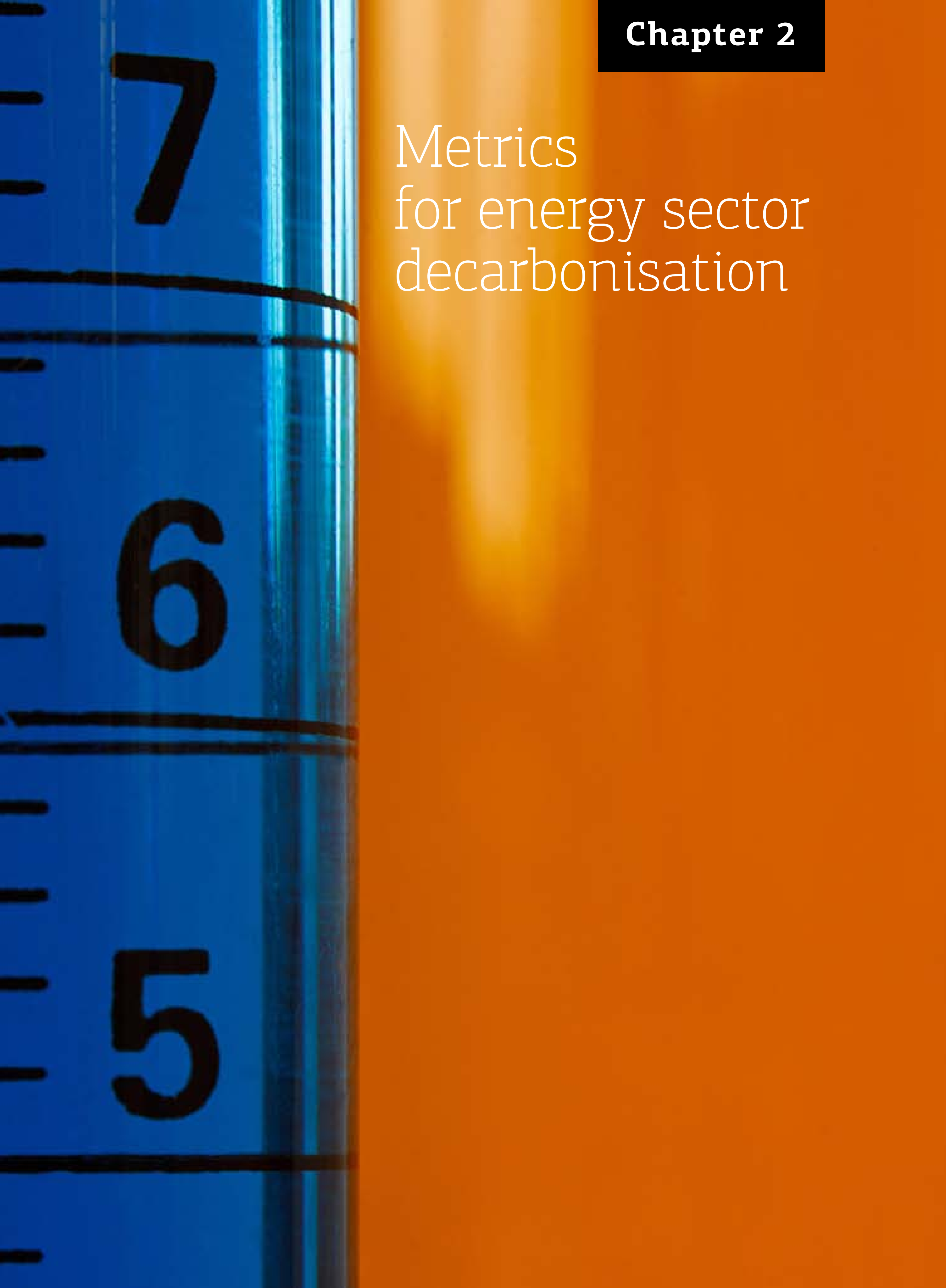
1.59 Production costs for PEMFCs for transport



For sources and notes see page 82

Chapter 2

Metrics for energy sector decarbonisation



Metrics for energy sector decarbonisation

National commitments on climate change are likely to include actions in the energy sector with both near-term and longer-term impact. A diverse set of energy metrics will be required to identify potential and track progress against a range of nationally determined mitigation goals.

Key findings

- Energy metrics can be used to identify potentials and set ambitious yet realistic national targets for emissions reduction. They can be used to inform the development of Intended Nationally Determined Contributions (INDCs), as well as to monitor progress on climate change action.
- Decarbonisation of the electricity sector will need to accelerate over the next decade to reach 2DS targets. By 2020 the average lifetime emissions intensity of all new-build plants in China, India and the United States will need to fall to levels near half that of current gas-fired plants or about one-third of the current global emissions intensity of power generation. In the European Union, the average new-build plant is nearly decarbonised by 2020.
- Technology-specific indicators to track progress on development and deployment should be complemented by sector-specific metrics in the power, buildings, industry and transport sectors. These metrics will cover both energy supply and energy demand indicators.
- IEA work in energy statistics and indicators, technology tracking, and energy sector modelling can contribute to the development of metrics and tracking frameworks for energy sector decarbonisation, either inside or outside the UNFCCC process.

Opportunities for policy action

- Sector- and technology-specific energy sector metrics should be identified at the country level, to underpin the development and tracking of ambitious and achievable national energy sector decarbonisation strategies.
- Concerted efforts should be made to scale up data collection and development of metrics in countries where lack of data poses a significant barrier to setting targets, meeting targets, and measuring progress in energy sector transformation.
- Governments should support the collection of detailed end-use energy data and the development of energy efficiency indicators that can be used to identify energy efficiency potential, monitor trends in energy use and monitor progress on policies.
- Energy metrics should be used in the UNFCCC process to track energy-framed INDCs (such as renewable energy targets), and also to track the underlying drivers of long-term decarbonisation.

The previous sections of this publication track progress of key technologies for energy sector decarbonisation at the global level. This section shifts the focus to individual countries, and discusses different types of metrics that could be useful to track progress on national actions towards energy sector decarbonisation. It illustrates how a series of energy sector-specific indicators could be used to set national targets and track progress.

Setting and tracking decarbonisation goals is of key importance in the international climate change negotiations process. A new climate agreement will be negotiated under the UNFCCC by the end of 2015 and come into effect from 2020. Parties to the UNFCCC will communicate their intended mitigation goals and actions for this new climate agreement during 2015. These INDCs will cover a diverse range of measures, including targets for GHG levels in the 2020-30 time frame and long-term GHG targets for 2050 or beyond. As the energy sector produces two-thirds of global GHGs, countries could also commit to specific goals and actions aimed at decarbonising the energy sector.

The choice of metrics used to set goals and track progress matters a great deal. First, understanding and accurately tracking all countries' actions, whether in terms of GHGs or specific energy metrics, will be critical to building the mutual trust that a successful international climate regime will rely on, as well as understanding the aggregate impact of all countries' efforts. Second, the choice of metrics used to express climate goals can itself have an influence on what decarbonisation actions countries choose to take, and the ambition of these efforts.

Choosing the right metrics for energy sector decarbonisation

In preliminary discussions on the 2015 climate agreement, it is becoming clear that a range of nationally determined mitigation goals, tracked via a variety of metrics, could be included in addition to short- and long-term GHG targets. Tracking a wider range of metrics would also help countries to better understand opportunities for action and associated benefits, and thus drive energy sector transformation in a more targeted manner in the short term. For countries with GHG goals for 2050 or beyond, a basket of energy sector metrics will be needed to understand whether energy infrastructure shifts and development of key technologies are on track. There are therefore many reasons that countries may be motivated to use energy sector goals and metrics, alongside and to support GHG emissions reduction goals (Prag, Kimmel and Hood, 2013):

- **Energy sector metrics can link more directly to policy influences.** Short-term total annual GHG emissions can vary for many reasons, including changing economic conditions, fuel prices and weather. Targets that are more closely linked to policies under the control of government (for example, a mandated share of renewable electricity generation) may be easier to adopt, as outcomes are more easily influenced or directed by policy, and decision makers can have more confidence that targets can be delivered.
- **The primary purpose of energy sector policies is often not emissions reduction.** Clean energy policies are implemented for a wide range of reasons and often have multiple benefits, of which emissions reduction is only one. For example, energy efficiency interventions can have benefits for energy security, health and well-being, industrial productivity and competitiveness, energy providers, energy consumers, public budgets, and macroeconomic outcomes, including jobs (IEA, 2014a). A focus on GHG outcomes that ignores wider benefits could result in less ambitious action.

- **Different metrics can reframe the challenge positively.** In the UNFCCC negotiations, emissions reduction has historically often been framed as a burden to be shared among countries. This sends the message that while action on climate change is necessary, it will be an economic burden. Discussions on the 2015 agreement are instead seeking to frame climate action positively, as an opportunity to be seized. Use of alternative metrics that express positive attributes (for example, improving GDP per unit of energy input, or increasing clean energy production) can help change the communication and perceptions of climate goals.
- **Alternative metrics can highlight short-term actions that underpin long-term transformation.** To date, most GHG reduction goals have short-term (five- to ten-year) targets.[1] This encourages implementation of the least-cost measures for short-term emissions reduction, which are not necessarily the same actions that would be cost-optimal from the perspective of long-term transformation. Tracking actions underpinning long-term transformation, such as lock-in of infrastructure and development of key technologies, would complement short-term GHG goals.

There is a wide range of metrics that could be used to track countries' energy sector climate goals (IEA, 2014b). In general, these will include metrics of the following types:

- **Metrics expressed in GHG terms,** such as total annual GHG emissions or emissions per unit of GDP or production, whether economy-wide, for the energy sector or disaggregated by sub-sector. These metrics capture the aggregate climate outcome of all energy sector actions. Under the UNFCCC, countries report national GHG inventories as part of the biennial reporting process.
- **Metrics expressed in non-GHG terms,** but which are nonetheless likely to have an impact on short- to medium-term GHG emissions levels. This category would include many energy sector metrics such as those used to track energy efficiency, renewable energy and other low-carbon energy deployment goals. Using such metrics can result in goals linked more closely to national priorities and available policy levers. Some high-level metrics of this type can be derived from GHG inventory data, but many will need additional data collection, and national capacity to collect and analyse specialised data.
- **Metrics that track actions with a significant impact on long-term emissions,** but minimal impact on short- to medium-term emissions (i.e. pre-2030). These would include tracking R&D of key technologies such as CCS, advanced vehicles, or infrastructure investment trends that lead to either decarbonisation or the lock-in of high-emissions infrastructure. Choosing metrics that capture progress towards long-term decarbonisation goals relies on capacity to collect and analyse relevant data, and on modelling capacity to understand countries' potential decarbonisation pathways.

A distinction can also be drawn between metrics that track the outcomes of policy (e.g. energy consumption per GDP), and metrics that track the drivers of emissions reduction (e.g. retrofit rate of existing buildings). These play complementary roles: *outcome* metrics are important to understand overall progress after implementation, while *driver* metrics give a more direct understanding of the transition pathway required and the consistency of current actions with the desired goals.

Summing up the parts: Energy sector decarbonisation metrics

To enable a more holistic or integrated view of trends in the energy sector, high-level indicators such as the IEA Energy Sector Carbon Intensity Index (ESCII) and the commonly used energy intensity indicator (total energy use per GDP) offer a starting point and can

1 Long-term carbon budgets, for example those in UK legislation, are the exception rather than the rule.

be developed at the global and country levels.[2] More detailed metrics at the sector level should also be developed to identify energy efficiency and emissions reduction potentials, and to enable comparisons among countries so that effective policies and measures can be identified. The sum of these individual metrics can help to better identify potential pathways for decarbonising the energy sector and aid countries in setting ambitious yet realistic energy and climate targets in line with their national circumstances.

The most appropriate set of metrics (or indicators) to evaluate and monitor progress in the energy sector towards nationally determined mitigation goals will vary from country to country, depending on local conditions, energy use trends, data availability and national targets. In addition to the ESCII and emissions intensity for the energy sector as a whole, these metrics should cover at least the four main sectors of power, buildings, industry and transport. The set should include measures of energy supply and demand, and both outcome and driver metrics. While some metrics are more comprehensive and refined than others, it is important to underline that no single metric can fully portray a country's progress towards a decarbonised and efficient energy system; an integrated assessment incorporating the most relevant indicators should be used. Where data are available, countries should strive to track progress using sub-sector, energy end use or equipment or technology indicators. In other cases, countries could use sectoral indicators until sufficient data are available to develop higher-level indicators.

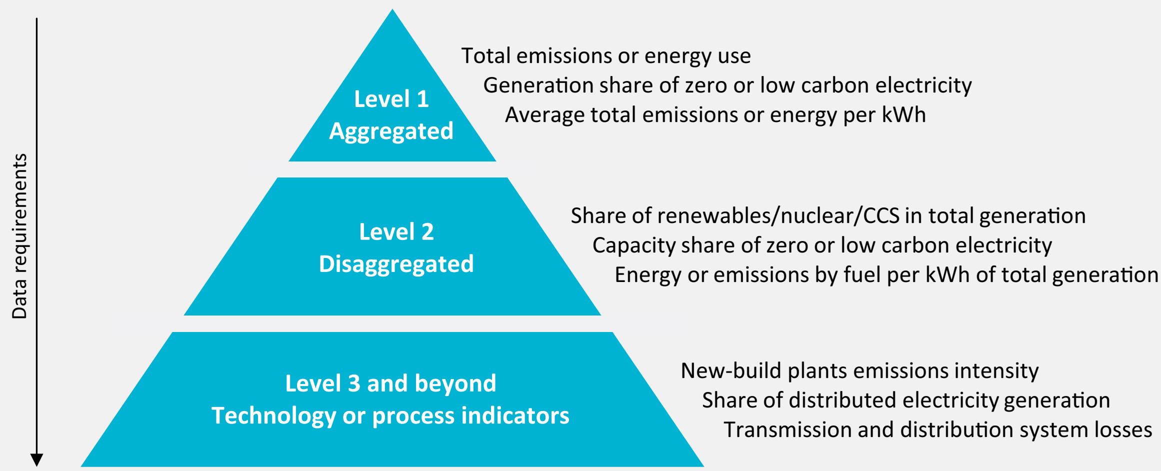
Role of electricity decarbonisation: A supply-side example

Electricity generation accounts for 25% of all global GHG emissions and almost 40% of all energy-related CO_2 emissions, as well as 38% of total primary energy (IEA, 2014c), so it is vital that the sector move from carbon-intensive fossil fuel-fired power to low-carbon options.

To evaluate progress and trends in the power sector comprehensively, technology-specific metrics for tracking progress on renewables, nuclear, efficient fossil fuel-fired power plants and CCS should be combined with sector-specific metrics such as average emissions per kilowatt hour produced and share of zero- or low-carbon electricity (Figure 2.1). These two metrics provide an overall picture of trends in the CO_2 intensity of electricity generation and can be categorised as overall energy supply sector (level 1) metrics. Additional indicators such as capacity deployment and generation of low-carbon generation or shares of specific renewables, nuclear or CCS deployment can be categorised as sub-sector (level 2) metrics and can help countries to identify the mix of technologies needed to avoid lock-in of carbon-intensive power generation. Where possible, technology-rich power sector modelling and scenario development (such as the IEA 2DS and techno-economic TIMES model) should be used to identify potential pathways for decarbonising the electricity sector and end-use sectors. Such tools require detailed resource assessments and electricity demand profiles that may not yet be available in all countries, so the first step may be to develop such assessments and profiles. Indicators at the more disaggregated technology or equipment level (level 3), covering electricity transmission and distribution or new-build plants emissions intensity, could also be developed.

2 Total carbon intensity of the energy mix (ESCII) and energy intensity, as well as GDP per capita and population constitute the four high-level Kaya identity factors.

Figure 2.1 Power sector decarbonisation metrics



Notes: These metrics are intended for illustrative purposes and not to be a definitive list. Levels do not indicate importance of a given metric. Figures and data that appear in this report can be downloaded from www.iea.org/etp/tracking.

Key point *A conceptual structure of an indicators pyramid portrays a hierarchy of energy indicators from most aggregated (top) to detailed indicators with significant data requirements.*

The combination of low-carbon power generation technologies each country needs will depend on the country's current generation mix, available national resources, the maturity of its generation assets, the state of its electricity grid, expectations of electricity demand growth, electricity demand profile, resource endowment, energy prices and public acceptance of various low-carbon technologies. Countries should take these factors into consideration when setting targets and monitoring progress.

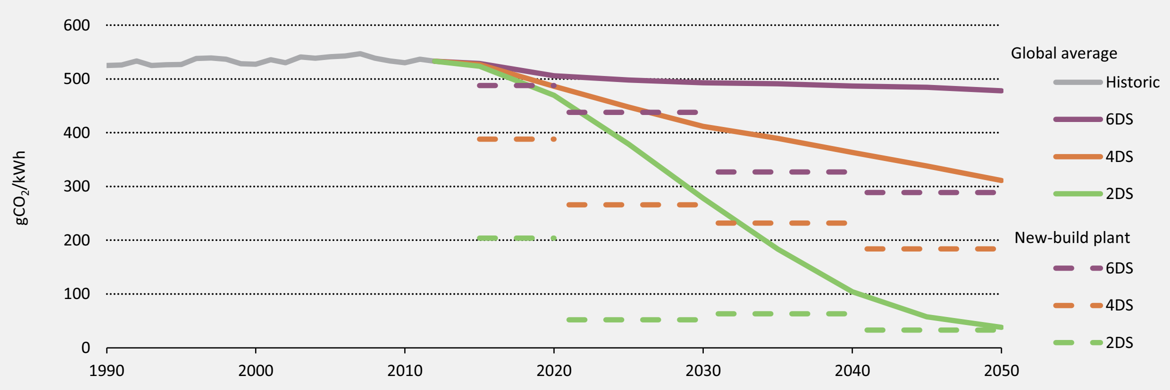
Metrics to help avoid power sector lock-in

Metrics can translate long-term goals into short-term actions consistent with that goal. To avoid locking in high-emissions infrastructure, it is vital to articulate what kind of short-term investments are consistent with long-term pathways that limit warming to 2°C, and to track progress in these investment patterns. For example, the average emissions intensity of new investments in power generation could be tracked and compared with the global fleet average emissions intensity to track what is consistent with a 2°C pathway (Figure 2.2).

To achieve the sharp decline in the average fleet-wide emissions intensity[3] of power generation needed to meet the 2DS, the average global emissions intensity of new generation[4] must be lower than that of natural gas or about one-third of current global levels in the period to 2020, and only 10% of today's levels after 2020 (Figure 2.2). Achieving this global 2DS target will require deeper reductions in emissions intensity in some regions than others; further details on these pathways are elaborated below for China, the European Union, India and the United States.

3 Fleet-wide average emissions refer to CO_2 intensity across all operating plants, irrespective of their age.
4 The lifetime emissions intensity of a new investment is calculated by dividing the modelled emissions generated by these plants by their total generation in each scenario over the lifetime of the plant over the model horizon up to 2050. High-efficiency coal plants will be later retrofitted for CCS and hence lead to relatively low lifetime emissions intensity.

Figure 2.2 **Global fleet average and new-build plants emissions intensity of power generation in IEA scenarios**



Key point *To achieve the sharp decline in fleet-wide emissions intensity in the 2DS, the average emissions intensity of new generation must be lower than that of natural gas by 2020 and only 10% of today's levels after 2020.*

A metric that tracks the expected lifetime emissions intensity of new investment in power generation would therefore be a useful addition to current measures of fleet-average parameters. Expected lifetime emissions from new plants could be reported based on emissions intensities, expected running hours and expected plant lifetime. Including plans to retrofit for CCS in these estimates would also focus greater attention on the need for timely development of CCS technologies.

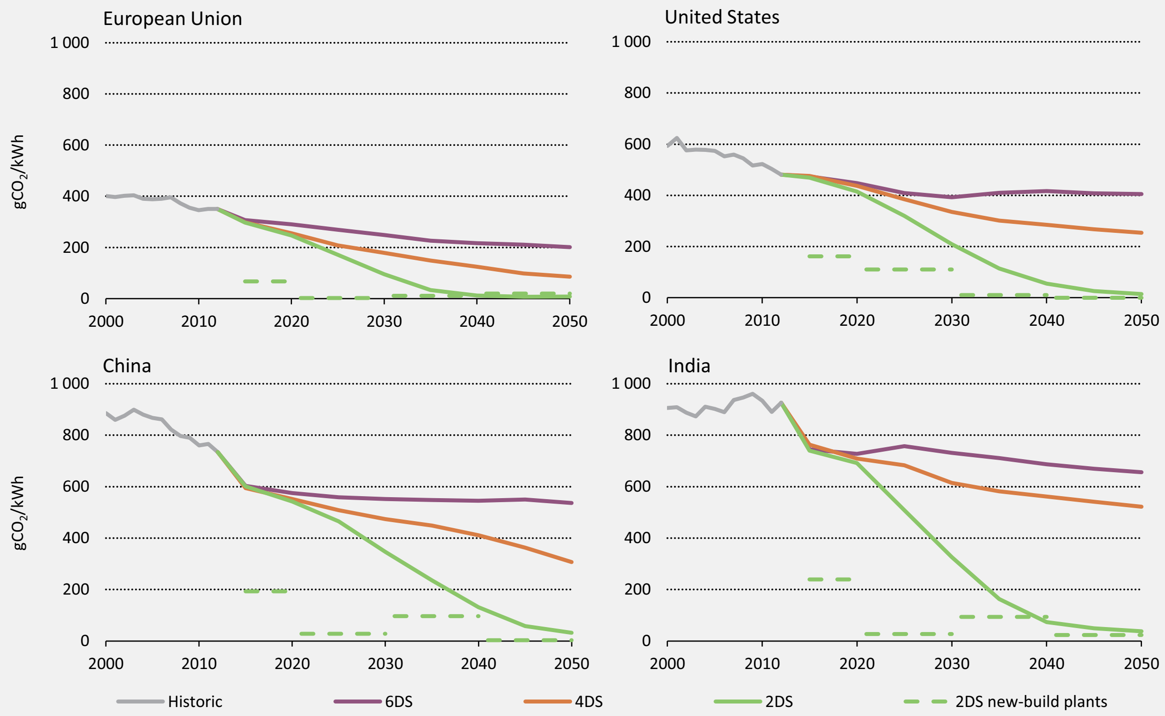
New-build plants emissions intensity could also be tracked by considering investment spending, rather than capacity or generation. In the 2DS, from 2020 to 2030 around 85% of global investment in new generating capacity needs to be in non-fossil fuel or CCS-equipped plants (IEA, 2014f).

The analysis above can be applied at the national/regional level to help inform investment decisions and better understand their long-term impact on emissions. Using the 2DS, electricity sector metrics at the national/regional level have been identified for China, the European Union, India and the United States (Figure 2.3). These four economies account for approximately 60% of total electricity production, which is expected to rise to 85% by 2050, so it is crucial for them to take early action to reduce global energy-related emissions.

The average CO_2 intensity of electricity generation has fallen since 2000 in all of these economies except India. China and the United States have reported the largest drops. Policies to phase out inefficient coal plants and wider deployment of wind and solar power helped to cut emissions intensity by 17% in China between 2000 and 2012. The development of cheap shale gas in the United States triggered a switch from coal to gas-fired generation that lowered average emissions intensity by 19%.

In the European Union, reductions in emissions intensity have been more modest as policies to phase out nuclear power, combined with ongoing use of coal, have partially offset rapid expansion of renewable generation. Since 2000, the emissions intensity of electricity generation in India has risen slightly (by 2%) because rapid growth in electricity demand has been mainly satisfied by subcritical coal plants and because existing coal capacity is ageing and poorly maintained.

Figure 2.3 Power sector fleet average and new-build plants emissions intensity



Key point *Emissions intensities of new-build plants should be lower than natural gas-fired power generation (350 gCO_2/kWh) by 2020 and reaching near decarbonisation levels by 2030.*

In all regions and in all scenarios, the average emissions intensity of power generation is expected to decline as more low-carbon electricity sources are deployed. Only the 2DS, however, describes a more dramatic transformation, in which in all four regions by 2020 the average emissions intensity of new-build plants needs to be well below that of gas-fired power generation (350 gCO_2/kWh) and reaching near decarbonisation levels by 2030 (less than 30 gCO_2/kWh in all regions but the United States). To achieve the sharp decline in the average intensity of power generation in the 2DS, a significant share of unabated coal-fired power will need to be retired or retrofitted with CCS, in addition to the deployment of low-carbon generation.

In China and India, where electricity production is dominated by coal-fired plants, demand for electricity continues to rise with economic development and increased living standards. In the 2DS, these countries still deploy significant shares of fossil-fueled plants over the next decade, but mainly highly efficient coal plants that later will be retrofitted with CCS; together with low-carbon power generation such as renewables and nuclear, this helps to reduce the average intensity of new-build plants. After 2030, electricity demand growth will level off in China and the costs of low-carbon generation technologies will be more competitive. The average intensity of new-build plants in China and India will need to converge to near decarbonisation, reaching levels similar to those in the European Union. In 2040, the emissions intensity of new-build plants increases in China and India because of the need to replace older fossil plants used for peaking and to meet flexibility requirements from high shares of variable renewables.

While decarbonising electricity may be considered the most important supply-side measure, it is not the only one. Options to replace the use of fossil fuels in the end-use sectors are also important and are highlighted in later sections, as are measures in the oil, gas and coal industry to improve efficiency and reduce emissions.

Benefits and role of early action on energy efficiency

While decarbonising the energy supply will be central to achieving ambitious emissions reduction targets, countries will also need to take action to reduce or limit growth in energy demand. The importance of energy efficiency in reducing emissions is undisputed, yet progress on implementing energy efficiency measures continues to remain off track. In some countries this is due to insufficient understanding of where energy is used and where the largest potential exists for reducing energy consumption. All countries need to understand their consumption by end use and to be able to track these changes over time. The development of energy efficiency indicators at sector, sub-sector, energy end use or technology level (levels 2, 3 and beyond) that track trends in energy use can help countries to identify energy savings potentials and priorities, as well as developing more effective energy efficiency policies.

Where detailed energy end-use data is available (e.g. for water heating or for production of ammonia), countries should aim to track energy efficiency at the sub-sector, end use or technology level (levels 2, 3 and beyond in Figures 2.4, 2.5 and 2.6). In countries where limited data are available, sectoral level indicators (e.g. energy use in the residential sector per capita) can be used as a proxy to monitor energy efficiency trends until data collection systems allow more comprehensive evaluation (level 1 in Figures 2.4, 2.5 and 2.6). The two IEA energy efficiency indicator manuals describe in detail how to develop and use such indicators (IEA, 2014d; 2014e).[5]

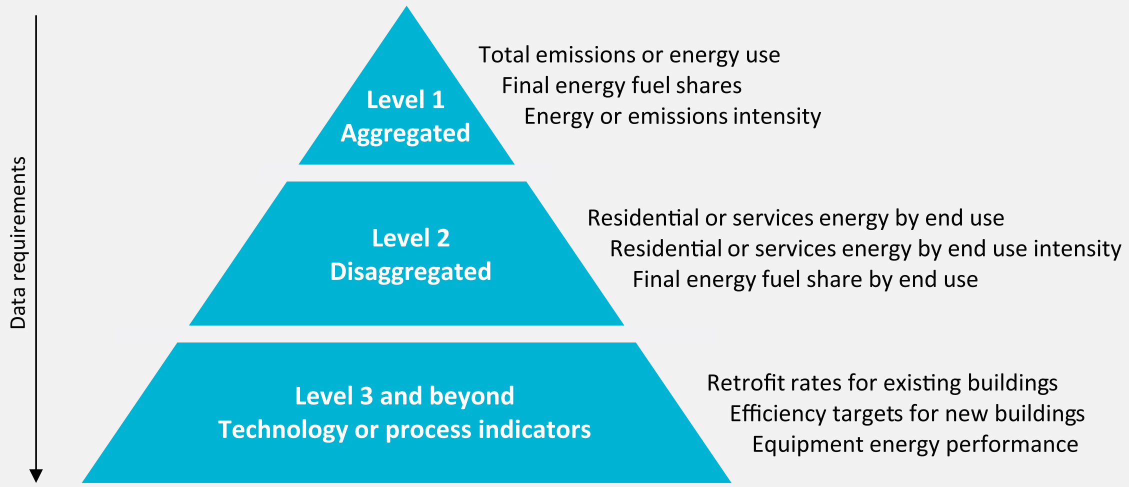
Energy efficiency indicators are considered *outcome* metrics and should be combined with *driver* metrics that can determine long-term emissions trajectories. In the buildings sector, driver metrics include rates of implementation for deep renovation or stringent building codes for new buildings. In the transport sector, driver metrics include vehicle fuel economy standards or deployment of advanced vehicles such as EVs or FCEVs. The following section highlights possible metrics for the three largest energy demand sectors: buildings, industry and transport. Relevant countries could also develop metrics for energy use in agriculture and other transformation sectors (e.g. refineries).

Sustainable buildings: Residential and services energy use and emissions
Metrics to monitor trends in energy use and emissions in the buildings sector should include energy efficiency indicators for the residential and services sector as well as overall buildings energy and emissions intensity. Such measures need to cover both energy demand and energy supply. For countries where limited data are available, sectoral indicators such as building energy consumption per capita or share of renewables in buildings provide a starting point (level 1 in Figure 2.4). Where the necessary end-use data are available for residential and services, more detailed indicators can be developed for each sub-sector or end use (level 2) or equipment type (level 3 or beyond, e.g. technology or equipment by fuel type in Figure 2.4).

5 www.iea.org/topics/energyefficiency/subtopics/energyefficiencyindicators/.

The most important end uses for which indicators should be developed will depend on the current and expected profile of energy use in the buildings sector in each country. In cold climates, for example, space heating often accounts for more than half of all energy use. In warm climates, appliances often use the largest share of energy; with potentially high growth in energy use for space cooling, particularly in lower-income countries where air conditioning has yet to be widely deployed. Actions that have the largest impact on a country's buildings energy use should be prioritised.

Figure 2.4 Metrics to track progress in buildings



Note: This figure is intended for illustrative purposes, not as a definitive list of indicators.

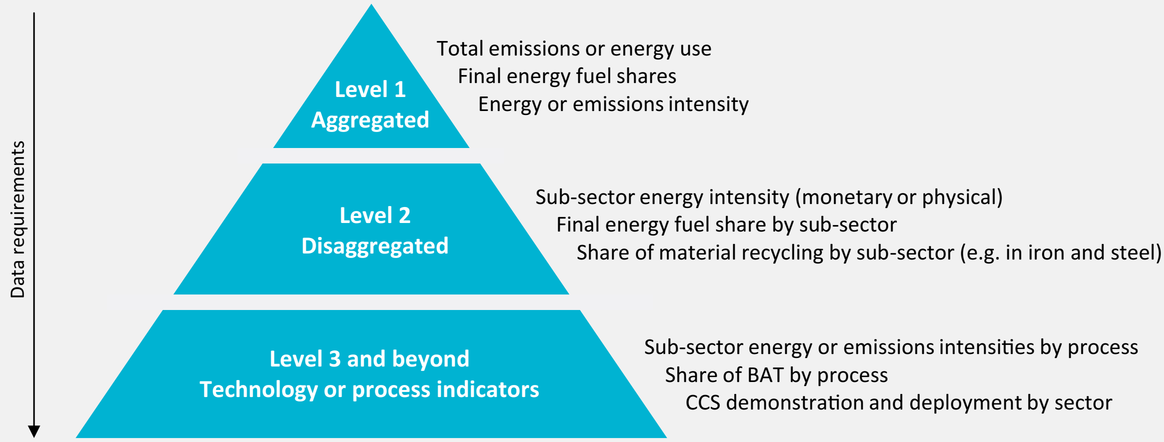
Key point *Aggregate indicators provide a general explanation of trends in energy consumption, but to understand the key drivers and to provide policy-relevant analysis on how to influence these trends, detailed disaggregated indicators are required.*

Industrial transition: Industry energy use and emissions

Significant progress has been made in reducing energy use and emissions in industry, particularly in the most energy-intensive sectors (steel, cement, chemicals, paper and aluminium), driven by efforts to reduce the high share of overall costs associated with energy. Countries have also recognised the need to prioritise action in these industries; many have already implemented policies aimed at reducing both energy use and emissions. Industry will need to focus on using more low-carbon fuels and feedstocks, as well as developing new technologies to reduce energy and emissions even further.

Metrics to monitor trends in industry should cover energy efficiency indicators and energy supply, as well as RD&D metrics for the development and deployment of new process technologies (e.g. smelt reduction technologies in steel) and other measures (Figure 2.5). Driver metrics such as those related to the development of carbon capture technologies for industry will be particularly important in the long term, given the need to reduce process-related emissions from sectors such as cement and steel, especially in those countries where consumption and production of these materials is growing rapidly.

Figure 2.5 Metrics to track progress in industry



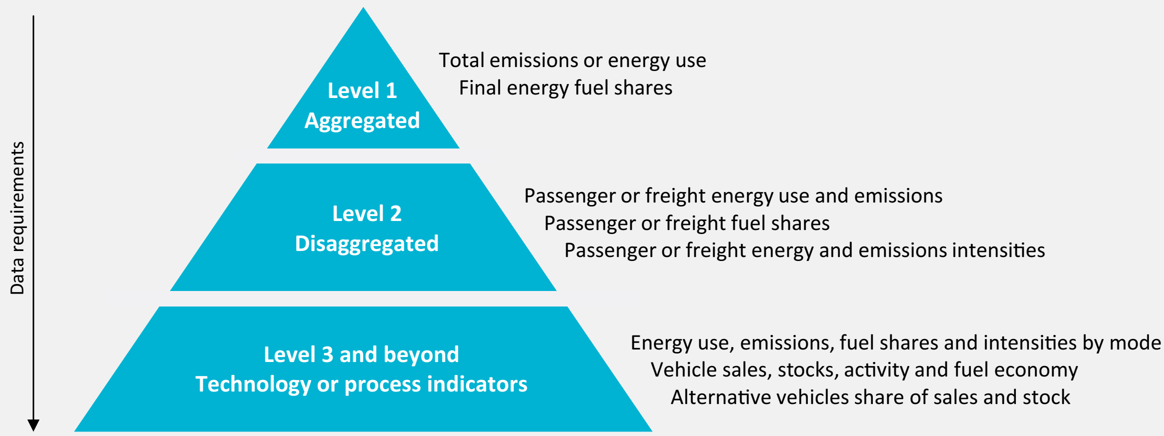
Note: This figure is intended for illustrative purposes, not as a definitive list of indicators.

Key point *It is rarely possible to define a single "true" indicator that fully describes energy use and CO_2 emissions of a sub-sector or a process. A set of indicators is necessary to understand energy and emissions trends.*

Moving to sustainability: Passenger and freight transport energy use and emissions

Energy use in transport is expected to become one of the fastest-growing sectors as global demand for transport, particularly for cars, rises 70% by 2030 and 140% by 2050. Decarbonising transport will require avoiding and shifting demand to more efficient modes,

Figure 2.6 Metrics to track progress in transport



Note: This figure is intended for illustrative purposes, not as a definitive list of indicators.

Key point *Aggregate changes in transport energy use can be better explained and analysed in terms of its components with the proposed hierarchy.*

improving fuel economy of vehicles, and developing advanced vehicles. While significant progress has been made in developing and deploying alternative vehicles such as EVs and FCEVs, these vehicles are unlikely to be adopted widely until after 2030. In the nearer term, therefore, action to avoid and shift transport demand to more efficient modes and to improve the fuel economy of vehicles will have more immediate benefits.

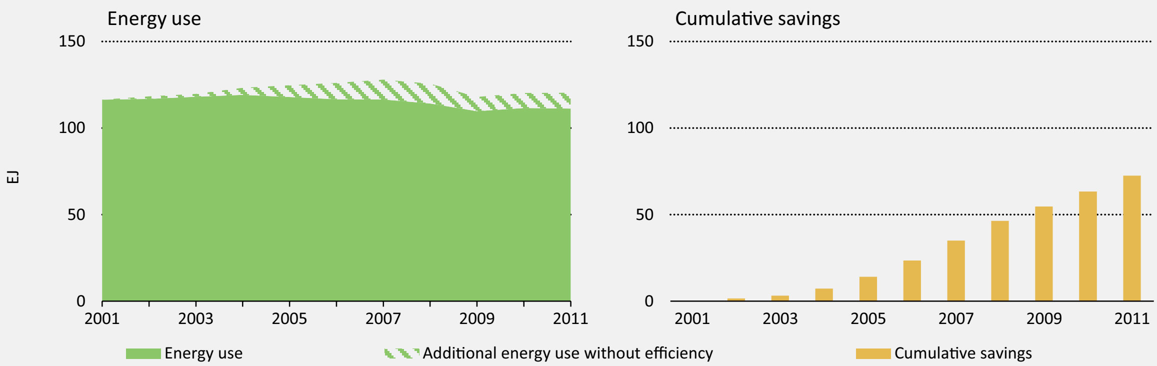
The metrics needed to monitor trends at the global and country level for transport will hence need to cover technology development of advanced vehicles as well as improvements in the energy efficiency of transport (Figure 2.6). Energy efficiency indicators should be developed for both passenger and freight transport, as the drivers and technology options for these two sub-sectors follow different pathways. Countries should combine energy efficiency indicators in transport with indicators to monitor progress at the technology level.

Better understanding the potential contribution of energy efficiency

Energy efficiency indicators on their own cannot be used to predict trends in energy consumption or energy savings. Other factors, such as activity levels and the mix of the activities (structure) at the economy or sectoral level, also influence trends in energy consumption. Understanding how each factor affects energy consumption is essential to determining which offers the greatest potential for energy savings, and the areas that should be prioritised for the development of energy efficiency policies. It is necessary to undertake decomposition analysis to estimate the impact of energy intensity changes (commonly ascribed to energy efficiency improvement).

Energy use in 18 IEA member countries would have seen an additional 9 EJ, or 8% higher, in 2011 (IEA, 2014f), if energy efficiency improvements had not been made (Figure 2.7). These improvements resulted in cumulative savings of 72 EJ over the decade. Such improvements can be translated into reductions in energy-related emissions, showing how important it is in the near term to curb energy use in order to reduce emissions. Energy efficiency indicators can help to quantify the potential contribution of energy efficiency measures to near- and long-term emissions reduction at the national level, thus helping countries to set appropriate targets and monitor progress towards stated goals.

Figure 2.7 Early reductions in emissions through energy efficiency in 18 IEA member countries

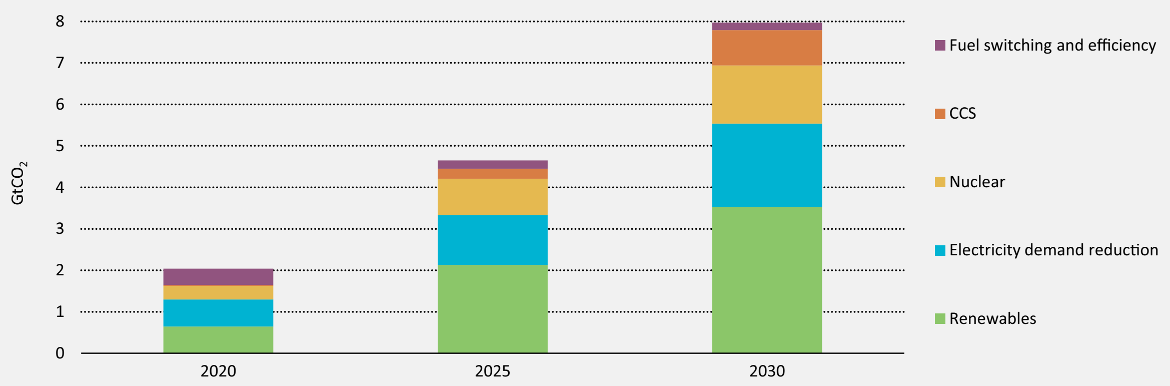


Key point *Energy efficiency has been a consistent and important factor in reducing energy demand.*

Linking energy supply and demand – need for action on both sides

Decarbonising energy supply, particularly in the electricity sector, will be critical to achieving deep energy-related emissions reduction, although this transformation will take decades. Nearer-term improvements in energy efficiency – for example, in the buildings sector – can provide immediate energy and emissions reductions while countries decarbonise the power sector, which globally is the most CO_2-intensive sector. Each 1% reduction in electricity consumption in the buildings sector (equivalent to about 100 TWh in 2012) can help to reduce emissions from power generation by 60 $MtCO_2$,[6] equivalent to an installed capacity of 45 GW of wind power (15 000 turbines) or 23 GW of coal-fired power (46 plants). While tracking progress on power sector decarbonisation through the deployment of zero- or low-carbon technologies such as renewables, nuclear and CCS is important for long-term emissions reduction, impacts of energy efficiency should also be closely monitored given its role in contributing to near-term emissions reduction, as well as other benefits.

Figure 2.8 **Saved emissions from reduced electricity demand and power sector decarbonisation**



Key point *Electricity demand reduction savings through energy efficiency measures are as important as power sector decarbonisation technologies in reducing overall electricity-related emissions.*

Conclusion

The metrics presented in this section are not an exhaustive list but are intended to illustrate how indicators covering energy supply and demand can be used to inform energy sector goals related to INDCs and to monitor progress towards energy sector decarbonisation. While countries should strive to develop metrics at the highest level possible, simpler metrics have also been identified for countries where data are still limited.

National commitments on climate change require strong action now by energy stakeholders that will reduce emissions in the near term and that will enable more significant, longer-term reductions. To evaluate progress within these different time frames, countries can use these metrics and frameworks to gain a better understanding of how energy is used

6 Calculated based on current global emissions intensity of electricity production.

nationally and which specific technologies can reduce energy consumption and decarbonise the energy sector. Capacity building will be needed to help countries improve data collection and to develop metrics and modelling tools to identify and track implementation of ambitious yet attainable goals. IEA expertise in energy statistics and indicators, technology tracking, and energy sector modelling can contribute to the development of these metrics and frameworks, both inside and outside the UNFCCC process.

Annexes

Acronyms, Abbreviations and Units

Acronyms

AES	Applied Energy Services
ASEAN	Association of South East Asian Nations
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAT	best available technology
BEV	battery-electric vehicle
BNEF	Bloomberg New Energy Finance
BOF	basic oxygen furnace
BSRIA	Building Services Research and Information Association
CAES	compressed air energy storage
CAGR	compound annual growth rate
CCGT	combined cycle gas turbine
CCS	carbon capture and storage
CFL	compact fluorescent lamp
CFPP	coal-fired power plant
CHP	combined heat and power
CZ	climate zone
DC	district cooling
DER	distributed energy resources
DH	district heating
DHC	district heating and cooling
DRI	direct reduced iron
EAF	electric arc furnace
EBC	energy in buildings and communities
EES	energy efficient strategies
ECES IA	Implementing Agreement for Energy Conservation through Energy Storage
EOR	enhanced oil recovery
EPO	European Patent Office
ESCII	Energy Sector Carbon Intensity Index
ETP	*Energy Technology Perspectives*
EU	European Union
EV	electric vehicle
EVI	Electric Vehicles Initiative
FBR	fast breeder reactor
FC	fuel cell
FCEV	fuel cell electric vehicle
FEH	final energy use for heat
FERC	Federal Energy Regulatory Commission (United States)
GDP	gross domestic product
Gen	generation
GHG	greenhouse gas
HDD	heating degree day

HENG	hydrogen-enriched natural gas
HPWH	heat pump water heater
HTP	high-temperature reactor
HVAC	heating, ventilation and air conditioning
IAEA	International Atomic Energy Agency
ICAO	International Civil Aviation Organization
ICT	information and communication technology
IEA	International Energy Agency
IECC	International Energy Conservation Code
IESA	India Energy Storage Alliance
IHS	Information Handling Service
IMO	International Maritime Organization
INDC	intended nationally determined contribution
I&S	iron and steel
ISGAN	International Smart Grid Action Network
ISO	International Organization for Standardization
ITC	investment tax credit
LBNL	Lawrence Berkeley National Laboratory
LCA	life-cycle assessment
LCOE	levelised cost of energy
LCV	light commercial vehicles
LED	light-emitting diode
LHV	lower heating value
Li-ion	lithium ion
LNG	liquefied natural gas
MEPS	minimum energy performance standard
MF	multiple family
MTRMR	*Medium-term Renewable Energy Market Report*
Na-ion	sodium ion
NaNiCL	sodium nickel chloride
NaS	sodium sulphur
NBP	National Balancing Point
NEA	Nuclear Energy Agency
NZEB	near-zero energy building
OCGT	open-cycle gas turbine
OECD	Organisation for Economic Co-operation and Development
OHF	open-hearth furnace
PEM	proton exchange membrane
PHEV	plug-in hybrid-electric vehicle
PLDV	passenger light-duty vehicle
PPA	power purchase agreement
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
RE-FEH	renewable energy – final energy use for heat
RES	renewable energy source
SEAD	Super-Efficient Equipment and Appliance Deployment
SF	single family
SMR	small modular reactor
STE	solar thermal electricity
TCEP	*Tracking Clean Energy Progress*
TIMES	The Integrated MARKAL-EFOM System
UAE	United Arab Emirates
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change
US DOE	United States Department of Energy
US EPA	United States Environmental Protection Agency
UTES	underground thermal energy storage
U value	thermal transmission value
V2H	vehicle-to-home
VRB	vanadium redox
WEO	*World Energy Outlook*
WLTP	worldwide harmonised light vehicle test procedure
ZEB	zero-energy building

Abbreviations

2DS	*ETP 2015* 2°C Scenario
4DS	*ETP 2015* 4°C Scenario
6DS	*ETP 2015* 6°C Scenario
CO_2	carbon dioxide
H_2	hydrogen gas

Units of measure

ACH	air changes per hour
bcm	billion cubic metres
EJ	exajoule
GJ	gigajoule
Gt	gigatonne
GW	gigawatt
GWh	gigawatt hour
km	kilometre
kW	kilowatt
kWh	kilowatt hour
m^2	square metre
Mbtu	1 000 British thermal units
Mt	megatonne
MW	megawatt

MWh	megawatt hour
PJ	petajoule
TJ	terajoule
toe	tonne of oil-equivalent
TWh	terawatt-hour
U value	W per K per m^2
USD	United States dollar
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.

The notes in this section provide additional sources and details related to data and methodologies.

Throughout the report quoted annual averages are calculated as compound average growth rates.

Renewable power (page 20)

Figure 1.1, 1.2, 1.4 and 1.7: source: data for 2000-20 from IEA (2014g), *Medium-Term Renewable Energy Market Report,* OECD/IEA, Paris.

Nuclear power (page 26)

Figure 1.8 and 1.9: source: Data from IAEA (International Atomic Energy Agency) (2014), PRIS (Power Reactor Information System) database, IAEA, Vienna, www.iaea.org/pris/ (accessed 26 March 2015)and NEA (Nuclear Energy Agency) and IAEA (International Atomic Energy Agency) (2014), *Uranium 2014: Resources, Production and Demand (The Red Book),* OECD/NEA, Paris.

Figure 1.10: source: realised grid connection data from IAEA PRIS database; OECD/NEA.

Construction span from first concrete to grid connection. Grid connection for projects under construction is estimated based on recent public information.

Natural gas-fired power (page 28)

Figure 1.11: NBP = National Balancing Point (United Kingdom), representative of European gas prices.

Sources: Henry Hub: Intercontinental Exchange; NBP: GasTerra; Japan LNG: Japan Customs.

Figure 1.12: Oil-fired power generation is negligible in Germany and the United States (<1%), but represents 14% in Japan (2013).

Figure 1.13: 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.

Carbon capture and storage (page 32)

EOR is a closed cycle process which involves injecting CO_2 into older oil reservoirs to increase oil recovery and prolong production. The CO_2 is injected into the reservoir, recovered from the produced oil and re-injected. Some CO_2 is retained in the sub-surface in each cycle, leading cumulatively to the storage of significant amounts of CO_2; however, EOR projects are not necessarily subject to the same stringent monitoring requirements as dedicated storage projects and therefore it is difficult to account for the performance and permanence of the storage.

Figure 1.17: Large-scale projects are defined in accordance with the Global CCS Institute: projects involving the annual capture, transport and storage of CO_2 at a scale of at least 800 000 tonnes of CO_2 (tCO_2) for a coal-based power plant, or at least 400 000 tCO_2 for

other emissions-intensive industrial facilities (including natural gas-based power generation). Advanced stage of planning implies that projects have reached at least the Define stage in accordance with the Global CCS Institute's Asset Lifecycle Model. GCCSI (Global CCS Institute) (2014), *The Global Status of CCS: 2014,* GCCSI, Melbourne.

Figure 1.18: source: BNEF (Bloomberg New Energy Finance) (2014b), Clean Energy Investment Trends, BNEF, London, http://about.bnef.com/tools/ (accessed 19 January 2015).

Private spending represents the publicly disclosed cost of projects including CCS that are in construction or operation and have a capacity equal to or greater than 100 MW in power generation (and all industrial projects). Private spending figures reflect the total cost of a project (i.e. the entire cost of a facility equipped with CCS) with the exception of a small number of cases where cost estimates for the CCS process are publicly available. Grants represent all public funds awarded to projects excluding repayable loads, tax incentives and bonds. All figures shown do not include spending prior to 2005 on CCS projects such as In Salah, Sleipner and Weyburn. Spending in nominal USD.

Figure 1.19: data in USD 2013 prices and purchasing power parity (PPP).

Industry (page 34)

Figure 1.20: Industry totals include feedstock use in the chemicals and petrochemicals sector, and blast furnaces and coke ovens in the iron and steel sector.

Textbox: source: ISO 50001-certified sites information as of end of May 2014, Peglau, R. (2014), Federal Environment Agency of Germany, Umweltbundesamt, personal communication.

Figure 1.21: Industrial energy use per unit of industrial value-added in USD 2013 prices and PPP.

Iron and steel (page 36)

Figure 1.22: 2DS targets for energy intensity in 2020 are, in some cases, higher than 2012 energy intensity. This short-term increase is due to limitations in penetration of energy efficient processes which rely on availability of scrap metal. Beyond 2020, energy intensity decreases again, based on both scrap availability and deployment of new technologies. Energy use includes blast furnaces, coke ovens, iron ore agglomeration processes, steel-making and fuel use allocated to the generation of heat that is produced and used on-site through co-generation systems. Comparisons of this indicator among countries and regions are limited, as there are considerable differences across the iron and steel sector, specifically structure and quality of iron ore. 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 = 20.0-25.0 GJ/t DRI; scrap-based EAF = 350 kWh to 370 kWh/t crude steel (1.3 GJ/t crude steel).

Figure 1.24: BOF = basic oxygen furnace, OHF = open-hearth furnace.

Figure 1.25: In this figure only direct CO_2 emissions are considered. Indirect emissions from electricity use are not included. In regions where the EAF process route is prevalent, this can make up a large share of the overall emissions related to iron and steel manufacturing.

Transport (page 40)

Figure 1.30: Total aviation transport energy includes international bunkers.

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 than 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.

Fuel economy (page 42)

Figure 1.33: The growth in non-OECD car markets implied a reduced coverage of markets with fuel economy policies in place.

Electric vehicles (page 44)

Figure 1.34: source: Electric Vehicles Initiative – IEA (International Energy Agency) (2015), *Global EV Outlook 2015*, OECD/IEA, Paris.

Figure 1.35: source: MarkLines (2014), MarkLines Automotive Industry Portal database, MarkLines, Tokyo, www.marklines.com/en/ (accessed 26 March 2015).

Figure 1.36: source: MarkLines (2014), MarkLines Automotive Industry Portal database, MarkLines, Tokyo, www.marklines.com/en/ (accessed 26 March 2015).

Buildings energy efficiency (page 46)

Figure 1.38: In France, building codes have varied scaling factors based on climate and type.

Figure 1.39: Multiple family (MF) and single family (SF) do not represent the full electricity consumption but rather the building code portion for thermal loads. See IEA Energy in Buildings and Communities (EBC) Implementing Agreement Programme Annexes 56 and 61 for detailed economic and technical data.

Building envelopes (page 48)

Figure 1.41: source: IEA (2013c) *Transition to Sustainable Buildings: Strategies and Opportunities to 2050*, OECD/IEA, Paris.

Appliances, lighting and equipment (page 50)

Figure 1.42: source: EES (Energy Efficient Strategies) and Maia Consulting Ltd. (2014), *Energy Standards and Labelling Programs Throughout the World in 2013*, report commissioned by Australia Department of Industry, EES and Maia Consulting.

Figure 1.43: source: SEAD (Superefficient Equipment and Appliance Deployment) (forthcoming), LBNL (Lawrence Berkeley National Laboratory) dataset, personal communication, superefficient.org.

Figure 1.44: EU countries represent the nine largest EU markets; United States data include both boilers and furnaces.

Source: BSRIA (Building Services Research and Information Association) (2015), Condensing boilers market share and forecasts database, BSRIA, United Kingdom.

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

Text box: source: data available for Austria, Estonia, France, Germany, Japan, Korea, Norway, Slovenia, United Arab Emirates. Euroheat & Power (2013), *District Heating and Cooling: Country by Country Survey 2013,* Euroheat & Power, Brussels.

Renewable heat (page 54)

Figure 1.48: Final energy for heat (FEH) is defined as the direct use of energy for heat plus the use of commercial heat (heat produced and sold to a third party). A more detailed discussion on the methodology and derivation of the FEH indicator is presented in IEA (2014h), *Heating without Global Warming: Market Developments and Policy Considerations for Renewable Heat*, OECD/IEA, Paris. (www.iea.org/publications/freepublications/publication/FeaturedInsight_HeatingWithoutGlobalWarming_FINAL.pdf).

Official IEA statistics do not distinguish between modern and traditional use of bioenergy, as the distinction is difficult to make and currently not possible to quantify. In the absence of data, an estimate is made based on the geography where the biomass is consumed. Modern bioenergy is estimated as biomass consumption in the residential sector in OECD and non-OECD Europe and Eurasia, while traditional use of biomass is estimated as residential consumption in non-OECD regions excluding non-OECD Europe and Eurasia.

Smart grids (page 56)

Figure 1.52: Regional definitions: Asia Pacific: Afghanistan, American Samoa, Armenia, Australia, Azerbaijan, Bangladesh, Bhutan, British Indian Ocean Territory, Brunei Darussalam, Cambodia, People's Republic of China, Christmas Island (Indian Ocean), Cocos (Keeling) Islands, Comoros, Cook Islands, Fiji, French Polynesia, Guam, Heard and McDonald Islands, Hong Kong (China), India, Indonesia, Japan, Kazakhstan, Kiribati, Korea, the Democratic People's Republic of Korea, Kyrgyzstan, Lao People's Democratic Republic, Malaysia, Maldives, Marshall Islands, Mayotte, Federated States of Micronesia, Midway Islands, Mongolia, Myanmar, Nauru, Nepal, New Caledonia, New Zealand, Niue, Norfolk Island, Northern Mariana Islands, Pakistan, Palau, Papua New Guinea, Paracel Islands, Philippines, Pitcairn, Samoa, Seychelles, Singapore, Solomon Islands, Spratly Island, Sri Lanka, Chinese Taipei, Tajikistan, Thailand, Tokelau, Tonga, Turkmenistan, Tuvalu, Uzbekistan, Vanuatu, Viet Nam, Wake Island, Wallis and Futuna Islands.

Europe: Albania, Andorra, Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus[1], Czech Republic, Denmark, Estonia, Faroe Islands, Finland, Former Yugoslav Republic of Macedonia, France, Georgia, Germany, Gibraltar, Greece, Guernsey, Hungary, Iceland, Ireland, Isle of Man, Italy, Jersey, Republic of Kosovo, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Republic of Moldova, Monaco, Montenegro, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, San Marino, Serbia, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom.

Latin America: Anguilla, Antigua and Barbuda, Argentina, Aruba, Bahamas, Barbados, Belize, Bermuda Islands, Bolivia, Bouvet Island, Brazil, British Virgin Islands, Cape Verde, Cayman Islands, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Falkland Islands (Malvinas), French Guiana, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Montserrat, Netherlands Antilles, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Saint Helena, St. Kitts-Nevis, Saint Lucia, Saint Pierre and Miquelon, St. Vincent and the Grenadines, South Georgia and the South Sandwich Islands, Suriname, Trinidad and Tobago, Turks and Caicos Islands, Uruguay, Venezuela, Virgin Islands of the United States, West Indies.

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1 1. Footnote by Turkey: The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of United Nations, Turkey shall preserve its position concerning the "Cyprus issue".

2. Footnote by all the European Union Member States of the OECD and the European Union: The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

Middle East/Africa: Algeria, Angola, Bahrain, Botswana, Burkina Faso, Burundi, Cameroon, Central African Public, Chad, Congo, Democratic Republic of the Congo, Cote d'Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, the Islamic Republic of Iran, Iraq, Israel[2], Jordan, Kenya, Kuwait, Lebanon, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Morocco, Mozambique, Namibia, Niger, Nigeria, Oman, Palestinian Authority, Qatar, Réunion, Rwanda, Sao Tome and Principe, Saudi Arabia, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Syrian Arab Republic, United Republic of Tanzania, Togo, Tunisia, Turkey, Uganda, United Arab Emirates, Western Sahara, Yemen, Zambia, Zimbabwe.

North America: Canada, Greenland, United States.

source: Navigant (2014), *Smart Electric Meters, Advanced Metering Infrastructure and Meter Communications: Global Market Analysis and Forecasts*, Navigant, Chicago; IHS (IHS Technology) (2014), *Grid-Connected Energy Storage Report 2014*, IHS, Englewood, Colorado.

Figure 1.53: source: EPO (European Patent Office) (2014), PATSTAT (Worldwide Patent Statistical Database), EPO, Munich, www.epo.org/searching/subscription/raw/product-14-24.html (accessed 26 March 2015).

Energy storage (page 58)

Figure 1.54: source: Platts (2013), *World Electric Power Plant Database*, 2013 edition, Platts, New York, www.platts.com/products/world-electric-power-plants-database.; ECES IA (Implementing Agreement for Energy Conservation through Energy Storage) (2014), Energy storage capacity data, personal communication with Halime Paksoy, Chair.

Figure 1.55: source: India Energy Storage Alliance (IESA) data and estimates, Fernands, S. (2014), "Energy storage: Missing link for microgrids, smart grids and renewables in the US and India", presentation at European Utility Week, Amsterdam, 4-6 November.

Figure 1.56: source: Data for solar thermal storage is for 2012, for Japan 2009, for Sweden 2013 and for Denmark 2014; US DOE (2014b), *2014 Global Energy Storage database*, US DOE, Washington, DC, www.energystorageexchange.org/projects (accessed 26 March 2015).

Hydrogen and fuel cells (page 60)

Figure 1.57: source: adapted from Decourt, B., B. Lajoie, R. Debarre and O. Soupa (2014), *Hydrogen-Based Energy Conversion. More Than Storage: System Flexibility*, SEI (SBC Energy Institute), Paris.

Figure 1.58: source: adapted from US DOE (United States Department of Energy) (2014a), *2013 Fuel Cell Technologies Market Report*, US DOE, Washington, DC.

Figure 1.59: source: adapted from Spendelow, J., J. Marcinkoski and S. Satyapal (2012), *DOE Fuel Cell Technologies Program Record*, US DOE (United States Department of Energy), Washington, DC.; McKinsey & Company (2010), *A Portfolio of Power-Trains for Europe: A Fact-Based Analysis. The Role of Battery Electric Vehicles, Plug-in Hybrids and Fuel Cell Electric Vehicles,* McKinsey & Company, Paris.

Textbox: source: Bonhoff, K. (2012), "Country update Germany", presented at the IPHE (International Partnership for Hydrogen and Fuel Cells in the Economy) Steering Committee Meeting, Cape Town, 3 May.

2 The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD and/or the IEA is without prejudice to the status of the GolanHeights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

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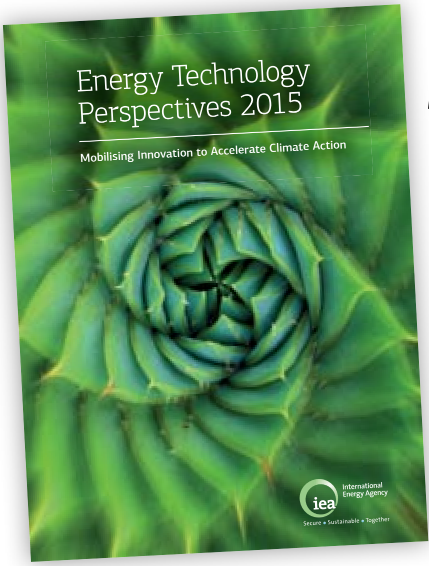

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Tracking Clean Energy Progress 2015

Energy Technology Perspectives 2015 Excerpt
IEA Input to the Clean Energy Ministerial

Published annually, the *Tracking Clean Energy Progress* (*TCEP*) report highlights how the overall development and deployment of clean energy technologies evolve, year on year. Each technology and sector is tracked against the interim 2025 2°C Scenario (2DS) targets of the IEA *Energy Technology Perspectives 2015* (*ETP 2015*), which lays out pathways towards a sustainable energy system in 2050. This comprehensive overview examines the latest developments in key clean energy technologies:

- **Recent trends** with reference to technology penetration, market creation and technology developments.
- **Tracking progress** in each technology and sector segment, which includes a quantitative evaluation on progress towards meeting the 2DS.
- **Recommended actions** which outline the measures required to overcome existing barriers to meeting the 2DS.

In 2014 renewable power generation continued to progress, the number of electric vehicles (EVs) increased rapidly, and a significant milestone for carbon capture and storage (CCS) was reached; however, the deployment rate of most clean energy technologies is no longer on track to meet 2DS targets. The overall growth rates of clean energy technologies have slowed significantly, and existing opportunities for deployment are not being exploited, preventing significant benefits from being realised. Policy certainty, incentives, regulation and international co-operation are required to meet stated ambitions and transform the global energy system.

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