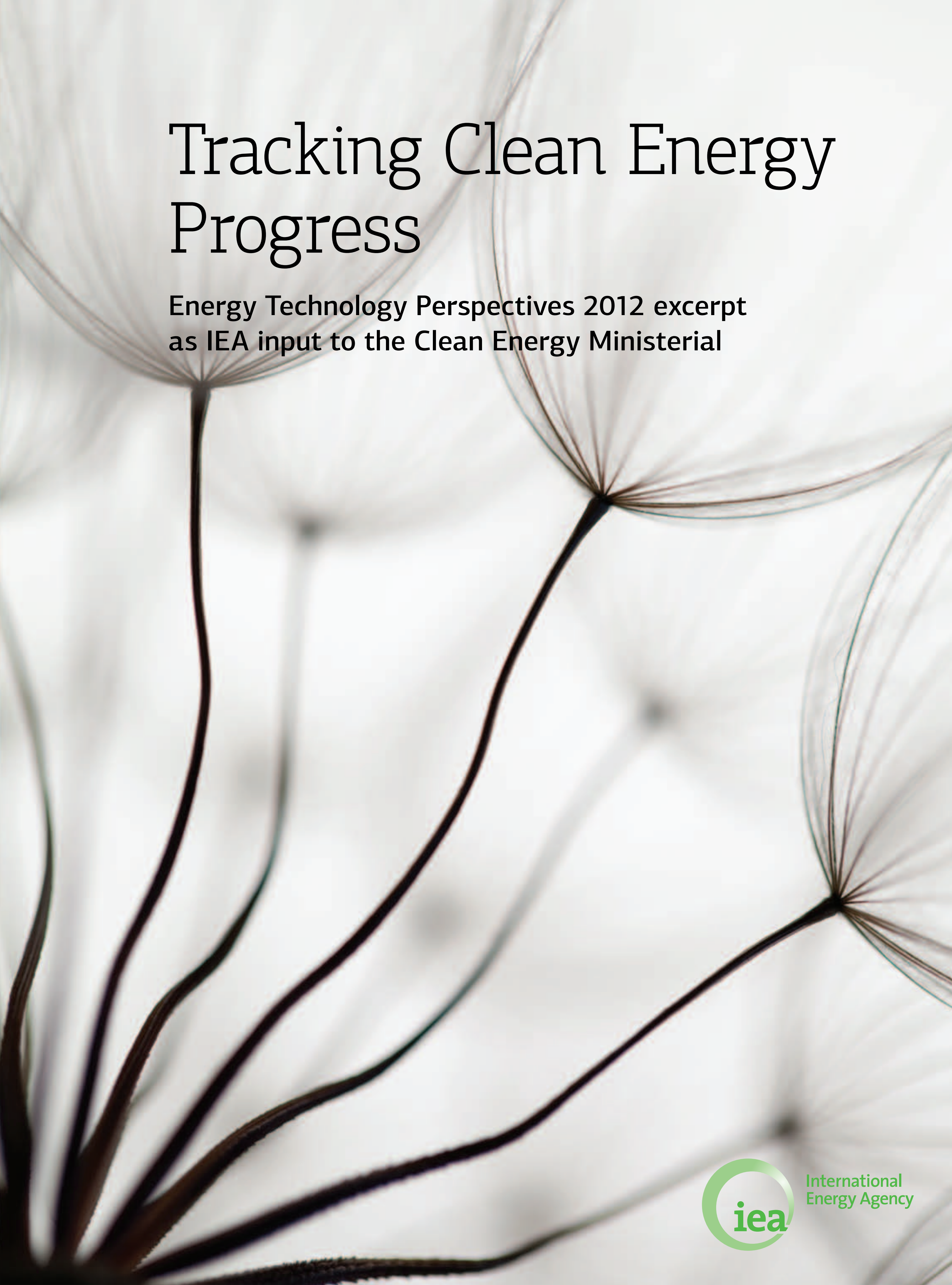

Tracking Clean Energy Progress

Energy Technology Perspectives 2012 excerpt as IEA input to the Clean Energy Ministerial

International Energy Agency

Energy Technology Perspectives 2012

Pathways to a Clean Energy System

Global demand for energy shows no signs of slowing; carbon dioxide emissions keep surging to new records; and political uprisings, natural disasters and volatile energy markets put the security of energy supplies to the test.

More than ever, the need for a fundamental shift to a cleaner and more reliable energy system is clear. What technologies can make that transition happen? How do they work? And how much will it all cost?

The 2012 edition of *Energy Technology Perspectives* (ETP), to be released in June, answers these and other fundamental questions. Its up-to-date analysis, data and associated website are an indispensible resource for energy technology and policy professionals in the public and private sectors.

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ETP 2012 is the International Energy Agency's most ambitious and comprehensive publication on new energy technology developments. It demonstrates how technologies – from electric vehicles to wind farms – can make a decisive difference in achieving the internationally agreed objective of limiting global temperature rise to 2°C above pre-industrial levels. It also provides guidance for decision makers on how to reshape current energy trends to build a clean, secure and competitive energy future.

Tracking Clean Energy Progress

Energy Technology Perspectives 2012 excerpt as IEA input to the Clean Energy Ministerial

International Energy Agency

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 28 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

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

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Key Findings

Recent environmental, economic and energy security trends point to major challenges: energy related CO_2 emissions are at an historic high, the global economy remains in a fragile state, and energy demand continues to rise. The past two years (2010 and 2011) also saw the Deepwater Horizon oil spill off the Gulf of Mexico, the Fukushima nuclear accident in Japan, and the Arab Spring, which led to oil supply disruptions from North Africa. Taken together, these trends and events emphasise the need to rethink our global energy system. Whether the priority is to ensure energy security, rebuild national and regional economies, or address climate change and local pollution, the accelerated transition towards a lower-carbon energy system offers opportunities in all of these areas.

The *Energy Technology Perspectives 2012* 2°C Scenario (*ETP* 2DS)[1] highlights that achieving this transition is technically feasible, if timely and significant government policy action is taken, and a range of clean energy technologies are developed and deployed globally. Based on current trends, are we on track to achieving this transition? Are clean energy technologies being deployed quickly enough? Are emerging technologies making the necessary progress to play an important role in the future energy mix? These are the key questions addressed in this report.

In summary, the following analysis finds that a few clean energy technologies are currently on track to meet the 2DS objectives. Cost reductions over the past decade and significant annual growth rates have been seen for onshore wind (27%) and solar photo-voltaic (PV) (42%). This is positive, but maintaining this progress will be challenging.

Government targets for electric vehicles stock (20 million by 2020) are ambitious, as are continued government nuclear expansion plans in many countries, in both of these cases, significant public and private sector efforts will be necessary to translate plans into reality.

The technologies with the greatest potential for energy and carbon dioxide (CO_2) emissions savings, however, are making the slowest progress: carbon capture and storage (CCS) is not seeing the necessary rates of investment into full-scale demonstration projects and nearly one-half of new coal-fired power plants are still being built with inefficient technology; vehicle fuel-efficiency improvement is slow; and significant untapped energy-efficiency potential remains in the building and industry sectors.

The transition to a low-carbon energy sector is affordable and represents tremendous business opportunities, but investor confidence remains low due to policy frameworks that do not provide certainty and address key barriers to technology deployment. Private sector financing will only reach the levels required if governments create and maintain supportive business environments for low-carbon energy technologies.

1 *Energy Technology Perspectives 2012* is a forthcoming publication that demonstrates how technologies can make a decisive difference in achieving the internationally agreed objective of limiting global temperature rise to 2°C above preindustrial levels. See Box 1.1 for information on the *ETP 2012* scenarios.

Table I.1 Summary of progress

CO_2 reduction share by 2020*	On track?	Technology	Status against 2DS objectives	Key policy priorities
36%		HELE coal power	Efficient coal technologies is being deployed, but almost 50% of new plants in 2010 used inefficient technology.	CO_2 emissions, pollution, and coal efficiency policies required so that all new plants use best technology and coal demand slows.
		Nuclear power	Most countries have not changed their nuclear ambitions. However, 2025 capacity projections 15% below pre-Fukushima expectations.	Transparent safety protocols and plans; address increasing public opposition to nuclear power.
		Renewable power	More mature renewables are nearing competitiveness in a broader set of circumstances. Progress in hydropower, onshore wind, bioenergy and solar PV are broadly on track with 2DS objectives.	Continued policy support needed to bring down costs to competitive levels and deployment to more countries with high natural resource potential required.
			Less mature renewables (advanced geothermal, concentrated solar power (CSP), offshore wind) not making necessary progress.	Large-scale research development and demonstration (RD&D) efforts to advance less mature technologies with high potential.
		CCS in power	No large-scale integrated projects in place against the 38 required by 2020 to achieve the 2DS.	Announced CCS demonstration funds must be allocated. CO_2 emissions reduction policy, and long-term government frameworks that provide investment certainty will be necessary to promote investment in CCS technology.
23%		CCS in industry	Four large-scale integrated projects in place, against 82 required by 2020 to achieve the 2DS; 52 of which are needed in the chemicals, cement and iron and steel sectors.	
		Industry	Improvements achieved in industry energy efficiency, but significant potential remains untapped.	New plants must use best available technologies; energy management policies required; switch to lower carbon fuels and materials, driven by incentives linked to CO_2 emissions reduction policy.
18%		Buildings	Huge potential remains untapped. Few countries have policies to enhance the energy performance of buildings; some progress in deployment of efficient end-use technologies.	In OECD, retrofit policies to improve efficiency of existing building shell; Globally, comprehensive minimum energy performance codes and standards for new and existing buildings. Deployment of efficient appliance and building technologies required.
22%		Fuel economy	1.7% average annual fuel economy improvement in LDV efficiency, against 2.7% required to achieve 2DS objectives.	All countries to implement stringent fuel economy standards, and policies to drive consumers towards more efficient vehicles.
		Electric vehicles	Ambitious combined national targets of 20 Million EVs on the road by 2020, but significant action required to achieve this objective.	RD&D and deployment policies to: reduce battery costs; increase consumer confidence in EVs, incentivise manufacturers to expand production and model choice; develop recharging infrastructure.
		Biofuels for transport	Total biofuel production needs to double, with advanced biofuel production expanding four-fold over currently announced capacity, to achieve 2DS objectives in 2020.	Policies to support development of advanced biofuels industry; address sustainability concerns related to production and use of biofuels.

Note: *Does not add up to 100% as 'other transformation' represents 1% of CO_2 emission reduction to 2020; Red= Not on track; Orange= Improvements but more effort needed; Green= On track but sustained support and deployment required to maintain progress.

Recommendations for Energy Ministers

Member governments of the Clean Energy Ministerial (CEM)[2] process not only represent 80% of today's global energy consumption, but also about two-thirds of projected global growth in energy demand over the next decade. If the 2DS objectives are achieved, CO_2 emissions among CEM member countries would decrease by over 5 gigatonnes (Gt), and they would save 7 700 million tonnes of oil equivalent (Mtoe)[3] through reduced fuel purchases. Globally, the near-term additional investment cost of achieving these objectives would amount to USD 5 trillion by 2020, but USD 4 trillion will be saved through lower fossil fuel use over this period. The net costs over the next decade are therefore estimated at over USD 1 trillion[4]. More impressively, by 2050, energy and emissions savings increase significantly as CO_2 emissions peak, and begin to decline from 2015. In this timeframe, benefits of fuel savings are also expected to surpass additional investment requirements for decarbonising the energy sector. Potential savings among CEM countries in 2050 amount to over 29 Gt of CO_2 emissions and about 160 000 Mtoe through reduced fuel purchases. This is equivalent to more than a 50% reduction in CO_2 emissions from 2010 levels, and fuel purchase savings equivalent to twice total CEM country energy imports over the past 40 years. This combination of reduced energy demand and diversification of energy sources will result in far reaching energy security benefits.

Currently, CEM and governments around the world are not on track to realising these benefits. Few forums have as significant a potential to make a major impact on global clean energy deployment, and possess the operational flexibility to make it happen: this opportunity and momentum must be seized. Joint commitments taken at the third Clean Energy Ministerial can help overcome existing barriers to clean energy technology deployment, and scale-up action where it is most needed. This can be achieved by raising the ambition of Clean Energy Ministerial efforts to:

- **Encourage national clean energy technology goals – supported by policy action and appropriate energy pricing** – that send strong signals to the markets that governments are committed to clean energy technology deployment.
- **Escalate the ambition of international collaboration** – by building on the CEM Initiatives to take joint actionable commitments, and closely monitor progress against them.

With these two objectives in mind, if taken up by energy ministers, the following three key recommendations, and specific supporting actions, can help move clean energy technologies from fringe to main-stream markets.

2 CEM governments include Australia, Brazil, Canada, China, Denmark, the European Commission, Finland, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, Norway, Russia, South Africa, Spain, Sweden, the United Arab Emirates, the United Kingdom, and the United States.

3 Unless otherwise stated, fuel and emissions savings, and investment needs are calculated based on comparison with the 6DS scenario (see Box 1.1 for scenario details).

4 Accounts for the undiscounted difference between additional required investments and fuel savings potential. Based on fuel prices assumptions consistent with the 6DS.

1. Level the playing field for clean energy technologies

Price energy appropriately and encourage investment in clean energy technology

The Clean Energy Ministerial has proven to be a valuable mechanism to support actions that address individual technology challenges, but the national policy frameworks that create large-scale markets for clean energy technology uptake are even more critical. First, energy prices must appropriately reflect the "true cost" of energy (*e.g.* through carbon pricing) so that the positive and negative impacts of energy production and consumption are fully taken into account. Second, inefficient fossil fuel subsidies must be removed, while ensuring that all citizens have access to affordable energy. In 2010, fossil fuel subsidies were estimated at USD 409 billion (up more than 37% from 2009), against the USD 66 billion allotted for renewable energy support. The phasing-out of inefficient fossil fuel subsidies is estimated to cut growth in energy demand by 4.1% by 2020 (IEA, 2011a). Third, governments must develop policy frameworks that encourage private sector investment in lower-carbon energy options. Financing remains a challenge for low-carbon energy technologies despite availability of capital. The question is how to transition traditional energy investments into investments in low-carbon technologies. An appropriate policy framework needs to cover not just climate policy, but also include energy and energy technology policy, and, critically, investment policy. These three actions will allow clean energy technologies to more effectively compete for private sector capital.

Develop policies to address energy systems as whole

Segmented approaches to energy investments rationalise the need for targeted initiatives, but overlook the potential for optimising the energy system as a whole. Electricity systems are experiencing increased deployment of variable renewables; more electricity will be used for electric vehicles and heating applications; and peak and global electricity consumption is rising. These three changes in the electricity sector urgently require new approaches that allow smarter energy delivery and consumption.

The understanding of energy production, delivery and use from an integrated, systems perspective will help leverage investments from one sector to another. This will require a better understanding of new technologies and stakeholders, who have traditionally not been involved in the energy sector. Revised approaches to energy system deployment must utilise existing and new infrastructure to develop flexible and smarter systems that allow for accelerated deployment, while simultaneously reducing costs.

Step-up to the CCS challenge

CCS technologies deserve to be singled out. CCS remains critical to reducing CO_2 emissions from the power and industry sectors, but fundamental challenges must be addressed if this technology is to meet its potential. Public funding for demonstration projects remains inadequate compared with the level of ambition associated with CCS; large-scale integrated projects are coming on line far too slowly; beyond demonstration projects, incentives to develop CCS projects are lacking; and too little attention has so far been given to CCS applications in industries other than the power sector, such as iron and steel, cement manufacturing, refining or biofuel production. Without CCS technologies, the cost of achieving CO_2 emissions reduction objectives will increase.

Energy ministers should:

- *Commit to, and report on, national actions that aim to appropriately reflect the true cost of energy production and consumption.*
- *Build on G-20 efforts to phase-out the use of inefficient fossil fuel subsidies, while ensuring access to affordable energy for all citizens.*
- *Consider how new mechanisms for systems thinking could be established, by increasing the CEM focus on cross-cutting energy systems issues. CEM governments should build on insights from the High Renewable Electricity Penetration case studies completed for discussion at CEM3, the work of the International Smart Grid Action Network (ISGAN), and the Clean Energy Solutions Center, to accelerate the creation of tools and best practices for optimising electricity systems.*
- *Accelerate progress against the seven recommendations made by the Carbon Capture, Use and Storage Action Group (CCUS) during CEM2. It is especially important to scale-up funding for first-mover demonstration projects and focus on opportunities for CCS applications in industry. Governments should also implement the recommendations presented by the CCUS Action Group to CEM3.*

2. Unlock the potential of energy efficiency

Implement energy efficiency policies and enhance efficiency standards

There have been incremental improvements in energy efficiency globally, but its large potential has yet to be tapped. In the buildings sector, improvements in the efficiency of the building shell will have the largest impact on energy savings. This can be achieved through the stringent application of integrated minimum energy performance codes and standards for new and existing buildings, retrofitting the current building stock, and deploying available energy-efficient technologies. For industry, major potential still remains for energy and economic savings through the use of best available technologies and adoption of energy management systems. In transport, improving fuel economy is the number one action needed to reduce CO_2 emissions within the next decade.

The IEA has developed 25 energy efficiency recommendations to help governments achieve the full potential of energy efficiency improvements across all energy-consuming sectors. If implemented globally without delay, actions outlined in the recommendations could cumulatively save around 7.3 Gt of CO_2 emissions per year by 2030 (IEA, 2011b).

Leverage the role of energy providers in delivering energy efficiency

Energy providers have proven effective in delivering energy efficiency if the right regulatory framework and enabling conditions are established. In fact, over USD 10 billion per year is spent by energy providers on end-use energy efficiency, and this amount is expected to double over the next five years. Given this success to date, and the pressing need to scale-up energy efficiency investments, governments should consider carefully how to mobilise energy providers to deliver energy efficiency.

Energy ministers should:

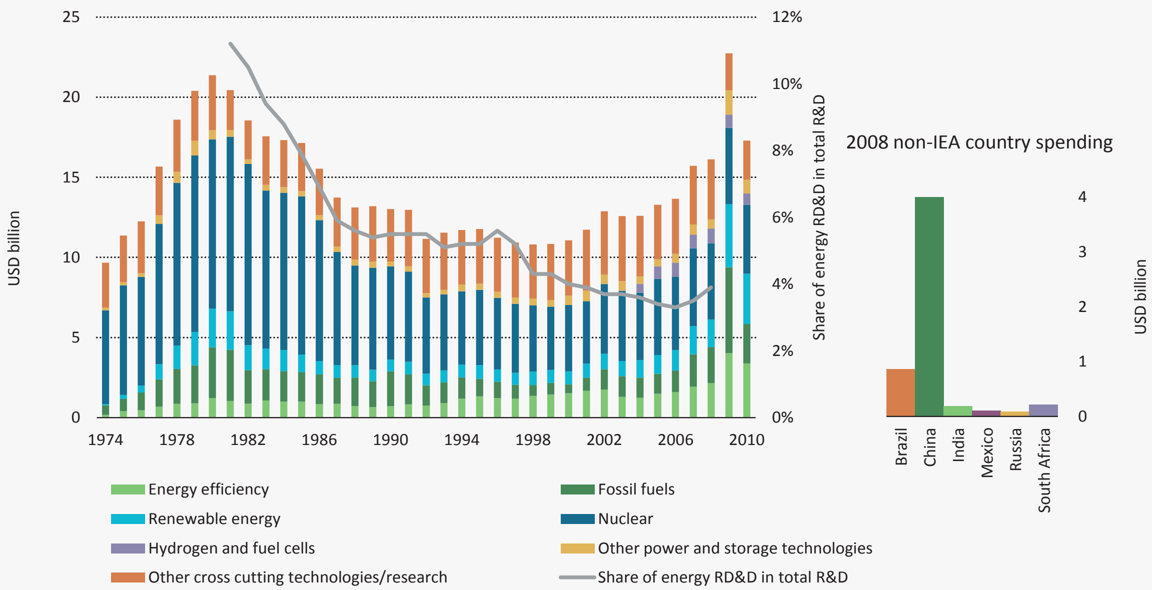
- *Commit to the application of the* 25 Energy Efficiency policy recommendations *to help leverage energy efficiency potential across all energy-consuming sectors.*
- *Expand the focus of the Super-Efficient Equipment and Appliance Deployment Initiative (SEAD) to strive for more stringent efficiency standards and harmonised test procedures globally. SEAD or other CEM initiatives could also broaden their focus to look at global best practices in building energy codes and standards, to help governments to design and implement integrated building energy savings policies.*
- *Cooperate with the four Global Fuel Economy Initiative (GFEI) partners (IEA, International Transport Forum, United Nations Environment Programme and FIA Foundation) to expand efforts related to the development and implementation of stringent fuel economy standards, and fiscal support measures. Broadening the GFEI's mandate could also be considered, with a view to addressing the challenge of fuel economy from freight trucks, buses and other modes of transport; and to explore government coordination to improve and eventually align fuel economy test procedures, in order to maximise on-road fuel efficiency and cut compliance costs.*
- *Promote cooperation and knowledge-sharing through large-scale energy efficiency programmes, such as energy provider delivery of energy efficiency to their customers. This can be done by building on the outputs of the PEPDEE (Policies for Energy Provider Delivery of Energy Efficiency) Initiative[5], to implement identified regulatory mechanism options that could help mobilise energy providers to deliver energy efficiency.*

3. Accelerate energy innovation and public RD&D

In a period of continued fiscal austerity, government support for technology innovation remains critical. Annual global public RD&D spending remains lower than what is necessary to achieve the performance and cost objectives required to make clean energy competitive. However, promising renewable energy technologies, such as offshore wind and CSP, and capital intensive technologies, such as CCS and Integrated Gasification Combined Cycle (IGCC), face impediments to deployment. While public RD&D peaked in 2009 as a result of economic stimulus spending, it declined in 2010 to just above 2008 levels. Preliminary 2011 data suggests, however, that spending is again on the rise. Overall, the energy sector only accounts for about 4% of total government R&D spending, down from above 11% in 1980. This small share and significant decline represents a major challenge given the strategic importance of this sector. Coupled with continued measures aimed at fostering early deployment to provide opportunities of learning and cost reduction for more mature technologies, targeted RD&D efforts will help bring key early stage clean energy technologies to market.

5 PEPDEE is an initiative under the International Partnership on Energy Efficiency Cooperation (IPEEC), led by the UK Department of Energy and Climate Change (DECC), and implemented by the IEA and the Regulator Assistance Project (RAP).

Figure I.1 Government RD&D expenditure



Notes: Historical RD&D data is for IEA countries and includes Brazil from 2007; share of energy RD&D in total R&D is for IEA countries only. The share of energy in total R&D spending is likely to be somewhat underestimated given lack of precision in data categorisation. Some energy related spending may be allocated to other R&D spending categories, such as "Energy & Environment" or "General University Funds". Nonetheless, the energy share shows a broadly decreasing trend and remains low.

Sources: Country submissions for IEA and OECD countries, Russia and Brazil; Kempner R., L. Diaz Anadon, J. Condor (2010) for South Africa, China and Mexico.

Key point *Global public energy sector RD&D spending remains a small share of total RD&D budgets and spending levels have seen a recent decrease from peak spending in 2009.*

Energy ministers should:

- *Share technology specific data on public spending on energy RD&D to help develop a global picture of RD&D gaps and needs. Additionally, CEM governments should consider joint RD&D efforts to improve the performance and reduce the costs of technologies at the early innovation phase, including sharing lessons learned on innovative RD&D models.*
- *Broaden the scope of the Multilateral Solar and Wind Working Group, by collectively pledging to joint RD&D efforts to improve the performance and reduce the costs of renewable energy technologies entering the deployment phase. For example, to address the challenges faced by offshore wind technologies, critical elements include the development of the larger scale wind turbines that can be deployed off-shore and platforms suited to deeper water. For CSP, improved heat-transport media and storage systems are essential. To further spur deployment of renewable energy technologies, governments should also consider best policies for encouraging generators to increase investment in such technologies, including by facilitating novel business models and the development of voluntary labeling programmes.*
- *To support governments in achieving their current electric vehicle targets, the Electric Vehicle Initiative (EVI) could be strengthened, with resources to effectively co-ordinate EV RD&D and planning efforts, and expand work to ensure adequate coordination, among governments, manufacturers, and other stakeholders around the world.*

PART 1

Tracking Clean Energy Progress

Recent environmental, economic and energy security trends point to major challenges: energy related CO_2 emissions are at an historic high, the global economy remains in a fragile state, and energy demand continues to rise. The past two years (2010 and 2011) also saw the Deepwater Horizon oil spill off the Gulf of Mexico, the Fukushima nuclear accident in Japan, and the Arab Spring, which led to oil supply disruptions from North Africa. Taken together, these trends and events emphasise the need to rethink our global energy system. Whether the priority is to ensure energy security, rebuild national and regional economies, or address climate change and local pollution, the accelerated transition towards a lower-carbon energy system offers opportunities in all of these areas.

Energy Technology Perspectives 2012 demonstrates that achieving this transition is technically feasible – and outlines the most cost-effective combination of technology options to limit global temperature rise by 2050 to 2ºC above pre-industrial levels, While possible, it will not be easy. Governments must enact ambitious policies that prioritise the development and deployment of cleaner energy technologies at a scale and pace never seen before. Based on recent trends, are clean energy technologies being deployed quickly enough to achieve this objective? Are emerging technologies making the necessary progress to play an important role in the future energy mix? And if not, which technologies require the biggest push?

Answering these questions requires looking across different technology developments simultaneously, as technology transition requires changes throughout the entire socio-technical system. This includes the technological system, its actors (government, individuals, business, and regulators), institutions, and economic and political frameworks (Neij and Astrand, 2006). The success of individual technologies depends on a number of conditions: the technology itself must evolve and become cost-competitive; policies and regulations must enable deployment; markets must develop sufficient scale to support uptake; and the public must embrace new technologies and learn attendant new behaviours (Table 1.1).

Using available quantitative and qualitative data, this report tracks progress in the development and deployment of clean energy[6] and energy-efficient technologies in the power generation, industry, buildings and transport sectors, given their essential contributions to the *ETP 2012* 2°C Scenario (2DS) objectives (Figure 1.1).

Technology progress is evaluated by analysing three main areas:

- ***Technology progress,*** using data on technology performance, technology cost and public spending on RD&D.
- ***Market creation***, using data on government policies and targets, and private investment.
- ***Technology penetration***, using data on technology deployment rates, share in the overall energy mix and global distribution of technologies.

6 "Clean energy" here includes those technologies outlined as necessary, and playing a major role in reducing CO_2 emissions under the *ETP 2012* 2°C Scenario (2DS), and for which sufficient data were available to undertake analysis. Natural gas technologies and recent developments are not included in this analysis, but will be discussed in detail in the Gas Chapter of *ETP 2012*.

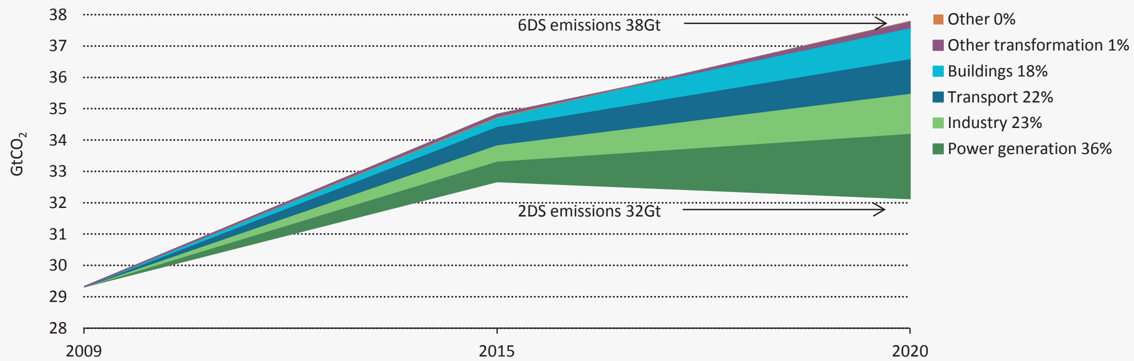
Table 1.1 Factors that influence clean energy technology development and deployment progress

Technology progress	Technical efficiency improvements Competitive cost of technologies
Market development	Creation of technology markets through enabling policies Knowledge and competencies of market analysts and private-sector investors Parity of energy and electricity prices Manufacturing capacity and supply chain development Skills and competencies to build and operate new technologies
Institutional, regulatory and legal frameworks	Changes to institutions and processes to support adoption of new technologies Legal and regulatory frameworks to enable technology deployment
Acceptance by social frameworks	Knowledge and education Acceptance of new technologies

Assessing these elements together provides an overview of whether technologies are, or are not, likely to achieve the 2DS objectives by 2050, using 2020 deployment milestones as interim evaluation benchmarks. The short-term focus (present to 2020) emphasises actions over the next decade that are required both to capture available energy savings opportunities and to set the course for technologies that will play a larger role in post-2020 decarbonisation, such as carbon capture and storage (CCS) and electric vehicles.

Importantly, the analysis in this report also identifies major bottlenecks and enablers for scaling up the spread of each clean energy technology.

Figure 1.1 Key sector contributions to world CO_2 emissions reductions



Source: Unless otherwise noted, all tables and figures in this report are derive from IEA data and analysis.

Key point *All major sectors must contribute to achieve the* ETP 2012 *2DS.*

Box 1.1 *ETP 2012 scenarios*

6°C scenario (6DS). This scenario is not consistent with a stabilisation of atmospheric concentrations of greenhouse gases. Long-term temperature rise is likely to be ***at least*** 6°C. Energy use will almost double in 2050, compared with 2009, and total GHG gas emissions will rise even more. The current trend of increasing emissions is unbroken with no stabilisation of GHG concentrations in the atmosphere in sight. The 6DS emissions trajectory is consistent with the *World Energy Outlook (WEO)* Current Policy Scenario through 2035 (IEA, 2011a).

4°C scenario (4DS): Energy use and GHG emissions rise, but less rapidly than in the 6DS and, by 2050, at a declining rate. This scenario requires strong policy action. Limiting temperature rise to 4°C will also require significant efforts to reduce other greenhouse gases besides carbon dioxide. It will also require significant cuts in emissions in the period after 2050. The 4DS emissions trajectory is consistent with the *World Energy Outlook (WEO)* New Policy Scenario through 2035 (IEA, 2011a).

2°C scenario (2DS). The emission trajectory is consistent with what the latest climate science research indicates would give a 80% chance of limiting long-term global temperature increase to 2°C , *provided that non-energy related CO_2 emissions, as well as other greenhouse gases, are also reduced.* Energy-related CO_2 emissions are cut by more than half in 2050, compared with 2009, and continue to fall after that. The 2DS emissions trajectory is consistent with the *World Energy Outlook (WEO)* 450 Scenario through 2035 (IEA, 2011a).

While this report assesses progress and makes recommendations in individual technology areas, it should be emphasised that to effectively plan for a clean energy future, governments must approach the transition holistically. The success of individual technologies does not necessarily translate into a successful transition. Much more important is the appropriate combination of technologies within integrated and flexible energy production and delivery systems. Enabling technologies, such as smart grids and energy storage, are equally vital and should be prioritised as part of national energy strategies.

Box 1.2 Quality and availability of progress tracking data

Data included in this analysis is drawn from IEA statistics, country submissions through the CEM and G-20 processes, publicly available data sources, and select purchased data sets. Significant improvements to data quality and completeness would benefit future progress tracking efforts:

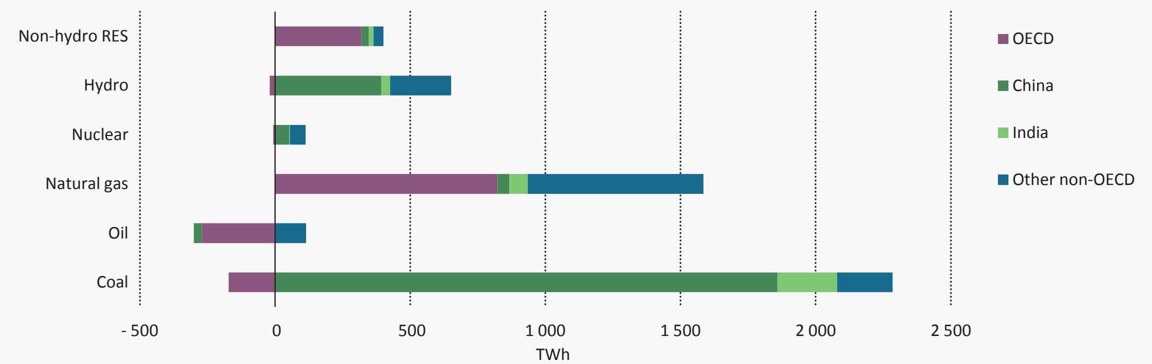
- Major progress in deployment of clean energy technology has been driven by countries outside OECD, but gaps exist in non-OECD country data.
- While public RD&D data is included in this report, private RD&D data is not. While efforts have been made to assess the possibility of enhancing private RD&D data collection, major barriers remain, including lack of appropriate frameworks for industry to confidentially report data, and a general lack of incentive for industry to report this data. Private RD&D is, however, estimated to represent a large share of RD&D spending in some technology areas. Better information on private RD&D spending would help government prioritise allocation of public RD&D funds.
- Significant scope remains for the collection of data related to energy efficiency technologies, including data on appliance efficiencies, sales and market share. In addition better and more complete data on buildings and industry energy efficiency is necessary, in particular given its large-scale potential.
- Data to support the assessment of smartness of electricity grids is underway and will complement this analysis in the future.

Power Generation

The power generation sector is expected to contribute more than one-third of potential CO_2 emissions reductions worldwide by 2020 under the 2DS, and almost 40% of 2050 emissions savings. Enhanced power generation efficiency, a switch to lower-carbon fossil fuels, increased use of renewables and nuclear power, and the introduction of CCS are all required to achieve this objective. Over the past decade, however, close to 50% of new global electricity demand was met by coal (Figure 1.2). This trend must be reversed quickly to successfully reduce power sector carbon emissions and have any chance of meeting the 2DS objectives.

This section focuses on progress in the development and deployment of higher-efficiency, lower-emissions (HELE) coal technology, nuclear power, and renewable power.

Figure 1.2 Changes in sources of electricity supply, 2000-09



Note: Non-hydro RES = renewable energy sources other than hydropower. TWh = terawatt hours.

Key point *Coal remains the largest source for global power generation and supplied the largest share of additional electricity demand worldwide over the past decade. The share of natural gas is also increasing, particularly in some OECD economies.*

Higher-efficiency and lower-emissions coal

Progress assessment

Coal is a low-cost, available and reliable resource, which is why it is widely used in power generation throughout the world. It continues to play a significant role in the 2DS, although its share of electricity generation is expected to decline from 40% in 2009 to 35% in 2020, and its use becomes increasingly efficient and less carbon-intensive. Higher efficiency, lower emissions (HELE) coal technologies - including supercritical pulverised coal combustion (SC), ultra-supercritical pulverised coal combustion (USC) and integrated gasification combined cycle (IGCC) - must be deployed. Given that CCS technologies are not being developed or deployed quickly, the importance of deploying HELE technology to reduce emissions from coal-fired power plants is even greater in the medium term.

From a positive perspective, HELE coal technologies increased from approximately one-quarter of coal capacity additions in 2000 to just under half of new additions in 2011. By 2014, global SC and USC capacity will account for 28% of total installed capacity, an increase from 20% in 2008. Given their rapid expansion, China and India will account for more than one-half of combined SC and USC capacity. More concerning, however, is the fact that in 2010, just below one-half of new coal-fired power plants were still being built with subcritical technology (Figure 1.6).

IGCC technology, in the long term, offers greater efficiency and greater reductions in CO_2 emissions, but very few IGCC plants are under construction or currently planned because costs remain high (Figure 1.4). Recent demonstration plants in the United States had cost overruns that soared far beyond expectations. For example, costs of the US Duke Energy 618 megawatt (MW) IGCC plant (in Edwardsport, IN) increased from an original estimate of USD 3 400 per kilowatt (kW) in 2007 to over USD 5 600/kW in 2011 (Russell, 2011).

Significant variation persists in achieved efficiencies of installed coal power-plant technologies, but the gap between designed and actual operational efficiency is closing. Based on a sample of plant estimates, the efficiency of India's installed subcritical plants stood at 25% in the 1970s, while those installed in 2011 achieve efficiencies up to about 35%; efficiency of the SC and USC among OECD member countries improved from about 38% to close to 45% over the same period (Figure 1.3). Poor-quality coal resources and inefficient operational and maintenance practices often result in lower operational efficiency. Given the long-life span of existing coal infrastructure, a focus on improving operational efficiency of existing plants offers obvious energy and cost-savings opportunities without requiring additional capital investments.

In summary, although the rising share of more efficient coal technologies is positive, policies must be put in place to stop deployment of subcritical coal technologies, curtail increased coal demand and further reduce associated CO_2 emissions. Otherwise, the 2DS cannot be achieved.

Recent developments

From 2009 to 2011, demand for coal has continued to shift, particularly to China and India (Figure 1.7). Since 2000, China has more than trebled its installed capacity of coal, while India's capacity has increased by 50%. On an optimistic note, in 2011 China has built more SC and USC capacity (40 gigawatt, GW) than subcritical capacity (23 GW), and its power capacity from coal has slowed slightly, as its policy of diversification to nuclear and renewable sources takes effect.

Higher-efficiency and lower-emission coal overview

More advanced coal technologies are being deployed, but inefficient coal technologies still account for almost half of new coal fired power plants being built. Unless growth in coal-fired power generation and subcritical coal development curtails, we are unlikely to achieve the 2DS objectives.

Technology developments

Recent technology developments

Despite an increasing coal price, it remains among the cheapest power generation sources

IGCC offers the highest efficiency potential, but still requires dramatic cost reductions to take off

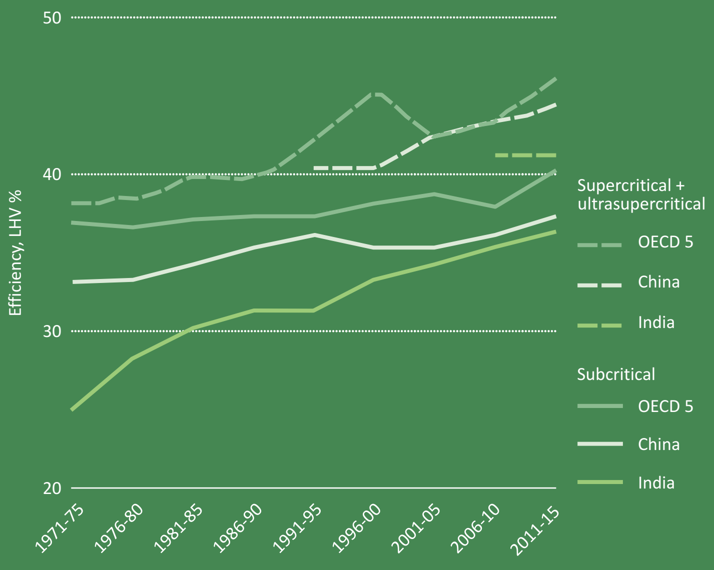
Achieved operational efficiency of coal technologies is improving, but potential for improvement remains

RD&D spending has remained relatively constant over the past decade

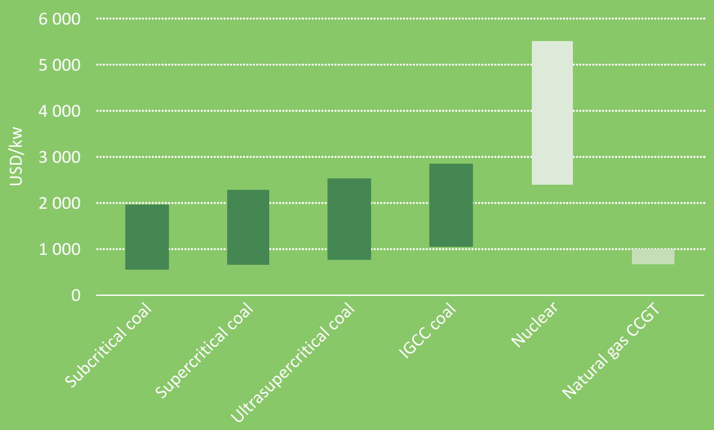
50%

IGCC EFFICIENCY POTENTIAL, BUT SIGNIFICANT COST REDUCTIONS STILL REQUIRED

1.3: Efficiency of coal-fired power plants

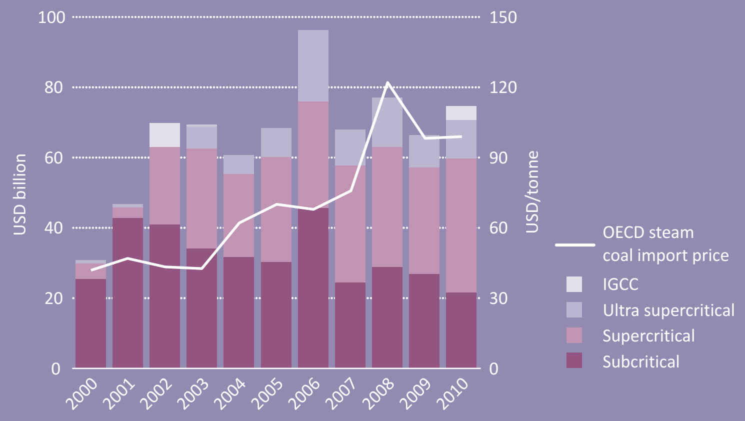


1.4: Investment cost of fossil and nuclear power



Market creation

1.5: Annual capacity investment and coal price



Key trends

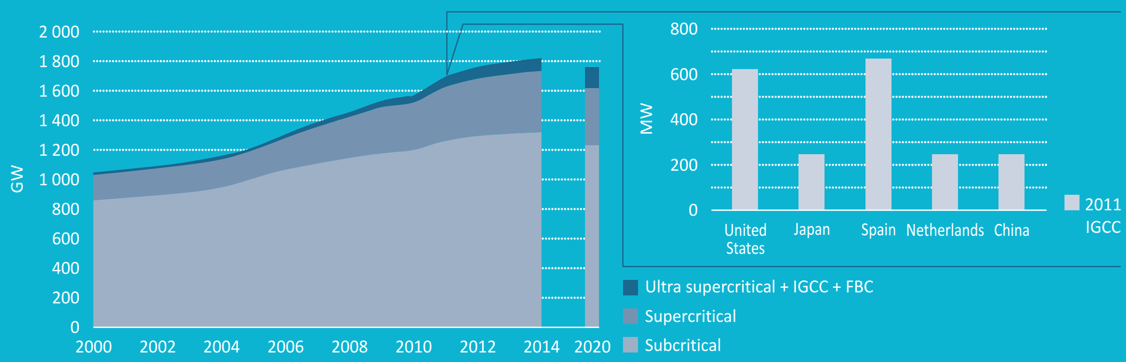
In much of Europe and the United States, natural gas is being favoured over coal for new power generation

Sustained coal price increases may favour more efficient coal technology investment and operation

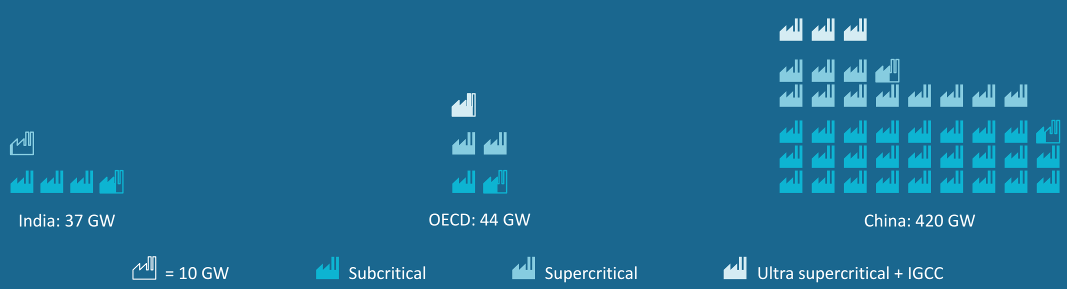
India's next five year plan will aim for 50% - 60% of new coal plants to be supercritical

Technology penetration

1.6: Coal technology deployment by technology (2000-14) and *ETP* 2DS



1.7: Capacity additions in major regions by technology (2000-10)



See notes on page 74

As of 2009, 25% of India's population still had no access to electricity. To meet this large latent demand, India has rapidly increased construction of new coal-fired power plants, with 35 GW of additional capacity in 2011 (a threefold increase over 2010 additions). Until 2010, all new plants in India were built with subcritical technology, but from 2010 to 2011, preliminary estimates suggest that 8.5 GW of SC capacity was installed, compared with 36 GW of new subcritical capacity.

Coal prices increased significantly, which if sustained, may provide greater impetus to build high-efficiency plants and operate existing plants more efficiently. When power prices continue to be kept low, however, the additional capital investments required for higher efficiency plants (Figure 1.5) may prove challenging as profit margins are squeezed or losses incurred:

- Steam coal import prices among OECD member countries – a proxy for international coal prices – have risen sharply from just over USD 40 per tonne (t) in 2004 to more than USD 100/t in 2011 (Figure 1.5).
- Since 2006, coal prices in China have been fully subject to market pricing and domestic coal prices rose by more than 50% from 2006 to 2008 (China Electricity Council, 2010). The continued policy of keeping power prices relatively low meant that China's top five state-owned power generating groups incurred losses of USD 1.9 billion in the first five months of 2011. This transpired despite an increase in power prices, making future investments in higher-cost coal technologies a potential challenge (China Electric Council, 2011).
- In October 2011, Indonesia adopted a new price-indexing policy, which prompted a sudden hike in export prices that increased coal costs for countries, such as India, importing large amounts of Indonesian coal.

A number of OECD member country economies are starting to shift away from coal to gas, due to lower natural gas prices, emerging emissions regulation (particularly in the United States) and greater deployment of variable renewables (in Europe).

Scaling-up deployment

A combination of CO_2 emissions reduction policies, pollution control measures, and policies to halt the deployment of inefficient plants is essential to slow coal demand and limit emissions from coal-fired power generation. Governments are starting to adopt such policies, but must accelerate implementation to avoid a locking in inefficient coal infrastructure (Table 1.2).

- China's 12th Five Year Plan (2011 to 2015) explicitly calls for the retirement of small, ageing and inefficient coal plants and sends a strong message about the introduction of a national carbon trading scheme after 2020. In 2011, six provinces and cities were given a mandate to pilot test a carbon pricing system, which may go into effect as early as 2013. A shadow carbon price is likely to be implicit in investment calculations made by power providers.
- India's 12th Five Year Plan (2012 to 2017) contains a target that 50% to 60% of coal plants use SC technology. Early indications of India's longer-term policy direction suggest that the 13th Five Year Plan (2017 to 2022) will stipulate that all new coal-fired plant constructed be least SC.
- In Europe, the European Union (EU) Emissions Trading Scheme (ETS) and increasing government support for renewable sources of power have largely eliminated the construction of new coal plants.
- In the United States, if the Environmental Protection Agency's (EPA) coal emissions regulation is adopted and the country's continued shift to natural gas for power is sustained, new coal power plant construction will be limited.

Table 1.2 Key policies that influence coal plant efficiency in select countries

Country or region	Policy	Impacts and goals of policy
China	Its 11th Five Year Plan mandated closure of small, inefficient coal-fired power generation. In 12th Five Year Plan, coal production is capped at 3.8 billion tonnes by 2015; all plants of 600 MW or more must be SC or USC technology.	In 2010, 70 GW of small, inefficient coal-fired power generation was shut down; in 2011, 8 GW closed. 17% reduction in carbon intensity targeted by 2015; and 40% to 45% reduction by 2020.
India	The 12th Five Year Plan (2012 to 2017) states 50% to 60% of new coal-fired capacity added should be SC. In the 13th Five Year Plan (2017 to 2022), all new coal plants should be at least SC; energy audits at coal-fired power plants must monitor and improve energy efficiency.	The 12th and future Five Year Plans will feature large increases in construction of SC and USC capacity.
Indonesia	Began indexing Indonesian coal prices to international market rates (2011); put emissions monitoring system in place.	Likely to increase coal prices paid by large importers of Indonesian coal.
European Union	Power generation covered by the EU ETS. The first two phases saw over 90% of emissions credits "grandfathered" or allocated to power producers without cost, based on historical emissions. Beginning with phase 3 in 2013, 100% of credits will be auctioned.	GHG emissions reduction of 21% compared to 2005 levels under the EU ETS. Credit auctioning will provide further incentive to coal plants to cut emissions.
United States	The US EPA's GHG rule recommends use of "maximum available control technology".	New plants are all likely to have SC or USC technology, although pending EPA regulation, combined with low natural gas prices, suggest limited coal capacity additions in the future.
Australia	Generator efficiency standards defined best practice efficiency guidelines for new plants: black coal plant (42%) and brown coal (31%). Both have higher heating value net output. Emissions trading is under consideration for in 2013.	New plants will likely be SC or USC technology.

Nuclear power

Progress assessment

The nearly 440 nuclear reactors in operation across the world remained virtually constant over the last decade, with 32 reactors shut down and the same number connected to the grid. Overall, nuclear capacity increased by more than 6%, due to installation of larger reactors and power uprates in existing reactors.

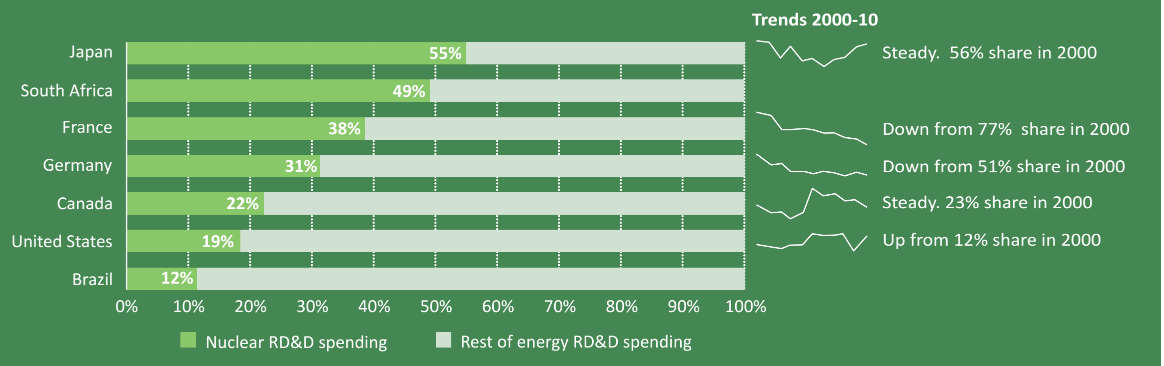
In 2010, nuclear energy was increasingly favoured as an important part of the energy mix - subject to plant life extensions, power uprates and new construction - given its competitiveness (especially in the case of carbon pricing) as an almost emissions-free energy source. Ground was broken on 16 new reactors, the most since 1985, mainly in non-OECD countries (Figure 1.10); in 2011, 67 reactors were under construction, 26 in China alone (Figure 1.12). The time length and cost of construction for nuclear power plants varies significantly by region and reactor type. Average overnight costs of generation III/III+ reactors range from about USD 1 560/kW to USD 3 000/kW in Asia and to about USD 3 900/kW to 5 900/kW in Europe (NEA, 2010). In terms of construction time, some are built in as little as four years, whereas in rare cases, it has taken as long as 20 to 27 years to complete construction (*e.g.* Romania, Ukraine).

Nuclear power overview

The vast majority of countries with nuclear power remain committed to its use despite the Fukushima accident, but projections suggest that nuclear deployment by 2025 will be below levels required to achieve the 2DS objectives. In addition, increasing public opposition could make government ambitions for nuclear power's contribution to their energy supply harder to achieve.

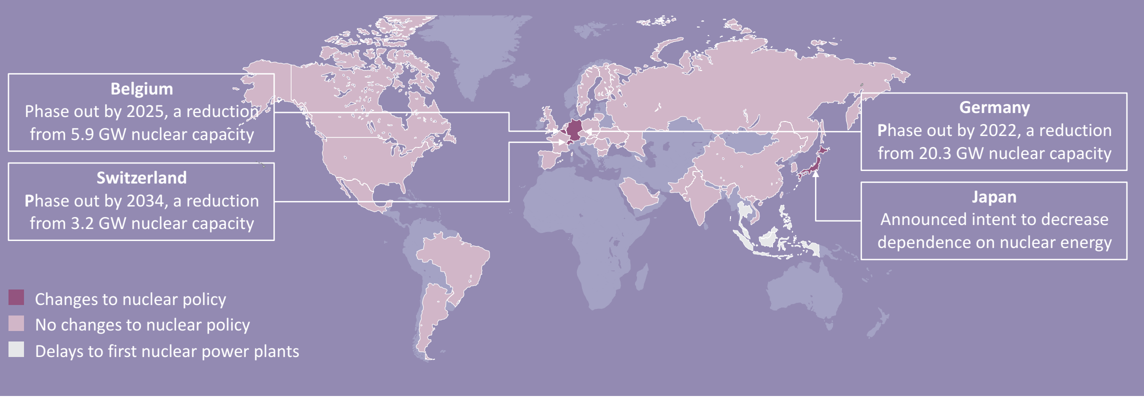
Technology developments

1.8: Share of nuclear in government energy RD&D spending, 2010

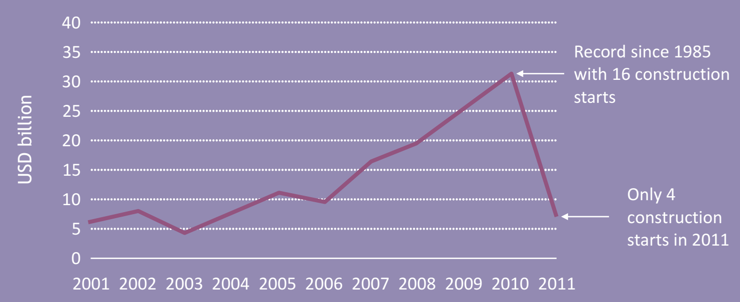


Market creation

1.9: Nuclear policy post-Fukushima



1.10: Annual capacity investment

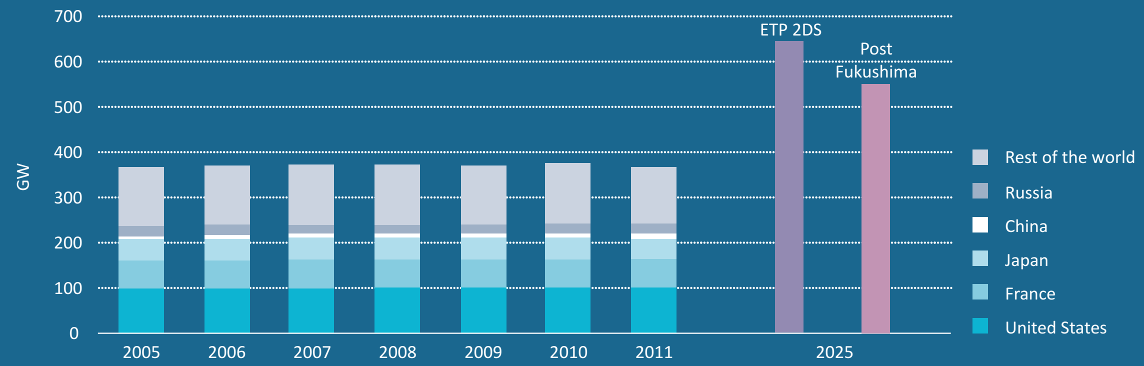


80

USD BILLION AVERAGE ANNUAL NEEDED TO 2025 TO ACHIEVE 2DS OBJECTIVES

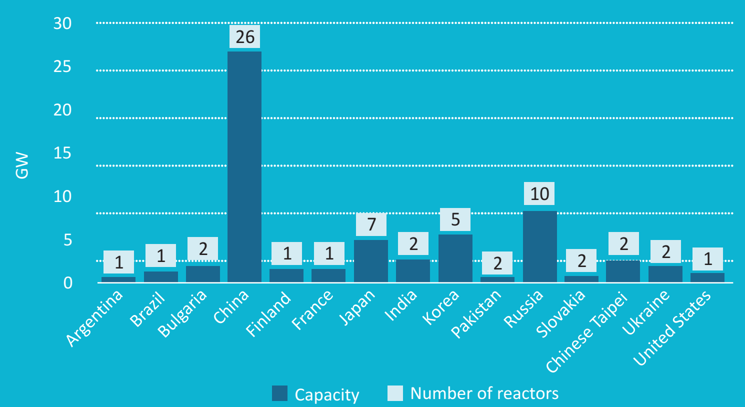
Technology penetration

1.11: Installed capacity and 2DS objectives



Source: IAEA

1.12: Reactors under construction, end 2011



Source: IAEA

Key developments

Stringent safety and risk-management protocols, enhanced transparency in management and decision making, and major public engagement efforts are necessary to achieve planned nuclear deployment goals

China is currently building the most reactors globally; their reactor construction times have decreased impressively, and are likely to become the fastest in the world

See notes on page 74

Recent developments

Since 2011, the earthquake and tsunami damage to the Fukushima-Daiichi nuclear power plant in Japan has cast some uncertainty over the future of nuclear power. Some countries are choosing to phase out nuclear reactors; most confirmed that they are keeping nuclear in their energy mix or will develop it further, albeit at a less ambitious rate than previously anticipated (Figure 1.9; Table 1.3). In addition, countries planning to introduce nuclear power for the first time (*e.g.* Indonesia, Thailand, Malaysia and the Philippines), are delaying and, in some cases revising, their plans.

Table 1.3 Nuclear policies, post-Fukushima

	Countries	Summary and implications
No changes to nuclear targets as a result of Fukushima accident	Argentina, Armenia, Bulgaria, Brazil, Canada, China*, Czech Republic, Finland, France, Hungary, India, Korea, Lithuania, Mexico**, Netherlands, Pakistan, Poland, Romania, Russia, Slovak Republic, Slovenia, Spain, Sweden, Taiwan, Ukraine, United Kingdom, United States.	Most countries have not changed their plans for nuclear energy as a result of the Fukushima accident. It is, however, expected that the execution and cost of projects will take longer than previously planned, given potential additional safety requirements, siting and permitting restrictions, and possible public opposition.
Changes to nuclear targets post-Fukushima	Belgium	Will phase out nuclear power by 2025, a reduction of 5.9 GW from nuclear capacity.
	Germany	Plans to phase out nuclear power use for commercial power generation by 2022, a reduction of 20.3 GW from nuclear capacity.
	Japan	Announced intent to decrease dependence on nuclear energy in the mid- and long term.
	Switzerland	Will phase out nuclear power by 2034, a reduction of 3.2 GW from nuclear capacity.
Delays or changes to first nuclear power plant introductions	Thailand, Malaysia, Philippines, Indonesia.	Further assessments to planned introductions of nuclear power, resulting in delays, or modifications to plans.

* After Fukushima, China froze the approval process for new plants, pending lessons learned from the damage, especially with respect to siting. The currently ambitious new building programme is under revision and may result in a decrease of 10 GW compared to 90 GW initially planned by 2020.
** Mexico recently declared that it was abandoning plans to build 10 reactors in the next 15 years and will instead develop gas-fired generation capacities. The decision is not the result of the Fukushima accident.

Following the Fukushima damage, all countries operating nuclear reactors have carried out stress tests to assess plant safety in the event of extreme natural events (earthquakes and flooding). The results, currently under review by regulatory bodies, are expected to increase the stringency of safety standards and thus require more investment in safety upgrades, especially for older plants. Overall, the outcome of the stress tests may speed up the rate at which older plants are shut down (making approval of reactor life extensions more difficult to obtain); slow the start of new reactor projects (with siting and licensing expected to take more time), and negatively affect public acceptance of nuclear energy. In 2011, construction began on only four new nuclear reactors, a significant drop from 2010 (Figure 1.10).

Taking into account the nuclear phase-out in Germany, Switzerland and Belgium, potentially shorter reactor life spans, and longer planning and permitting procedures, nuclear energy deployment is projected to be about 100 gigawatts (GW) below the level required to achieve the 2DS objectives by 2025[7]. This represents a drop of about 15% against capacity projections before the Fukushima accident (Figure 1.11). At this rate, it is unlikely that nuclear deployment levels under the 2DS will be achieved.

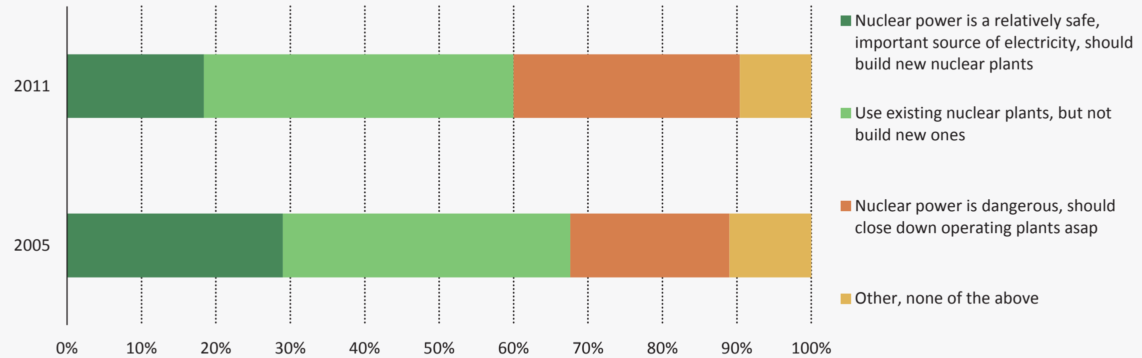
Interest in small modular reactors (SMRs) may revive, given their suitability to small electric grids. Their modularity and scalability, with more efficient transport and construction, should lead to shorter construction duration, lower cost and overall investment. Large-scale nuclear plants, however, are still more competitive than SMRs in terms of cost of kWh produced. The United States is licensing some of the more mature SMR designs, but it is unlikely at this point (given post-Fukushima re-analysis and low gas prices in the United States) that many SMR projects will launch before 2020.

Scaling-up deployment

In the post-Fukushima era, scaling-up nuclear power faces increasing challenges. A 2011 survey compared public opinion of nuclear power before and after the Fukushima nuclear accident, finding that public opinion against existing and new nuclear power plants rose from 60% in 2005 to 72% in 2011 (Figure 1.13).

To reach nuclear goals, countries need to make significant efforts to convince an increasingly sceptical public that nuclear power should continue to be part of the future energy mix. In addition, rising costs associated with enhanced safety measures, difficulty in extending reactor life spans, and longer and more stringent processes for siting and licensing of new plants must be overcome. Governments and plant operators also need to increase transparency in their decision-making processes and implement updated safety and risk-management protocols. Strong, independent nuclear regulatory bodies are required for industry oversight.

Figure 1.13 Public opinion of nuclear energy



Note: Countries included in survey data include France, Germany, India, Indonesia, Japan, Mexico, Russia, United Kingdom and the United States.
Source: GlobalScan, 2011.

Key point *A 2011 survey suggests that between 2005 and 2011, an increasing share of citizens responded that nuclear power was dangerous, and all operating plants should be shut down.*

7 2025 selected to highlight full impact of major plans to phase out nuclear energy.

Renewable power

Progress assessment

Renewable power (including hydropower, solar, wind, biomass, geothermal and ocean) progressed positively (posting 13% average annual growth in installed capacity) in the last 10 years. While starting from a small base, non-hydro renewables have been growing more rapidly, with generation doubling over the past five years (Figure 1.17). In 2010, their share of total electricity production remained at about 3%.

While the portfolio of renewable technologies is becoming increasingly competitive, given the right resource and market conditions, renewables are still more expensive than fossil fuel-based power technologies (Figure 1.15). Costs of some renewables have however dropped impressively over the past decade (in particular, solar PV).

From 2000 to 2011, driven by strong policy support, ***solar PV*** was the fastest-growing renewable energy technology worldwide with an average annual growth above 40% in this period. Growth, however, has been concentrated in only a few markets (Germany, Italy, the United States and Japan). Regions with good solar potential (*e.g.* Africa and parts of Asia) need to add significant solar capacity to meet the technology contribution share in the 2DS scenario.

Progress in ***concentrated solar power*** (CSP) has been less impressive. The first commercial plants, built in the 1980s in the United States, are still in operation, but further project development lagged in the 1980s and 1990s. Today, the industry has hundreds of MW under construction and thousands under development worldwide. Spain has taken over as the world leader in CSP and, together with the United States, accounted for 90% of the market in 2011. Algeria, Morocco and Italy also have operational plants, while Australia, China, Egypt, India, Iran, Israel, Jordan, Mexico, South Africa and the United Arab Emirates are finalising or considering projects. While the project pipeline is impressive, the economic recession and lower PV costs show evidence of diverting and slowing CSP projects (*e.g.* the United States converted a number of planned CSP projects to PV).

Onshore wind is on pace to achieve the 2DS scenario objectives by 2020, if its current rate of growth continues (27% average annual growth over the past decade). It is among the most cost-competitive renewable energy sources and can now compete without special support in electricity markets endowed with steady winds and supportive regulatory frameworks (*e.g.* New Zealand and Brazil). China, United States, Germany and Spain built the majority of the new power capacity and generation from wind in the past decade.

Offshore wind is an emerging technology and requires further RD&D to enhance technology components (*e.g.* offshore wind platforms and large wind turbines) and bring down technology costs. Several governments have recently invested substantial amounts in large-scale demonstration activities. For example, in May 2011, the United Kingdom committed over GBP 200 million (USD 317 million) to establish a network of technology and innovation centres, including the Offshore Renewable Energy and Technology Innovation Centre. China and Germany, plus other governments, are making offshore wind a policy priority. The next few years will determine the future success of this technology.

Box 1.3 **Achieving competitiveness through well-designed policy support**

The competitive position that onshore wind technologies enjoy today is the result of a technology push driven by Denmark in the 1980s. Strong RD&D funding and programme support, coupled with the creation of sufficient industrial capacity and deployment of effective policy frameworks, is a powerful example of how governments can foster technology progress and create markets.

Average annual growth in ***geothermal*** electricity generation reached 3% between 2000 and 2010. Geothermal electricity provides a significant share of total electricity demand in Iceland (25%), El Salvador (22%), Kenya (17%), the Philippines (17%), and Costa Rica (13%). In absolute terms, in 2010, the United States produced the most geothermal electricity, at 17 TWh.

Where an accessible high-temperature geothermal resource exists, generation costs are competitive with other power generation alternatives. Despite this, geothermal electricity generation has not reached its full potential and is falling behind the deployment levels required to achieve the 2DS objectives by 2020. Given the unique nature of geothermal resources, the technology is still considered relatively risky and is only exploited in a limited number of countries.

Electricity from ***solid biomass, biogas, renewable municipal waste and liquid biofuels*** has been steadily increasing since 2000, at an average of 8% annual growth. This progress is broadly on track with the 2DS objectives. But future progress will depend heavily on the cost and availability of biomass.

Hydropower provided about 82% of all electricity from renewable energy sources in 2010, increasing at an average rate of about 3% per year between 2000 and 2010. China, Brazil, Canada, the United States and Russia are the world leaders in hydro power. In Brazil (80%) and Canada (60%), hydropower provides the largest share of power generation.

In the next decade, the installed capacity of hydropower will increase by approximately 180 GW, if projects currently under construction proceed as planned (a 25% increase of current installed capacity). One-third of this increase will be in China and Brazil alone; India also has large capacity under construction (IEA, 2011c). Delivering these projects on time and in a sustainable way is essential to achieve the 2DS goal, and additional projects should be identified and developed to offset any delays or cancellations.

Recent developments

2011 was an active year for renewable energy markets. For the first time, global investment in new renewable power plants (USD 240 billion) (Figure 1.16) surpassed fossil-fuel power plant investment, which stood at USD 219 billion (BNEF, 2011; IEA[8]). This is a positive development, but several factors point to a potentially turbulent 2012. Rapid reductions in technology cost will stimulate deployment, but industry consolidation is looming as number of smaller and higher-cost manufacturers become uncompetitive, in particular for PV and wind. The slow economic recovery across Europe and parts of North America will likely have different impacts from country to country: In those countries where long-term, effective and cost-efficient policies are implemented, renewables will be relatively sheltered from the crisis. On the contrary, in countries where governments are rethinking policy schemes, investor confidence may decline. In general, the costs of financing are increasing, and developers may struggle to raise capital for renewable projects that require intensive up-front capital investments.

A number of market developments offer useful insights. In 2010, China became the world leader in total installed capacity of wind, ahead of the United States, who had a difficult year. 2011 saw China keeping its lead, while the United States market continued to grow compared to 2010. In China however, out of the 63GW of cumulative installed onshore wind capacity, only 47 GW were grid connected at the end of 2011. The government has taken steps to remedy this situation. In general, the overall trend is clear: the centre of gravity for wind energy markets has begun to shift from OECD regions to Asia, namely, China (IEA, 2011c).

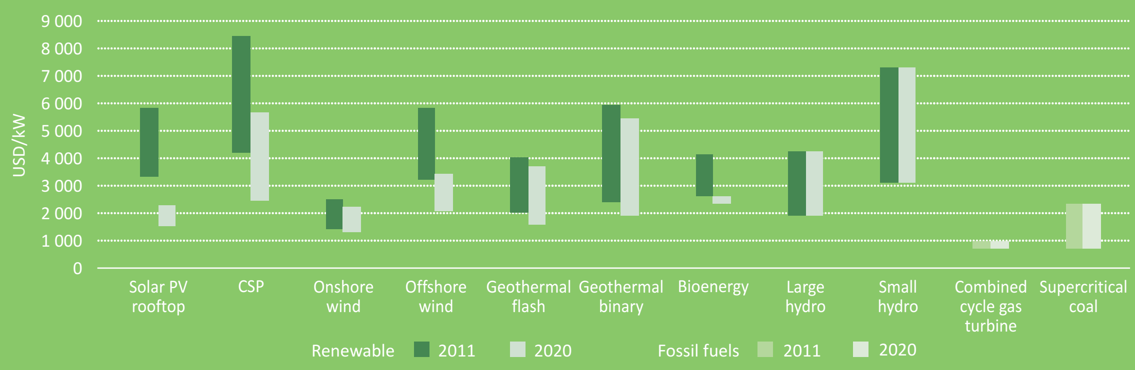
8 Data for non-hydro renewables from BNEF, 2011; hydro investment estimates are derived from IEA analysis.

Renewable power overview

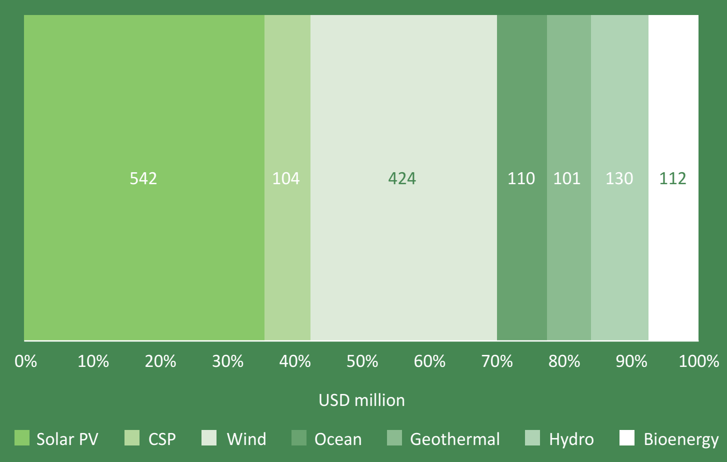
A portfolio of renewable power technologies have seen positive progress over the past decade, and are broadly on track to achieve the 2DS objectives by 2020. Some renewable technologies still need policy support to drive down costs, boost competitiveness and widen their market reach. Enhanced RD&D is also needed to speed up the progress of promising new generation renewable technologies that are not advancing quickly enough (e.g. CSP and offshore wind).

Technology developments

1.14: Technology investment costs, 2011 and 2DS objectives



1.15: Public RD&D spending in 2010



Key technology trends

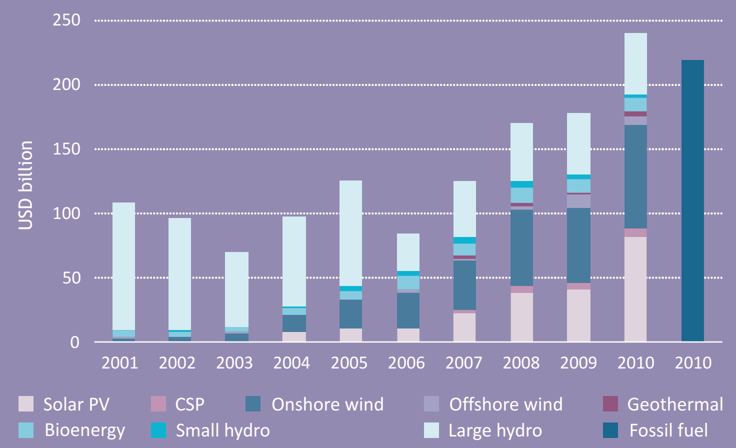
The different renewable technologies are at very different stages of development

A portfolio of renewables is becoming increasingly competitive

Solar PV has seen particularly impressive progress with up to a 75% decrease in system costs in just three years in some countries

Market creation

1.16: Annual capacity investment



Average annual investments required to 2020

Onshore wind 60

Offshore wind 10

Solar PV 50

CSP 15

Hydro 80

Bioenergy 10

Geothermal 10

USD billion

Technology penetration

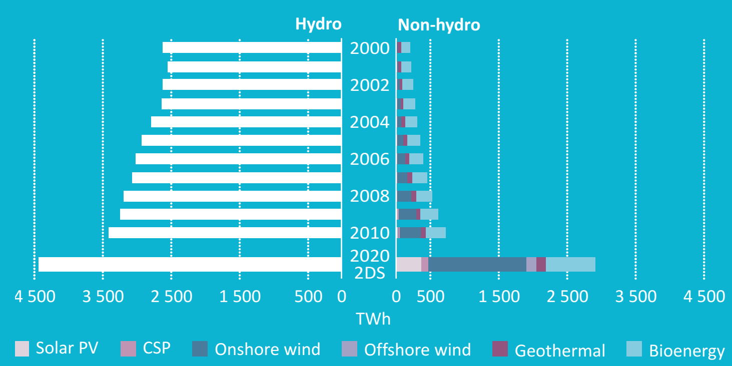
Deployment to new markets

Hydropower, bioenergy, geothermal and onshore wind are already deployed across many countries and continents

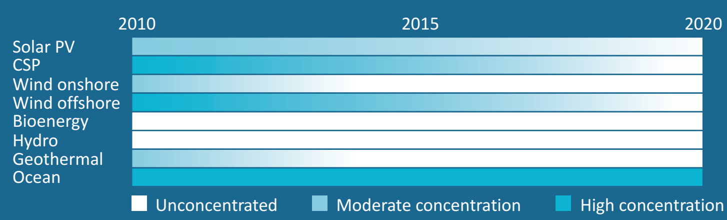
Solar PV must deploy to more countries with large resource potential to maintain high rates of growth

Offshore wind, solar CSP, and ocean hold large potential, but the scale-up of projects over the next decade is critical to achieve 2DS targets

1.17: Renewable power generation and 2DS



1.18: Market concentration and required diffusion



See notes on page 74

Under favourable market and resource conditions, onshore wind is also nearing competitiveness. In Brazil's 2011 capacity auctions, wind energy was more competitive than gas generation, even in the absence of specific government support for wind energy. This is promising for the future of renewables competitiveness.

Solar PV had a record market deployment year in 2011, with 27 GW of new capacity installed worldwide, an increase of almost 60% with respect to the 17 GW of new additions in 2010. Italy became the first market worldwide (9 GW), followed by Germany (7.5 GW), which remains the country with the largest cumulative installed capacity. High rates of PV deployment resulted from attractive and secure rates of return for investors, while government-supported tariffs remained high while system prices decreased rapidly (in some countries, PV system prices decreased by 75% in three years). However, the growth of PV has so far remained concentrated in too few countries. This has escalated total policy support costs, triggering an intense debate about the need to reduce tariffs and/or introduce caps to policy support. These uncertainties may reduce future investor confidence in these markets. In the future, it is likely that European market deployment will slow, while new markets will emerge (*e.g.* China and India) and other OECD markets will increase (*e.g.* the United States and Japan).

Scaling-up deployment

While progress in renewables has largely been on the upswing, the challenge of reaching or maintaining strong deployment of many renewable technologies should not be underestimated, particularly as the cumulative installed capacity grows and issues of grid integration of variable renewables such as wind and PV emerge in some countries. Keeping on track for the 2DS goals will require:

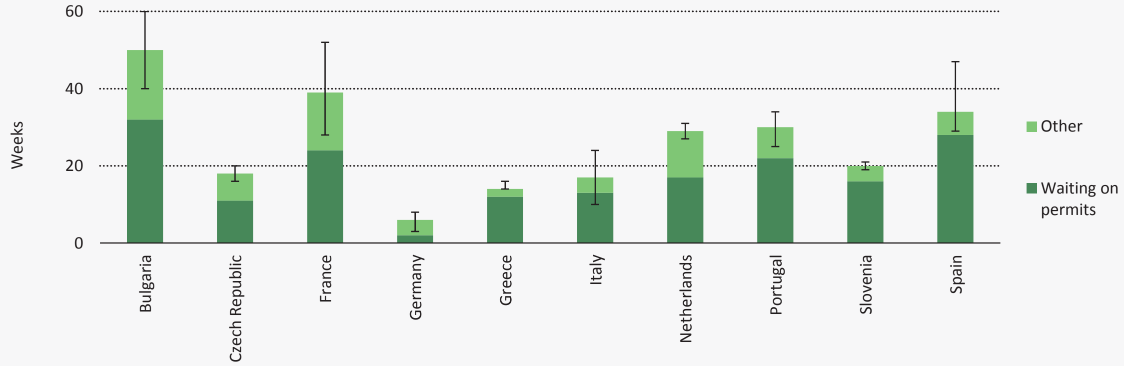
- in leading countries, sustained market deployment of renewable technologies that best fit their local market conditions (in terms of costs, resources and technology maturity);
- further expansion of renewables into markets with large resource potential, beyond the efforts in a few market-leading countries; and
- continued RD&D into emerging technologies, such as offshore wind, CSP and enhanced geothermal (Figure 1.14).

Government action is needed in a number of critical areas, such as ***effective and efficient policy design:*** An increasing number of governments are adopting renewable energy policies; over 80 countries had renewable energy policies in place in 2011 (*e.g.* feed-in tariffs, tradable green certificates, tenders, tax incentives, grants etc). These policies must, however, be designed to effectively keep pace with technology cost reductions, to keep policy costs to governments moderate and maintain investors' confidence , all while helping renewables to compete.

***Smooth planning and permitting processes*:** Delays in planning, restrictions to plans, lack of co-ordination among different authorities and delays in authorisation can jeopardise projects and significantly increase transaction costs for investors. Currently, the length of time for project approval processes varies significantly across countries. For example, waiting for permits for roof-top solar projects in certain European countries (with the exception of Germany) accounted for over 50% of the total project timeline (Figure 1.19). For emerging technologies, such as CSP and offshore wind, it is important to develop clear, streamlined planning and permitting processes so these technologies can be deployed rapidly.

Broader environmental management and public acceptance: Lack of public acceptance and sustainability concerns slowed the development of some renewable energy technologies. Hydropower is one example; multilateral development banks halted investment in

Figure 1.19 Time needed to develop small-scale roof-top photovoltaic projects in select European Union countries



Note: Average values shown; error bars show minimum and maximum total durations.
Source: PV legal, 2010; from IEA, 2011c.

Key point *Overcoming non-economic barriers such as planning and permitting process delays, is central to reducing project transaction costs and uncertainties.*

hydropower projects in the 1990s due to environmental and social challenges[9]. Major efforts continue to address these problems through the development of sustainability assessment protocols[10]. CSP is another example; many favourable sites are in semi-arid regions, where water scarcity can be an issue, given water requirements for CSP production. Managing water resources and associated environmental impacts are essential to ensuring the long-term sustainability and acceptance of this technology. In fact, these same issues need to be more broadly addressed for other clean energy technologies (*e.g.* CCS, bioenergy and biofuels).

***Grid integration and priority access*:** While many countries implemented attractive incentives for developing renewables projects, the power produced needs to be effectively integrated into the grid, along with assurances that energy will be purchased. This can be achieved through policy tools, such as priority dispatch and renewable off-take agreements[11].

Market diversification: The growth in PV is moderately concentrated in relatively few countries. To maintain positive growth rates, these and other renewable technologies need to expand into areas of significant resource potential (Figure 1.18).

Continued support for innovation and RD&D: Several technologies are approaching market competitiveness with conventional power generation for base-load (*e.g.* onshore wind, some bioenergy technologies) or for peak-load (*e.g.* solar PV), but less mature technologies (such as advanced geothermal, offshore wind and CSP) still require government RD&D support to improve performance and reduce technology costs (Figure 1.14). Offshore wind technologies require larger wind turbines that can be deployed off-shore and platforms suited to deeper water. For CSP, improved heat-transport media and storage systems are critical. Support for RD&D of these renewables needs to be coupled with continued measures that foster early deployment and provide opportunities for learning and cost reduction.

9 Multilateral development bank investment in hydropower project developments has since increased, with the World Bank investing over USD 1 billion in hydropower projects in 2008.
10 For example, IEA Hydropower Implementing Agreement, *Recommendations for Hydropower and the Environment;* International Hydropower Association, *Hydropower Assessment Sustainability Protocol.*
11 A renewables off-take agreement requires utilities to purchase produced renewable electricity.

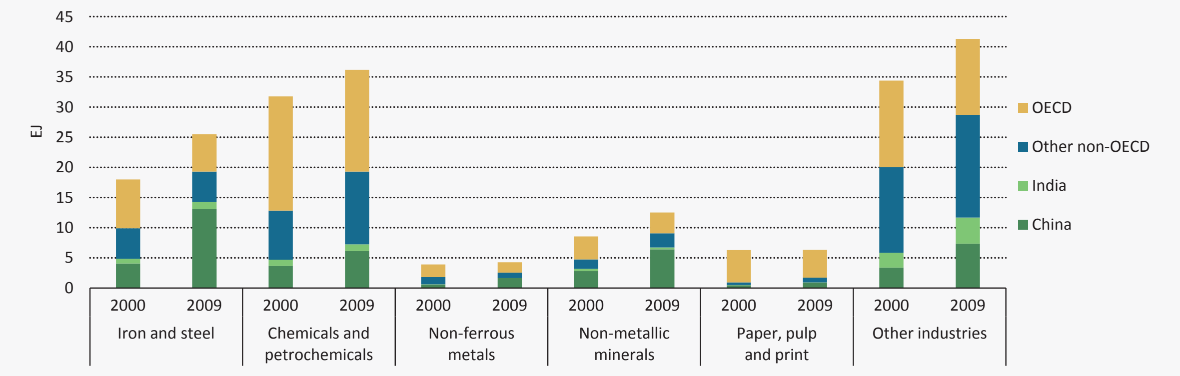
Industry

Industry accounts for about one-third of total final energy consumption and almost 40% of total energy-related CO_2 emissions. Developed economies relied on industrial development to drive economic growth, and many developing economies are now following a similar path. CO_2 emissions in the industry sector is projected to increase by close to 30% by 2020, but to achieve the 2DS objectives, industry must limit its increase of direct CO_2 emissions in 2020 by about 17% compared to the current level. If industry takes advantage of available options – deploying existing best available technologies (BATs), developing new technologies that deliver improved energy efficiency or enable fuel and feedstock switching, and promoting recycling and introducing CCS – it can achieve its 2DS targets. Over the next decade, priority should go to applying available BATs to newly built and refurbished manufacturing facilities, retrofitting existing plants, and optimising production processes to maximise energy efficiency.

Progress assessment

From 2000 to 2009, production and energy consumption in all industry sectors increased, although at different rates (Figure 1.20). Since 2000, growth has been primarily driven by developing economies: namely, China, which doubled its industrial energy consumption; and India, whose energy demand increased by 50%. OECD member countries experienced a major downturn in production, due in part to the economic recession since 2008: total materials production[12] in the OECD decreased from 1 691 million tonnes (Mt) in 2007 to 1 373 Mt in 2009.

Figure 1.20 Energy use by industry sector and region in 2000 and 2009

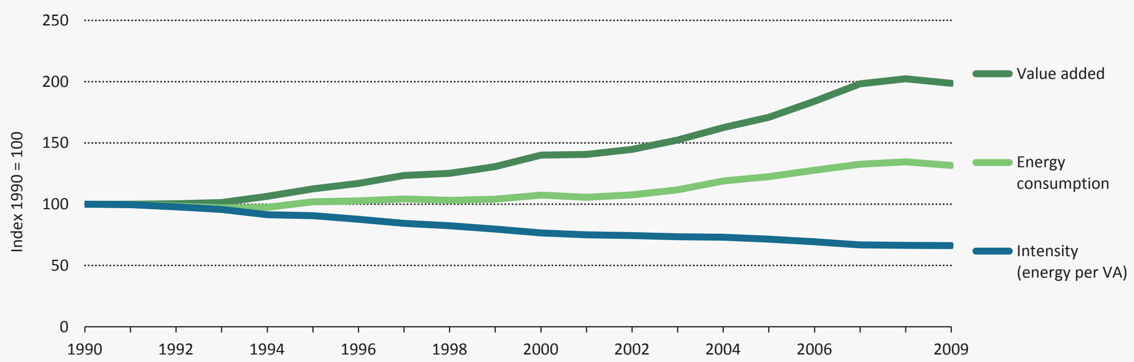


Key point *Energy use has increased across all industry sectors, but is primarily driven by China and emerging countries.*

12 Includes crude steel, cement, primary aluminium, paper and paperboard and feedstock use.

Improvement in industry energy intensity[13] helped slow growth in its energy consumption. Between 1990 to 2009, manufacturing value added doubled, while energy intensity decreased by an average of about 2% per year (Figure 1.21). From 2000 to 2009, however, rates of energy intensity improvement declined to an average of 1.6% per year. This data should, however, be treated with caution, as improvements in industry energy intensity does not necessarily mean that the industry is becoming more energy efficient. The changes in energy intensity can also be attributed to changes in the structure of the economy (including shifts from and towards energy-intensive industries) and fluctuations in materials prices.

Figure 1.21 **Progress in industrial energy intensity**



Note: Sector energy consumption data includes crude steel, cement, primary aluminium, paper and paperboard and feedstock use.
Sources: IEA Indicator analysis; Added value data: UN National Account, 2011.

Key point *Between 1990 to 2009, energy intensity improved on average at 2% per year.*

While this progress is laudatory, to achieve the 2DS objectives, the five most energy intensive industrial sectors[14] need to make marked progress in incorporating energy-efficient technologies, recycling and energy recovery, CCS, alternative materials use, and fuel and feedstock switching (Table 1.4). In the short term, though, these sectors must increase efficiency by steadily adopting the most efficient BATs when building or retrofitting facilities and optimising production systems, and manufacturing practices to reduce emissions significantly. After 2020, the introduction of CCS and the deployment of new technologies becomes crucial. These energy intensive sectors have significant untapped potential for CO_2 emission reductions needed to achieve the 2DS objectives.

Iron and steel

The recent rapid expansion of crude steel production (67% growth between 2000 and 2010) and the resulting additional capacity positively affected the energy efficiency of the iron and steel industry (World Steel, 2011). Additional capacity has reduced the average age of the capital stock, and the new plants tend to be more energy-efficient, although not all have introduced BATs. In several countries, existing furnaces have been retrofitted with energy-efficient equipment and energy-efficiency policies have led to the early closure of inefficient plants. The iron and steel sector still has the technical potential to further reduce energy consumption by approximately 20%.

13 The amount of energy used per unit of output, measured in terms of tonne of production.
14 These include the iron and steel, cement, chemicals, pulp and paper, and aluminium sectors.

Table 1.4 Share of technology contribution to industry CO_2 emissions reductions potential by 2020

Industry sector	Average energy efficiency	Recycling and energy recovery	CCS	Fuel and feedstock switching/ alternative materials	Total savings (Mt CO_2)
Iron and steel					354
Cement		na			119
Chemicals					440
Pulp and paper					49
Aluminium			na		7
Total					969

Note: Share of emissions reduction potential by 2020 denoted as follows: darkest green ≥50%; 10≤ medium green ≤50% ; light green ≤10%; Average energy efficiency includes improvements to existing facilities and the use of BATs as new facilities are built.

Key point *Over the next decade, improvements in energy efficiency in the five major sectors play the greatest part in reducing CO_2 emissions from industry.*

Cement

The thermal energy consumption of the cement industry is strongly linked to the type of kiln used and the production process. Vertical shaft kilns consume between 4.8 gigajoules per tonne (GJ/t) and 6.7 GJ/t of clinker[15]. The intensity of wet production process varies between 5.9 GJ/t and 6.7 GJ/t of clinker. The long drying process requires up to around 4.6 GJ/t of clinker; adding pre-heaters and pre-calciners (considered BAT in this sector) further reduces the energy requirement to between 2.9 GJ/t and 3.5 GJ/t of clinker.

Since 1990, the use of dry production process has increased in all geographical regions for which data are available. Despite the recent improvements in energy and emissions intensity, there is still significant room for improvement. If all plants used BATs, the global intensity of cement production could be reduced by 1.1 GJ/t of cement (from an intensity of 3.5 GJ/t of cement today).

Chemicals and petrochemicals

It is difficult to measure the physical production of the chemical and petrochemical industry, given the large number of products. Plastic production represents the largest and fastest-growing segment of the chemical and petrochemical sector, representing approximately 75% of the total physical production (Plastics Europe, 2011; SRI Consulting, 2009). The use of best practice technologies, process intensification, cogeneration[16], recycling and energy recovery together can save over 13 EJ in final energy.

Aluminium

The International Aluminium Institute (IAI) annually surveys facilities worldwide[17] on energy use in production. The average energy intensity of aluminium refineries, reported in IAI statistics, was 12 GJ/t of aluminum in 2000. The intensity remained relatively stable throughout the decade because most improvements occurred earlier, but in 2010, intensity saw a decrease to 11.2 GJ/t of aluminium. The application of BAT in the aluminium industry can help further reduce energy use in aluminium production by approximately 10%, compared with current levels.

15 Clinker is a core component of cement made by heating ground limestone and clay at a temperature of about 1 400°C to 1 500°C.
16 Cogeneration refers to the combined production of heat and power.
17 The survey covers around 70% of global metallurgical alumina and primary aluminium production.

Pulp and paper

The main production facilities for the pulp and paper sector are pulp mills, and integrated paper and pulp mills. Most of the sector's efficiency improvements have come from integrated pulp and paper mills that use recovered heat in the production process. Additionally, the production of recovered paper pulp uses 10 GJ to 13 GJ less energy per tonne than the production of virgin pulp. Current levels of recovered paper production vary from 30% in the Russian Federation to over 60% in Japan and Germany. Recycling rates can be increased in most regions, especially in many non-OECD countries, where the recovered paper production rate varies from 10% to 50%. The upper technical limit to waste paper collection is over 80% (CEPI, 2006), but practically it may be closer to 60%. Globally, the sector has improved energy intensity by 1.8% per year since 2005.

Recent developments

The global economic recession has, in many cases, slowed manufacturing production, resulting in a short-term increase in energy intensity because production processes are not optimised:

- World crude steel production fell from 1 351 Mt in 2007 to 1 232 Mt in 2009, mostly in OECD economies, where production sank by 25%. Led by China and India, steel production in Asia continued to climb, although at a slower place (World Steel, 2011).
- The cement industry grew, but the rate of growth dropped to 4% between 2007 and 2009 (compared to an overall average of 7% between 2000 and 2009). The sector's energy intensity improved in 2009 to 3.52 GJ/t cement (up from 3.38 GJ/t in 2007).
- From 2008 to 2009, primary aluminium production slumped by 7%, but preliminary data for 2010 suggests the beginning of recovery.

Scaling-up deployment

Important economic barriers to achieving energy savings potential in industry (*e.g.* required upfront capital investments, low fuel costs and long life spans of infrastructure) can be targeted by government policies and measures: energy management policies, minimum energy performance standards for industrial equipment, electric motors and systems, energy efficiency services for small- and medium-size enterprises, and complementary economic and financial policy packages that support investment in energy efficiency (Table 1.5). In particular, uptake of ISO 50001 energy-management systems and standards can help industry sectors continuously improve energy performance.

Many governments have advanced energy efficiency by implementing such policies, but more aggressive measures are required to achieve the industry sector's full energy-efficiency potential and the 2DS objectives.

Table 1.5 Policy action to enhance industrial energy efficiency

Recommendations	Policy options
Energy management in industry	Industrial energy management policies, including monitoring and measuring energy consumption, identifying energy-savings potential, setting benchmarks for industry energy performance, publicly reporting progress.
High-efficiency industrial equipment and systems	Mandatory minimum energy performance standards for electric motors and other categories of industrial equipment, such as distribution transformers, compressors, pumps and boilers. Measures to address barriers to energy-efficiency optimisation in design and operation of industrial processes (*e.g.* providing information on equipment energy performance, training initiatives, audits, technical advice and documentation, and system-assessment protocols).
Energy efficiency services for small and medium-sized enterprises	Support for energy audits, supported by information on proven energy efficiency practices; energy performance benchmarking.
Complementary policies to support industrial energy efficiency	Removal of energy subsidies and internalisation of external costs of energy through policies, such as carbon pricing. Increased investment in energy-efficient industrial equipment and processes through targeted financial incentives, such as tax incentives, risk-sharing or loan guarantees with private financial institutions, and promotion of the market for energy performance contracting.

Source: Adapted from IEA, 2011b.

Buildings

Residential and commercial buildings account for approximately 32% of global energy use and almost 10% of total direct energy-related CO_2 emissions. Including electricity generation emissions (plus district heat), buildings are responsible for just over 30% of total end-use energy-related CO_2 emissions.

Energy demand from the buildings sector will more than double by 2050. Much of this growth is fuelled by the rising number of residential and commercial buildings in response to the expanding global population. Between 2000 to 2010, global population rose by 12.9%. In the residential sector, mounting energy demand was further exacerbated as the number of people per household decreased in many economies (average OECD occupancy in the residential sector dropped from 2.9 in 2006 to 2.6 in 2009) and the size of households increased. For example, in the United States, average household size increased from 166 square metres (m^2) to 202 m^2 between 1990 and 2008, and China's urban houses increased in size from 13.7 m^2 to 27 m^2 per occupant between 1990 and 2005 (National Bureau of Statisitics, 2007).

Table 1.6 Opportunities for energy and CO_2 emissions savings in the buildings sector

Major savings areas	Relative importance over next decade
Building shell measures	
New residential buildings in OECD non-member countries	
Retrofits of residential buildings in OECD member countries	
New commercial buildings	
Retrofits of commercial buildings	
Energy efficiency	
Lighting	
Appliances	
Water-heating systems	
Space-heating systems	
Cooling-ventilation systems	
Cooking devices	
Fuel switching	
Water heating systems	
Space heating systems	
Cooking devices	

Note: Darker shading highlights relatively larger energy-savings potential over the next decade.

Key point *Significant potential for energy savings and CO_2 emission reductions over the next decade can be realised by improving the building shell in new buildings (globally) and by retrofitting existing buildings (in particular, in OECD member country economies).*

To achieve energy-savings potential in the buildings sector, strict energy-saving requirements for new buildings plus retrofits of existing buildings is necessary. The efficiency of the building shell must be upgraded and buildings need to incorporate more energy-efficient building technologies for heating, cooling and ventilation (HVAC) systems; high efficiency lighting, appliances and equipment; and CO_2-low or -free technologies, such as heat pumps and solar energy for space, and water heating and cooling (Table 1.6).

Progress assessment

Assessing the progress of energy efficiency in buildings is a challenge. Data on the deployment of energy efficient technologies are limited, and many different technologies and components contribute to the overall energy performance of buildings. Progress is therefore evaluated by reviewing building energy codes, improvements in appliance efficiency, and deployment of solar thermal and heat pump technologies for heating and cooling. This assessment remains largely incomplete until further global data collection enables better analysis of efficiency in the buildings sector. This will help drive policy prioritisation. In general, however, the limited assessment suggests that buildings require increased application of energy efficiency potential in order to achieve the 2DS objectives.

Building energy codes and minimum energy performance requirements

To effectively reduce building energy consumption, building energy codes must be mandatory, include minimum energy performance requirements for the overall building (including its various end-uses), cover the entire building stock and be stringently enforced. Currently, few countries meet these requirements:

- Building energy codes exist in all OECD member countries, and in a number of non-member countries (such as China, Russia, India and Tunisia). However, only European Union countries, China and Tunisia have *mandatory* building energy codes that require minimum energy performance.
- In other countries, energy codes are voluntary at the national level, while some provinces and states have made them mandatory (*e.g.* in the United States, building energy codes are mandatory in 22 of 50 states for residential buildings and are voluntary in all but eight states, which do not have energy codes). When codes are voluntary, there is usually no enforcement in place.

Box 1.4 European Energy Performance in Buildings Directive (EPBD)

The European Commission directive 2002/91/EC introduced the concept of minimum energy requirements for the overall energy consumption of buildings. It included five end-uses, in line with the current ISO standard (heating, cooling, ventilation, lighting for non-residential only and hot water).

The 2010 update to the EPBD directive 2010/31/EC also:

- provides methodologies for setting minimum performance requirements and for shifting the focus from upfront investment costs to life cycle costs;
- requires member states to report the national parameters and calculations used for setting their minimum energy performance every three years to the European Commission; and
- requires all new structures in the EU to be nearly zero-energy buildings by 2021 and 2020 for the public sector.

Member states are required to implement the EPBD update by the second half of 2012.

- Only France, Denmark and Tunisia include minimum energy performance requirements for the overall energy consumption of the buildings, applicable to five end-uses: heating, cooling, hot water, lighting and ventilation.
- Most energy codes only target new buildings or extensions, and therefore do not apply to a large proportion of the existing building stock. This is especially problematic in OECD countries, where most of the efficiency potential requires retrofitting existing buildings. In addition, a large part of the building stock in OECD countries was built before the first building energy codes emerged in the 1970s.

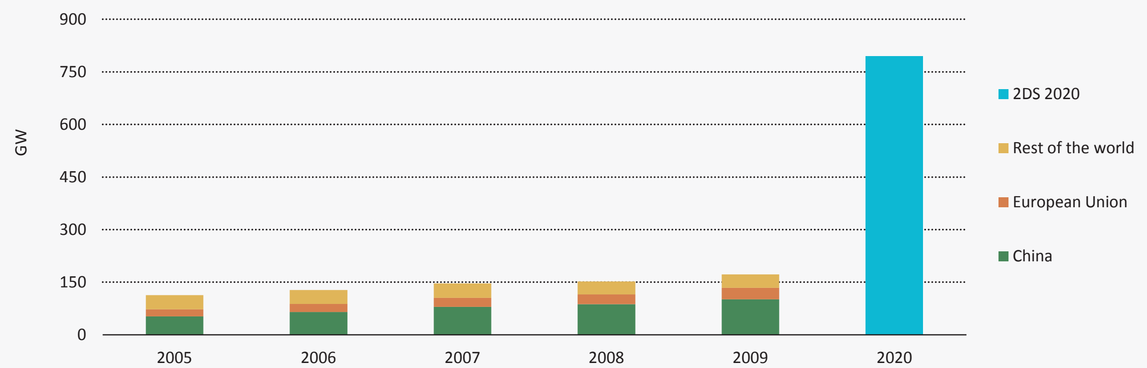
In summary, relatively little has been done to effectively address energy consumption in new and existing buildings globally, leaving significant untapped potential.

Low- and zero-carbon technologies for heating and cooling systems

Low-carbon or zero-carbon technologies for heating and cooling systems in residential and commercial buildings are critical to achieve the CO_2 emissions reductions in the 2DS. These include active solar thermal, heat pumps for both heating and cooling, and cogeneration for buildings and large-scale heating technologies (*e.g.* district heating systems and cogeneration for district heating). While these technologies are already commercially available, significant potential exists for enhanced deployment and improvements in system cost and efficiency (IEA, 2011e).

Solar thermal capacity of 172 GW_{th} at the end of 2009 (Figure 1.22) corresponded to around 250 million m^2. The majority of capacity is in China, Europe and North America. Early estimates for 2010 put capacity at around 200 GW_{th} or 280 million m^2 (IEA SHC, 2011). In 2009 the collector yield (energy output of installations) of all water-based solar thermal systems in operation was over 140 000 GW_{th}, equivalent to 14 million tonnes of oil equivalent (Mtoe), and 46 million tonnes of CO_2 emissions savings. The costs of solar thermal systems range from USD 1 100 to USD 2 140/kW for new single family dwellings, and USD 1 300 to USD 2 200/kW for retrofits of existing housing. For multi-family dwellings, costs are slightly lower, at USD 950 to USD 1 050/kW for new, and USD 1 140 to USD 2 050/kW for retrofits. In general, the pace of solar thermal system deployment must pick up dramatically to achieve the ETP 2DS objectives by 2020.

Figure 1.22 Active solar thermal systems deployment and 2DS 2020 objectives



Source: IEA analysis; IEA SHC, 2011.

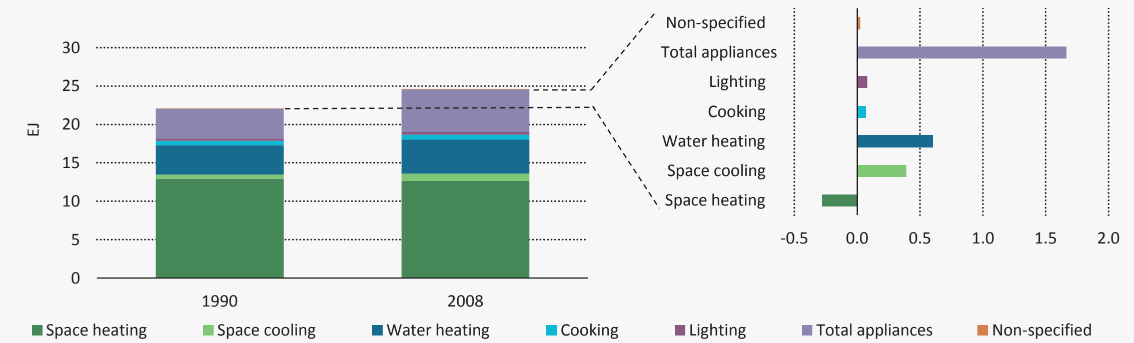
Key point *Accelerated, widespread deployment of solar thermal systems must occur to achieve the 2DS targets.*

While the global market for heat pumps is harder to assess, approximately one million ground-source heat pumps were installed in Europe in 2010, or 12.5 GW of installed capacity. Worldwide, an estimated 800 million heat pumps have been installed. Sales in Europe were just over USD 100 000, a drop of 2.9% between 2009 and 2010, following a 6.6% drop from 2008 to 2009 (EurObserv'ER, 2011). This slump is likely due to an uncertain financial outlook for many households, but studies also suggest that public scepticism about the technology persists in a number of countries. As a result of technological innovations, air-source heat pumps have, in recent years, been accepted under criteria outlined in the EU Renewable Energy Directive. Most are, however, employed to cool buildings in summer (moderate climate) at quite low efficiencies. They are estimated to account for 80% of the total heat pump market in Europe, with 350 000 sales in 2010.

Energy efficiency of building appliances

A sample of data from 18 OECD member countries highlights that, while space and water heating remain responsible for the largest share of end-use energy consumption, appliances accounted for more than one-half of the 11% increase in end-use energy consumption from 1990 to 2008 (Figure 1.23). This trend is mainly attributable to the rapidly rising use of small personal appliances and electronics, such as flat-screen televisions, mobile telephones and personal computers.

Figure 1.23 Energy consumption in buildings by end-use and share of increase in energy consumption, 1990-2008

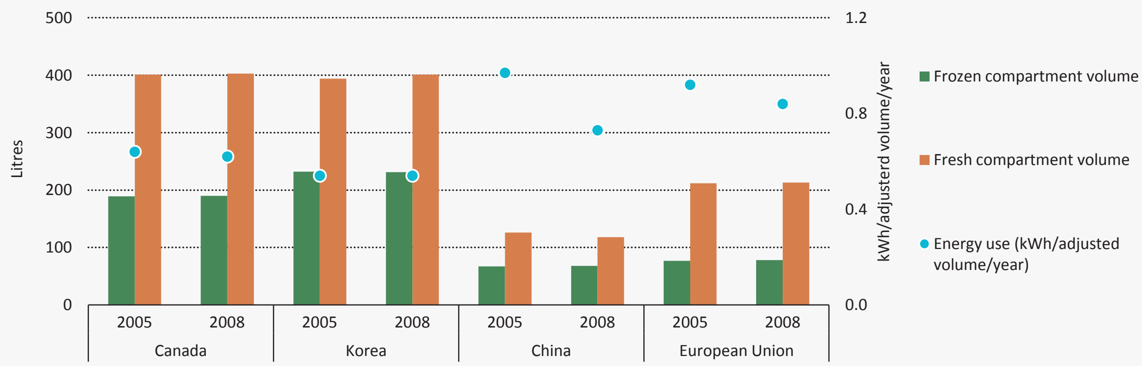


Note: Countries analysed are Australia, Austria, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, the Netherlands, Norway, Slovakia, Spain, Sweden, Switzerland, the United Kingdom and the United States.

Key point *The growing number of small appliances and electronics has increased building energy demand.*

Encouraging progress has been made in the energy efficiency of equipment and appliances, largely driven by minimum energy performance standards and labels. Energy efficiency of refrigerators, for example, has substantially improved in China and the European Union in a short period (Figure 1.25), and similar efficiency upgrades have been made to other appliance categories (*e.g.* washer/dryers, lighting, air conditioners, etc). On the whole, while positive, efficiency improvements have been offset by two important factors: the fast-climbing number and use of large appliances, as new markets are created (particularly in emerging non-member economies), and accelerating popularity of small personal electronics.

Figure 1.24 Energy use and volume for combined refrigerator and freezer units



Note: Efficiency of appliances is not directly comparable among countries or regions, given variations in test procedures. This graph mainly aims to highlight efficiency progress within economies over time, plus variations in appliance sizes in different regions.
Source: 4e IA, 2011.

Key point *Energy efficiency of appliances has improved rapidly in some countries, but trends towards larger appliances must be avoided to help reduce overall energy consumption.*

Scaling-up deployment

Enhancing the efficiency of buildings and scaling-up the deployment of energy-efficient buildings technologies needs targeted policies and measures.[18] In the buildings sector specifically, barriers such as split incentives between tenants and landlords, lack of awareness of efficient technologies, absence of qualified "green" technicians and high initial investment costs threaten market-driven energy savings measures (IEA, 2011b). Governments can address these barriers and promote buildings sector energy savings by implementing a package of policies, coupled with financing tools and models to help overcome high upfront investment costs. In particular, governments should:

- require all new buildings, as well as buildings undergoing renovation, to meet energy codes and minimum energy performance standards;
- support and encourage construction of buildings with net-zero energy consumption;
- implement policies to improve the energy efficiency of existing buildings with emphasis on significant improvements to building envelopes and systems during renovations;
- require building energy performance labels or certificates that provide information to owners, buyers and renters; and
- establish policies to improve the energy efficiency performance of critical building components in order to improve the overall energy performance of new and existing buildings.

In the area of appliances and equipment specifically, improvements in energy efficiency are mainly attributed to two policies: minimum energy performance standards and labels. Ideally, these policies should be combined, as is done in China, India and now the European

18 The IEA developed *25 Energy Efficiency Policy Recommendations* (2011b), which outlines a series of targeted policy measures for buildings, appliances and equipment, lighting, transport, industry, energy utilities and cross-sectoral issues.

Union. Governments must support these with test standards and measurement protocols, in addition to market transformation policies, to encourage consumers and manufacturers to accept higher efficiency. Several governments are making good progress in the development of standards and labels (Table 1.7), but significant savings potential remains. This is, in part due, to the fact that the development of these two major policies has been a component approach, rather than a systemic one. HVAC system product requirements, for example, focus on individual components (such as chillers in the case of the United States), but not on the terminal units, air handling units and other operational equipment. Enhanced international collaboration in this area can support the development of harmonised test procedures and more stringent appliance standards.

Table 1.7 Policies to enhance equipment and appliance efficiency

Appliances	Minimum energy performance standard	Labelling
Clothes washers	Brazil, Canada, China, European Union, India*, Korea, Mexico, Switzerland, United States	Australia, Canada, European Union, Korea, Mexico, New Zealand, Norway, Switzerland, Turkey, United States
Residential refrigerators	Australia, Brazil, Canada, China, European Union, India, Japan, Korea, Mexico, New Zealand, Switzerland, United States	Australia, Canada, European Union, India, Japan, Korea, Mexico, Norway, New Zealand, Switzerland, Turkey, United States
Commercial refrigerators	Australia, Brazil, Canada, European Union, India, Korea, Mexico, New Zealand, Switzerland, United States	European Union, Korea, Mexico, New Zealand, Norway, Switzerland, Turkey
Computers	Australia, India*, Japan	India*, Japan
Distribution transformers	Australia, Canada, China, European Union, India, Japan, Mexico, United States	India, Japan
Fans	Canada, India*, Korea, New Zealand	India, New Zealand
Motors	Australia, Canada, China, European Union, Korea, Mexico, New Zealand, Switzerland*, United States	Korea, Mexico, Switzerland*
Room air conditioners	Australia, Brazil, Canada, China, European Union, India, Japan, Korea, Mexico, New Zealand, South Africa*, Switzerland, United States	Australia, Canada, European Union, Japan, Korea, Mexico, New Zealand, Norway, Switzerland, Turkey, United States
Standby power	Eeropean Union, Mexico, South Africa*, United States	
Television	Australia, Brazil, China, European Union, Japan	Brazil*, Japan, United States
Phase out of conventional incandescent light bulbs	Australia, Brazil, China*, European Union, Japan*, Mexico, New Zealand*, Switzerland, United States	

Note: * Denotes that policy is voluntary in nature.
Source: CLASP database, IEA analysis.

Heating and cooling technologies and systems have not entered mainstream energy policy debate, in part due to the lack of data and information regarding their deployment levels and energy-saving potentials. Collecting such enhanced data (building characteristics plus technology deployment, cost and efficiency) will significantly help system planning for the buildings sector.

A number of policies to support greater use of low-carbon heating and cooling technologies are sparking attention, particularly renewable heat policies. While renewable heat sources have been covered indirectly under general renewable energy legislative frameworks since the 1990s, in the past 5 to 7 years, more targeted policies have been developed. The European Union Directive to promote the use of energy from renewable sources has been a key driver for this change in EU countries.

Direct capital cost subsidies, tax incentives and soft loans for the purchase of renewable heating systems are the most widely adopted financial mechanisms in the European Union that support renewable heat (IEA, 2011c). Other policy mechanisms, such as renewable obligations and feed-in tariffs, are also gaining traction: In 2011, the United Kingdom introduced the first feed-in tariff type policy for the heat market under its Renewable Heat Incentive (RHI) and will soon publish the "Heat Strategy", which prioritises further development of heat networks, especially in urban areas. While more countries are implementing dedicated renewable heat policies, finding the appropriate policy design is a challenge, given the distributed nature of heat generation and its fragmented market (IEA, 2011c). Sharpening the focus on developing dedicated renewable heat policies and sharing experiences on the most effective policy designs can accelerate deployment of renewable heat technologies.

Transport

Economic growth in emerging economies has spurred widespread demand for personal vehicles and moving freight by road. Energy demand in the transport sector has steadily increased in recent years and is projected to more than double by 2050. Currently, the transport sector accounts for 20% of the world's primary energy use and 25% of energy-related CO_2 emissions, but under the 2DS, it also holds the potential to reduce CO_2 emissions by 30% from current levels by 2050. Achieving this target requires a combination of improved fuel efficiency; new types of vehicles, such as battery electric (BEVs) and plug-in hybrid electric vehicles (PHEVs); and alternative fuels capable of reaching very-low CO_2 emissions per kilometre (*e.g.* advanced biofuels).

Road transport, including both light-duty vehicles (LDVs) and heavier-duty trucks, consumes the most energy (approximately three-quarters) in the transport sector and has experienced the most rapid growth in absolute terms (close to a 20% increase from 2000 to 2009). The best opportunity to make the transport sector more energy efficient lies primarily with LDVs.

Fuel economy

Enhancing the fuel economy of vehicles and vehicle fleets is the single most important measure to put into action over the next decade to curb fossil fuel use and reduce CO_2 emissions within the transport sector. Evidence to date suggests that many governments' fuel economy ambitions are not set high enough to achieve the 2DS objectives.

Progress assessment

Fuel economy levels vary significantly by country (Figure 1.25), from approximately 6 litres (L) per 100 km for the least fuel-intensive end of the spectrum (India) to over 9 L/100 km at the most fuel-intensive end (the United States). Average new-LDV global fuel economy improved at a rate of 1.7% between 2005 and 2008.[19] Trends also suggest that, while some countries are improving their fuel economy considerably (*e.g.* European Union), others are quickly becoming less fuel efficient (in many cases, owing to increased sales of larger vehicles, among other factors).

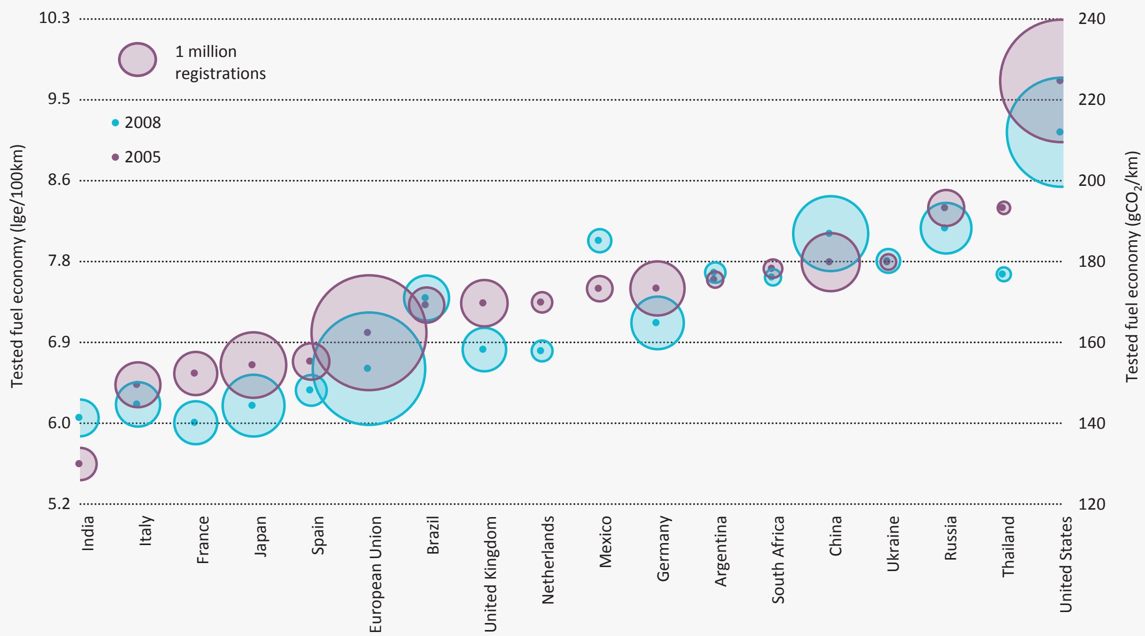
While the overall picture of fuel economy is positive, the rate of improvement is too low to achieve the 2DS by 2020. The 2DS is consistent with the Global Fuel Economy Initiative[20] (GFEI) objectives to improve the fuel economy of new LDVs by 50% by 2030: attaining average annual fuel economy improvement of 2.7% (Table 1.8).

If fuel economy standards, in line with the 2DS (5.6 L/100 km by 2020), become compulsory for all new vehicles worldwide LDV, fuel consumption in 2020 would drop by approximately 25%, rising to 50% in 2050 as the vehicle stock turns over (compared to the 2005 base level of fuel economy). Global CO_2 emissions from these vehicles will fall by roughly 0.2 gigatonnes (Gt) in 2020 and 1.5 Gt in 2050. This excludes savings from sales of

19 Average of 21 countries and sample of cars examined by the Global Fuel Economy Initiative.

20 The Global Fuel Economy Initiative (GEFI) is a partnership of IEA, UN Environmental Programme, International Transport Forum, and FIA Foundation. Its core objective is to improve global fuel economy by 50% by 2030.

Figure 1.25 Light-duty vehicle fuel economy and new vehicle registrations, 2005 and 2008



Note: Lge = litre of gasoline equivalent. GCO_2/km = grams of CO_2 emissions per kilometre.
Source: Polk, 2009; IEA analysis and data.

Key point *Fuel economy has improved in most countries, but decreased in some countries owing to the increase in sales of larger vehicles.*

Table 1.8 Progress of new vehicle fuel economy against the 2DS target

		2005	2008	2020	Average annual percentage change
Fuel economy (Lge/100 km)	Estimated global average	8.1	7.7		2005 to 2008 (actual): 1.7%
	2DS 2020 objectives	8.1	7.4	5.6	2005 to 2020 (required): -2.7%

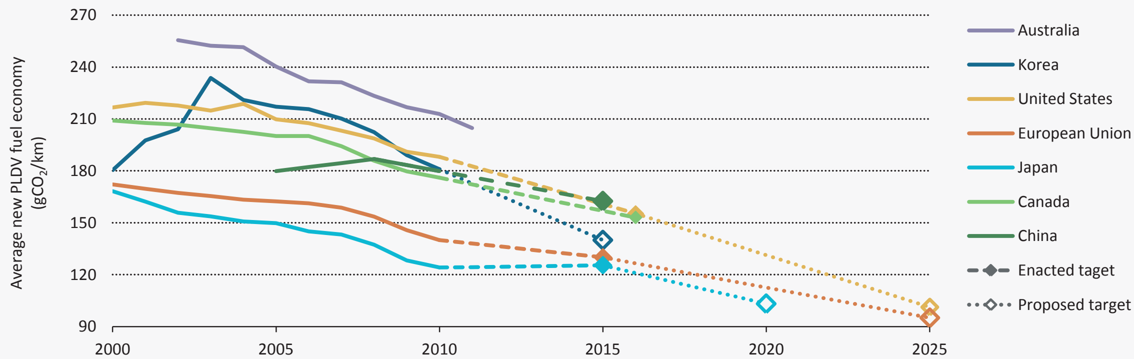
new technology vehicles, such as BEVs and fuel-cell vehicles. Improving all other modes (trucks, ships, aircraft, etc.) by estimated achievable amounts (improvement of 30% to 50% efficiency, depending on the mode) yields total savings to the transport sector of approximately 0.5 Gt in 2020 and 3 Gt in 2050. Oil demand can be cut by 3 million barrels per day (Mbbl/d) in 2020 and close to 20 Mbbl/d in 2050.

Recent developments

Attributing shifts in overall fuel economy to any one factor is not possible, but recent trends explain at least some of the observed fuel economy changes: some countries already have new (or stronger) fuel economy standards; in many countries, consumer demand is shifting to larger, heavier vehicles; and increases in fossil fuel prices are beginning to push consumers to buy more efficient vehicles.

New, more robust vehicle efficiency standards have indeed improved average fuel economy of fleets in a number of countries (Figure 1.26). In OECD countries, the market share of large sport utility vehicles (SUVs) decreased, while the number of smaller vehicles increased in some countries: Small cars gained approximately 5% market share in 2008 compared to 2005 (IEA, 2011d).

Figure 1.26 Vehicle fuel economy, enacted and proposed standards



Note: United States and Canada LDVs include light-commercial vehicles, SUVs and passenger vehicles.
Source: Enacted and proposed targets: GFEI, 2011; IEA analysis and data.

Key point *Although fuel economy and emissions standards for vehicle fuel economy will markedly improve efficiency, they are not sufficient to achieve the 2DS objectives.*

Conversely, as the purchasing power of economies grows, vehicle sales increase and as larger vehicles start penetrating the market, downward pressure is put on fuel economy, as seen in China. While a fuel-economy standard was introduced in 2005, the share of new large vehicle registrations increased from 2005 to 2008. On average, fuel economy worsened, although the fuel standard helped limit this effect.

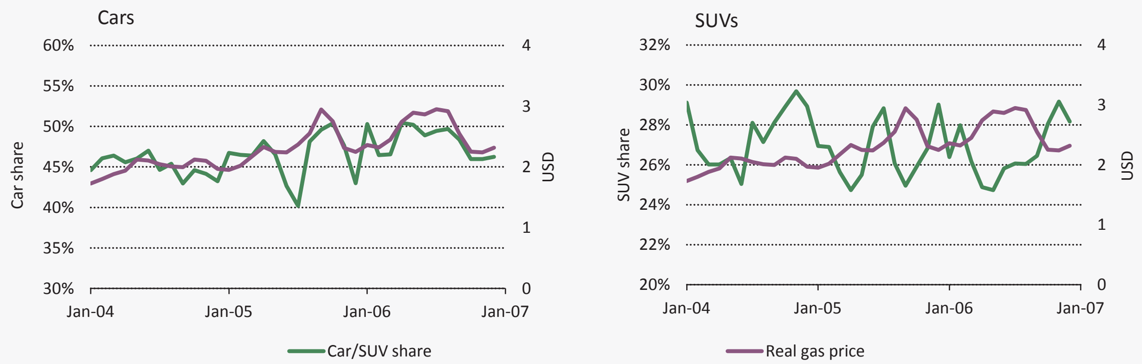
Avoiding purchase shifts to larger, more energy-intensive vehicles is critical. India, Indonesia and Mexico showed similar trends, although their economies have no fuel economy standards.

Studies also show that short-term and sustained high gasoline prices influence vehicle choice, with consumers purchasing more efficient vehicles as fuel prices climb – and are sustained. In particular, a study undertaken in the United States found that, as petrol prices increased, consumers purchased smaller, more efficient vehicles; the inverse was true when gasoline prices decreased, with an increase in the share of sport utility vehicles (SUVs) sold (Figure 1.27). This trend points to the impact that fuel prices have on consumer decision making.

Box 1.5 Impact of heavy-duty vehicles

The escalating number of trucks and lack of fuel-economy standards for commercial vehicles will have a major impact on CO_2 emissions and average fuel economy levels, particularly in OECD non-member economies. Most member countries are working on commercial vehicle fuel-economy standards, and some have been implemented. Much more must be done in this area.

Figure 1.27 United States passenger vehicle market shares and actual price of gasoline, 2004 to 2006



Note: The right hand scale shows the average inflation-adjusted price per gallon for all grades and formulations of gasoline; price is 2007 USD per gallon.
Source: CBO, 2008. Data from Congressional Budget Office is based on data from Automotive News and the Department of Energy, Energy Information Administration.

Key point *Higher fuel prices show evidence of driving consumers to purchase more efficient vehicles.*

Scaling-up deployment

Improving vehicle fuel economy and average fleet fuel economy is influenced by both technical advanced and consumer choices. On the technical front, factors include vehicle size, vehicle weight and power train characteristics (*e.g.* engine displacement, transmission type, fuel type, engine aspiration type and engine power). Consumers, however, when deciding which car to purchase, focus on the overall vehicle price, fuel prices, fuel type, parking space availability, design and style, safety, interior space and design, cargo volume, power and power-to-weight ratio, reliability and brand image (IEA, 2011d).

To improve fuel economy at the scale and pace required to meet efficiency and emissions objectives of the 2DS, governments must implement policies that address technical fuel economy requirements and consumer choice determinants. Fuel economy or GHG emissions standards have proven an important policy tool. While some governments have standards in place (Figure 1.26), many are only in force through 2020 (the United States' standards go through 2025). Existing fuel economy and emissions standards must be extended and made tougher in order to reach the 2DS fuel economy improvement goals. Countries without such standards should consider the implementation of this effective policy tool.

In addition, other measures, including vehicle taxes and incentives, fuel taxes, traffic control measures and the provision of consumer information, are required to help guide decision making by consumers (Table 1.9). Government implementation of such policies is relatively limited, despite the fact that consumers will ultimately decide whether to purchase a more, or less, fuel efficient vehicle.

Table 1.9 Technical and consumer policies in place, 2011

	Policy aspects	Governments
Policies targeting technical efficiency		
Fuel economy standards	Limit to litres/100 km across fleets or based or vehicle weight or class. Stringency of standards, test procedures and number of vehicles classes vary by country	Australia*, Canada, China, Korea*, Japan, United States
GHG emissions standard	Limit on emissions/km	European Union, California (United States)
Policies targeting consumer choice		
Fiscal incentives	Registration taxes increase with vehicle and engine size, and CO_2 emissions; sales incentives for more fuel efficient ad lower CO_2 emitting vehicles	Brazil, China, France, Germany, India, Italy, Japan, Korea, Russia, South Africa, Spain, Turkey, United Kingdom, United States
Consumer information	Labels showing vehicle fuel economy and GHG emissions	Australia, Brazil, Chile, European Union, China, India, Korea and others
Driving prioritisation and penalty	Driving lane prioritisation for high-efficiency vehicles; banning of SUVs and charges for low-efficiency vehicles	Several US states; London, Paris

* Policy under development.
Source: IEA analysis; UNCSD, 2011.

Electric vehicles and hybrid electric vehicles

Progress assessment

While fuel economy plays the central role in reducing transport-sector CO_2 emissions by 2020, the 2DS scenario also shows strong penetration of hybrid vehicles, plug-in hybrid electric vehicles (plug-in HEVs) and battery electric vehicles (BEVs), which reach substantial yearly sales (over 7 million) and stocks (over 20 million) in this time frame. While this represents rapid development of a nascent market, if achieved, BEVs and plug-in HEVs will still only account for 2% of the world vehicle fleet in 2020.

Many governments have adopted strong targets for electric vehicle deployment in the 2015 to 2020 timeframe (Figure 1.30) in line with the 2DS objectives, but to achieve this goal, sales must nearly double each year between 2012 and 2020, cost must continue to decline, infrastructure needs to develop, and consumer choice and confidence requires a boost.

Recent developments

Fuel price increases not only influence consumers to purchase more efficient vehicles, but also drive up interest in alternative transport modes. This was especially true for hybrids, which showed strong popularity in the United States in 2008. While interest has dropped off in the United States since then, hybrids have taken off in Japan. Since 2008, Japan overtook the United States as the largest hybrid market worldwide.

In 2011, BEV sales finished below expectations by analysts and automakers, making 2012 an even more crucial year for the electrification of the vehicle fleet. However, in a year which saw a continued recession and production bottlenecks because of the Great East Japan Earthquake (Figure 1.31), it is perhaps encouraging that the 40 000 EVs sold, matches the number of HEVs sold in six years (1997 to 2003).

While obstacles remain, BEV business models developed further in 2011, as did battery technologies; both are important to bringing down the cost of EVs.

In terms of business models, Paris launched an ambitious electric car sharing-scheme (Autolib), which aims to put 3 000 electric cars into service, while taking 22 500 conventional gasoline-powered vehicles off the road by 2014. This pilot test should help build consumer confidence in the technology.

Battery costs are often cited as the biggest hurdle to EV competitiveness with standard gasoline cars. Estimating battery costs is difficult, and hard to separate from prices, which can reflect marketing strategies as well as actual production cost. Based on available reports, batteries had, roughly, a cost-based price at medium-high volume production of around USD 750/kWh in early 2011. Reported costs through the year declined, and at the beginning of 2012 stand at around USD 500/kWh. If this improvement continues, EVs can reach USD 325/kWh or less by 2020, which is sufficient to bring them close to cost-competitiveness with vehicles with internal combustion engine, which is years ahead of past projections (Figure 1.28).

Scaling-up deployment

As noted, current government targets are in line with achieving the require sales of seven million annual EVs and plug-in HEVs, amounting to 20 million vehicles in stock globally by 2020. Achieving this goal, however, requires additional policy support, including incentives for consumers, policies that give confidence to manufacturers and funding to build recharging infrastructure.

Key elements for consumers include:

- Levelising the cost of ownership of EVs (*e.g.* monthly vehicle purchase, operation and fuel costs that compare with conventional gasoline-powered vehicles) via incentive programmes. It remains to be seen whether the current incentive levels, USD 5 000 to USD 7 500 per vehicle, in most OECD countries are sufficient to achieve this, but falling battery- and vehicle-costs will certainly help.
- Reducing concerns about battery life and vehicle resale value, possibly through battery leasing programmes.
- Providing adequate recharging infrastructure to enable full local access and mobility, and assuage range anxiety. Consumer education will also be an important factor in this regard, as evidence shows that current EV driving range (190 km) is well above average daily vehicle use in many countries (Figure 1.29) (Inter-urban range restrictions may take longer to address).
- Implementing some temporary advantages, such as priority access to urban parking spaces, access to low-emission zones, or access to priority access lanes on highways.

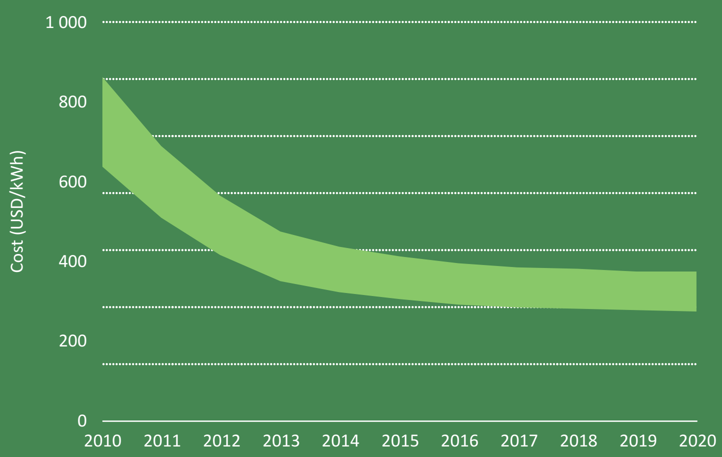
Key elements for manufacturers include enhanced deployment of EVs, which is highly dependent on manufacturer commitment to develop and market the vehicles. While production announcements seem to be in line with the levels required to achieve government sales targets through 2014, beyond this date, the picture is less certain. Current subsidy programmes with one to two year time horizons do not instil confidence in manufacturers that markets will develop and demand will grow (Figure 1.30). Longer-term, clearer policy signals from governments are necessary to shore up industry confidence and induce investment.

Electric vehicles overview

Governments have set targets to achieve 20 million electric vehicles (EVs) on the road by 2020, in line with levels required to achieve the 2DS objectives. Achieving this goal, however, hinges on increasing vehicle production, lowering costs, developing infrastructure and boosting consumer choice and confidence.

Technology developments

1.28: Estimated battery cost reductions to 2020



325

USD/KWH ESTIMATED TARGET PRICE FOR EVS TO BE COST COMPETITIVE WITH INTERNAL COMBUSTION ENGINE VEHICLES

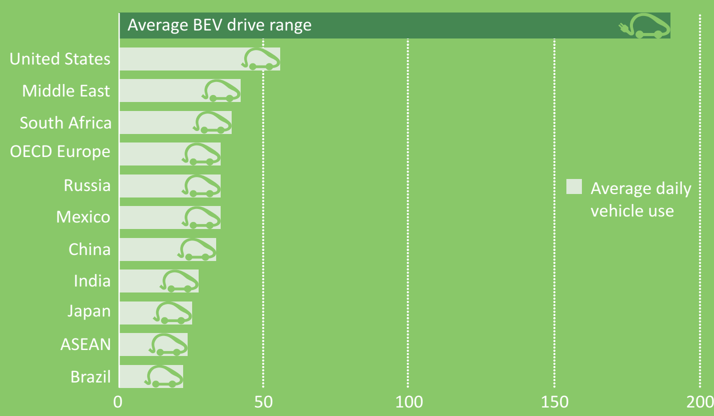
Key technology needs

Battery cost reductions are key to future EV competitiveness

While EV driving range is greater than average daily vehicle use, further improvements are required

Public confidence in the technology must be increased through consumer education and information

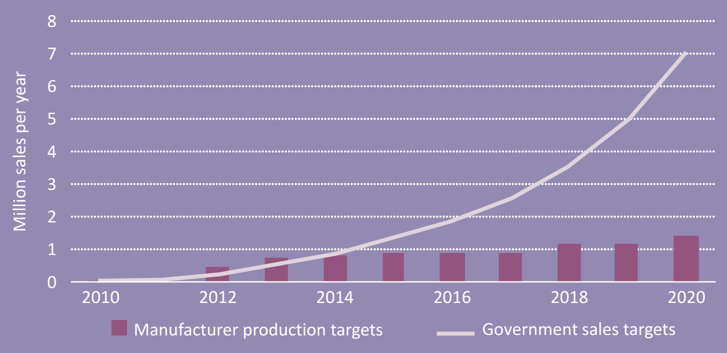
1.29: BEV driving range and average LDV travel per day



Source: CE Delft/ICF/Ecologic

Market creation

1.30: Government and manufacturers targets



Key developments

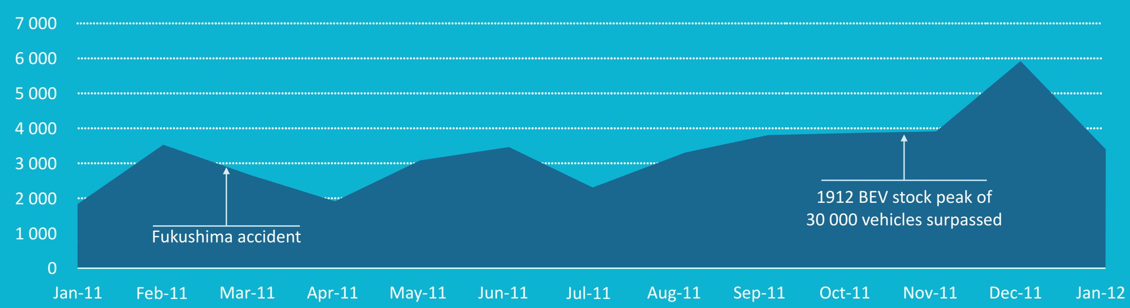
Government targets are set to achieve stock of 20 million vehicles by 2020

Manufacturer production after 2014 remains uncertain

1 billion in infrastructure investment over the past few years, against an average annual investment of over USD 2 billion to be on track with the 2DS by 2020

Technology penetration

1.31: World EV sales



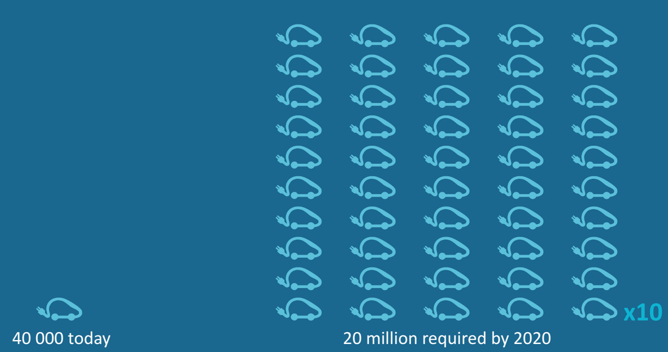
Source: MarkLines

Achieving EV goals

Annual sales of EVs must double every year between now and 2020 to achieve the 2DS objectives

To achieve this goal, policies to help levelise the cost of EV ownership will be necessary through incentive programmes, until battery costs come down

1.32: EV stock



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Biofuels

Progress assessment

Biofuels are one of the main alternative fuels that can offer very low net-GHG performance. In contrast to BEVs or vehicles running on hydrogen, biofuels have been produced commercially in both the United States and Brazil for several decades. The sector grew the fastest in the past ten years. Driven by policy support in more than 50 countries (Figure 1.35), production of global biofuels grew from 16 billion litres in 2000 to more than 100 billion litres in 2011 (Figure 1.36).[21] Globally, biofuels accounted for around 3% of road transport fuels, with a considerable share in Brazil (21%), and an increasing share in the United States (4%) and the European Union (about 3%).

Not all biofuels in the market today, however, can actually reduce GHGs on the scale needed to meet the targets in the 2DS. Improving the efficiency of conventional fuels, and commercially deploying advanced biofuels, will clearly still be required (Figure 1.33). In the 2DS, the use of biofuels increases to approximately 240 billion litres in 2020, which, when produced sustainably, leads to a reduction of approximately 0.1 Gt of CO_2 emissions in the transport sector.

Achieving the 2DS objectives largely depends on developing advanced biofuels, with a target of approximately 22 billion litres of gasoline equivalent (Lge) by 2020, and important reductions in production costs (Figure 1.32). Installed advanced biofuel capacity (lignocellulosic ethanol, biomass-to-liquids and other types) today is less than 200 million Lge, with most plants operating well below capacity. Nonetheless, another 1.9 billion Lge/year production capacity is currently under construction, and project proposals for an additional 6 billion Lge annual capacity by 2015 have been announced (IEA, 2011f). Given the industry's volatile nature and limited operational history, many of these facilities may experience delays and cancellations, or begin with low production rates. Without taking these potential shortfalls into consideration, achieving the 2DS by 2020 will still require a four-fold increase in production capacity beyond current announcements, which represents a major challenge. Achieving this will require a significant and sustained push by policy-makers.

Recent developments

Blending mandates for transport fuels and financial incentives have driven the rapid growth in the biofuels sector over the last ten years, but high feedstock prices, overcapacity, changing government policies, and public discussion on the sustainability of biofuels have recently slowed this growth. This may limit future expansion of fuels that rely on comparably costly feedstock (such as vegetable oil) and provide only limited GHG benefits. Several developments in 2011 point in this direction:

- In 2011, Brazil's bioethanol production was challenged by a poor sugarcane harvest and high sugar prices. Production dropped 15%, as many mills shifted from ethanol to sugar. This situation will likely reverse itself in the next few years as new sugarcane fields come into production.
- In the United States, the world's largest producer of biofuels, support measures and policies changed considerably, as of 2012. The ethanol blenders' tax credit (USD 0.45 per gallon for blenders of corn ethanol) and the tariff on imported ethanol (USD 0.54 per gallon tariff on imported ethanol) expired at the end of 2011. This may not lead

21 Production volumes in 2011 were actually slightly below those in 2010, mainly due to lower-than-expected ethanol production in Brazil. However, with new sugarcane fields coming into production, the shortage of Brazilian ethanol will disappear in the next few years.

to significant changes for the industry in the short term, as the biofuel blending mandate — the Renewable Fuels Standard 2 — is still in place and requires a steadily increasing proportion of biofuels to be blended into gasoline. This standard requires the blending of fuels other than corn-ethanol, such as cellulosic biofuels and other advanced biofuels, and limits the role of corn ethanol over time. Support for advanced biofuels, was also bolstered in 2011, when the United States announced intentions to invest USD 510 million in coming years to promote their production.

- In the European Union, overall biofuel production continues to grow, but the biodiesel sector is struggling with plant utilisation rates of around 50% of production potential. Higher feedstock prices, in combination with economic pressures and increasing GHG-reduction thresholds in EU legislation, will likely limit future growth of the biodiesel sector.

Scaling-up deployment

The development of advanced biofuels needs to be accelerated, primarily through dedicated government support for RD&D and, in particular, sound backing for the initial commercial production units. Financial support - direct financing, loan guarantees or guaranteed premiums for advanced biofuels - are crucial to reduce risks associated with large investment in pre-commercial technologies. A premium for advanced biofuels, similar to feed-in tariffs for renewable electricity, also effectively addresses the currently higher production costs compared to conventional biofuels. Support for advanced and other, truly low-GHG biofuels must continue until at least 2020 to ensure the scale-up and cost reductions necessary for biofuels to reach maturity and full commercialisation.

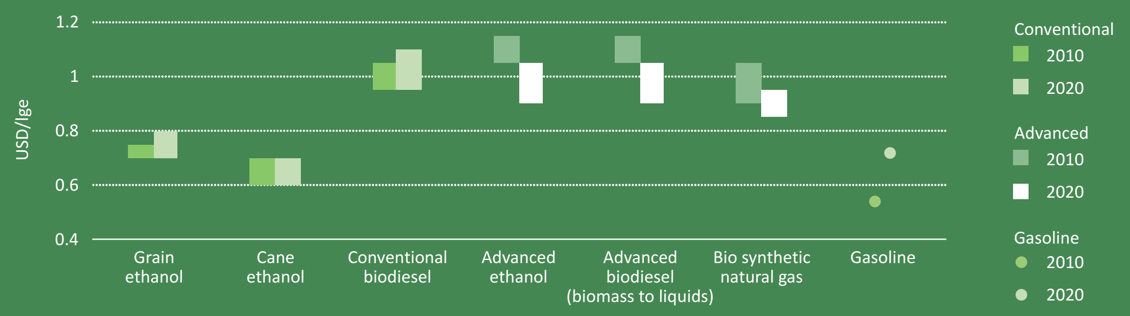
An important requirement for further expansion of biofuel production is that their use leads to considerable net-GHG reductions, compared to fossil fuels. Support policies for biofuels should add incentives promoting the most efficient biofuels (in terms of overall GHG performance), backed by a strong policy framework that ensures food security and biodiversity are not compromised, and that other social impacts are positive. This includes sustainable land-use management and certification schemes, as well as support measures that promote low-impact feedstock (such as wastes and residues) and efficient processing technologies. Sustainability certification should be based on internationally agreed-upon indicators, such as those developed by the Global Bioenergy Partnership, to help avoid market confusion.

Biofuels overview

Biofuels (bio-ethanol and biodiesel) have grown dramatically over the past decade due to strong policy support, but sustainability challenges may slow their production. Biofuels production needs to double, requiring a four-fold increase in advanced biofuels production over currently announced capacity by 2020, to achieve 2DS objectives.

Technology developments

1.32: Biofuel production costs, 2010 and 2DS objectives

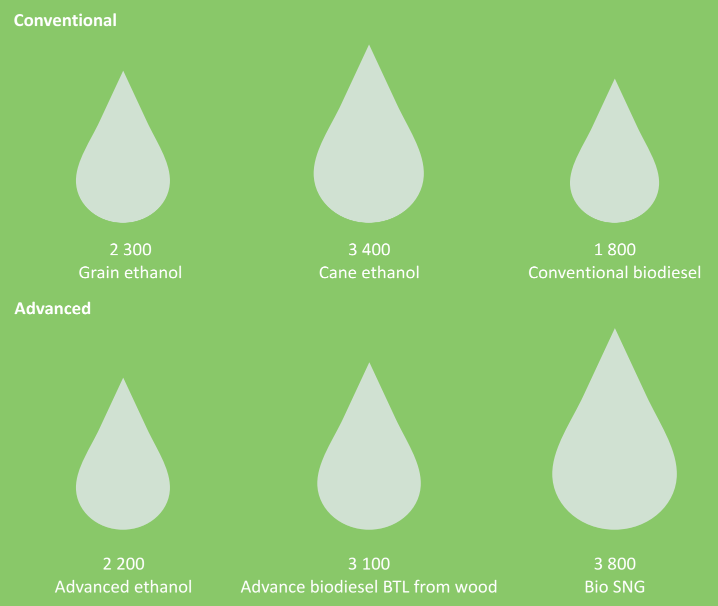


Technology needs

Cost reductions through RD&D and construction of commercial-scale advanced biofuel plants are required to achieve the 2DS objectives by 2020

Sustainability concerns must be addressed, through internationally harmonised sustainability certification, as basis for biofuels economic support measures

1.33: Litre of fuel equivalent per hectare



Market creation

1.34: Annual production capacity investment

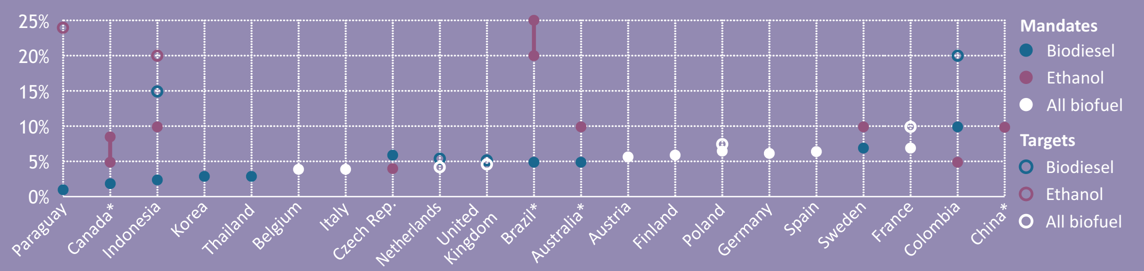
Source: BNEF

Market developments

To achieve the 2020 2DS objectives, an average annual investment of USD 110 billion will be required in biofuels

The United States, the world's largest producer of biofuels, has a production targets of 56 billion litres in 2012, up to 78 billion litres by 2015, and 136 billion litres by 2022

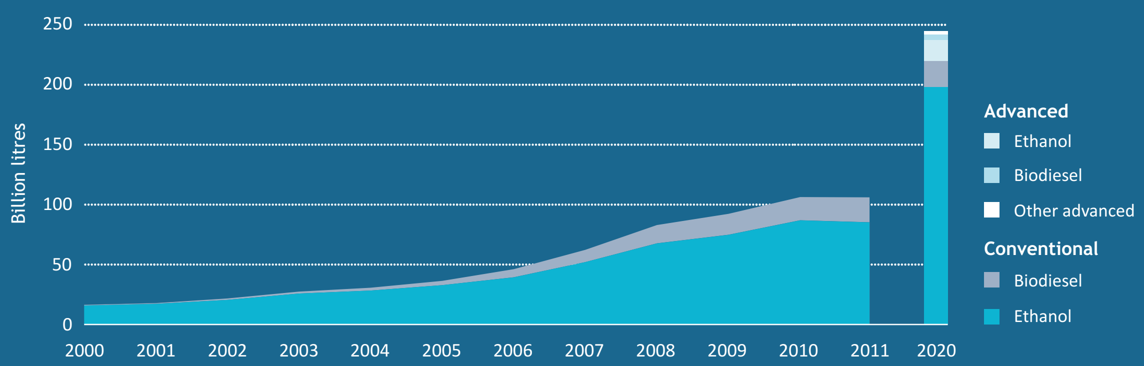
1.35: Blending mandates and targets in key regions



* Denotes a country where mandates are limited to sub-national territories or vary between sub-national territories (see notes).

Technology penetration

1.36: World biofuel production, 2000-11 and 2DS objectives



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Carbon Capture and Storage

Progress assessment

With the world's dependence on fossil fuels not expected to abate significantly in the short to medium-term, CCS is a critical technology to reduce CO_2 emissions and decarbonise both the industry and power sectors. Development and deployment of CCS is woefully off pace to reach the approximately 269 Mt CO_2 captured across power and industrial applications in 2020 in the 2DS. This is equivalent to about 120 facilities. Progress in CCS is largely characterised by the extent to which the technology evolves through large-scale demonstration projects. It also depends on sufficient funding and whether governments enact policies that support the demonstration and future deployment of the technology. Projects can be categorised by key development phases, defined as follows: **1. Identify:** establish preliminary scope and business strategy; **2. Evaluate:** establish development operations and execution strategy; **3. Define:** finalise scope and execution plan; **4. Execute:** detail and construct asset; and **5. Operate:** operate, maintain and improve asset.

Currently, 65 large-scale integrated CCS projects (LSIP) are under construction or in planning phases (GCCSI, 2012). Only four operating projects carry out sufficient monitoring to demonstrate permanent storage of CCS. Clearly, a challenging road lies ahead for deploying CCS in the near term (Figure 1.40). It can take upwards of ten years to build a new CCS project from the ground up through to operation, although this varies by sector and specific project. Considering the distribution of projects, by the middle of this decade, there should be about 10 operating large-scale integrated CCS projects. What is not clear, however, is whether they will incorporate sufficient monitoring to demonstrate permanent CO_2 storage. At minimum, an additional 110 planned projects must successfully be brought on line by 2020 to get back on track to meet the 2DS objectives. This is an incredibly ambitious target based on current deployment rates.

Recent developments

The current funding and policy environment represent a very serious challenge, since sustained effort by governments around the world is needed to promote CCS. The number of large, integrated operational projects remained constant throughout 2011, which was the result of new projects entering the development pipeline and existing project cancellations. Given the high capital cost, risks associated with initial projects and the fact that CCS is motivated primarily by climate policy, the technology needs strong government backing by way of CO_2 emissions-reduction policies and dedicated demonstration funding.

New funding for CCS demonstration projects peaked in 2008, when governments supported CCS technology demonstration as part of economic stimulus plans. Since this time, additional funding has been limited, and the allocation of announced funds still lags. Currently, approximately USD 21.4 billion is available to support large-scale CCS demonstration projects, but as of 2012, only 60% of available funding had been allocated to specific projects (GCCSI, 2011). Persistent global economic challenges in many countries will constrain governments' budgets further, which means public funding for CCS will likely be cut back. Already, USD 0.4 billion in previously announced CCS funding has been withdrawn (Figure 1.39). A few recent developments in CO_2 emissions policy, however, may provide some positive impetus in driving CCS development:

- The United Kingdom commenced an electricity market reform process in July 2011, intended to drive decarbonisation of the electricity sector, including through broad CCS deployment. Proposed measures include an emissions performance standard to ensure that no new coal-fired plants are built without CCS; a carbon price floor, intended to strengthen the incentive to invest in low-carbon generation; and feed-in tariffs combined with contracts-for-difference, to guarantee the price paid to generators.
- The Australian government passed new legislation on 8 November 2011 that introduces a AUD 23 (USD 24.6) per tonne carbon price starting 1 July 2012, which will increase 2.5% per year. The initial price is fixed for three years before shifting to an emissions trading scheme on 1 July 2015. The government expects the carbon price to encourage investment in low-emission technologies, including CCS.

These are examples of early steps towards policy architecture that is more favourable to wide-scale CCS deployment.

Scaling-up deployment

To scale-up CCS, dedicated government funding and a broad carbon policy must be supported by a long-term strategy for CCS deployment and enabling regulatory frameworks. The IEA has developed guidance on how policy design can support CCS technology uptake from demonstration to wide-scale deployment, as well as criteria for governments to consider when developing CCS laws and regulations, through a model legal and regulatory framework addressing 29 specific issues (IEA, 2010; IEA, 2012). Only three countries (Australia, Norway and the United Kingdom) meet the framework criteria: they are implementing development and deployment programmes and policies that are likely to be effective, and have a long-term CCS strategy (Table 1.10). For global progress to be made in CCS deployment, more countries will have to expand their CCS commitments. The private sector is otherwise highly unlikely to take on the risks of investing in CCS demonstration projects.

Table 1.10 Country policies and frameworks to support CCS deployment

Comprehensive legal and regulatory frameworks in place*	
Permitting processes allowing exploration for, access to and use of pore space for geologic storage of CO_2	Australia**, Canada**, European Union, France, Italy, Norway, Spain, United Kingdom, United States
Frameworks for managing project-period and long-term liability associated with storage operations and stored CO_2	Australia**, Canada**, European Union, France, Italy, Norway, Spain, United Kingdom
Monitoring, reporting and verification requirements	Australia**, Canada**, European Union, France, Italy, Norway, Spain, United Kingdom, United States
Financial and policy incentives	
R&D programme and support	Australia, Canada, European Union, Finland, France, Germany, Italy, Japan, Korea, Norway, South Africa, Spain, Sweden, United Arab Emirates, United Kingdom, United States
Demonstration programme and support	Australia, Canada, European Union, France, Italy, Korea, Norway, Spain, United Arab Emirates, United Kingdom, United States
Deployment programme and support	Norway, United Kingdom
A price or limits on CO_2 emissions that could lead to use of CCS in the power and industrial sectors	Australia (from July 2012), Canada (from July 2015), EU ETS, UK electricity market reform (from 2014)
Deployment strategy	
Long-term policy frameworks in place	Australia, Norway, United Kingdom

* Highlights only select criteria from IEA's Carbon Capture and Storage Model Regulatory Framework.
** Indicates activity is also occurring at a sub-national level (*i.e.* state or province).

Carbon capture and storage overview

Carbon capture and storage contributes a major share of potential CO_2 emissions reductions in the 2DS, but progress in building commercial-scale demonstrations has been painfully slow. For CCS to remain an option for curbing CO_2 emissions from power and industry – governments must urgently scale-up financial and policy support.

Technology developments

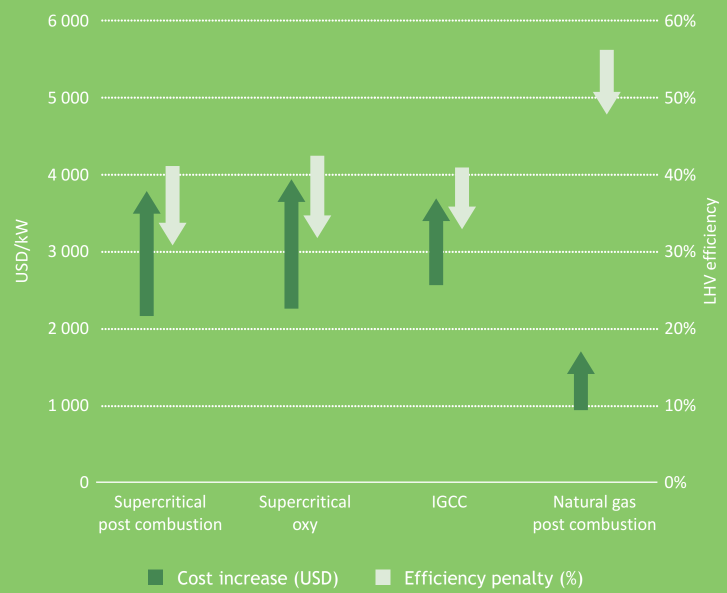
1.37: IEA government spending on CCS R&D

Technology needs

Energy and resource penalties associated with capture must be reduced through technology improvements and experience

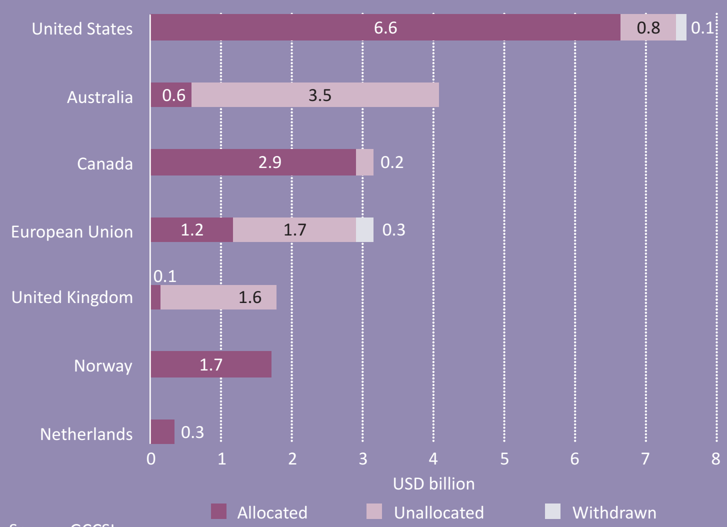
Additional large-scale storage sites are required to validate design, management and monitoring tools

1.38: Cost increase and efficiency penalty



Market creation

1.39: CCS project funding status, end 2011



Source: GCCSI

Key developments

Countries must assess and recognise the role of CCS in their energy future, and develop suitable deployment strategies

Announced funding must be allocated to large-scale CCS demonstration projects with high probabilities of success

Technology penetration

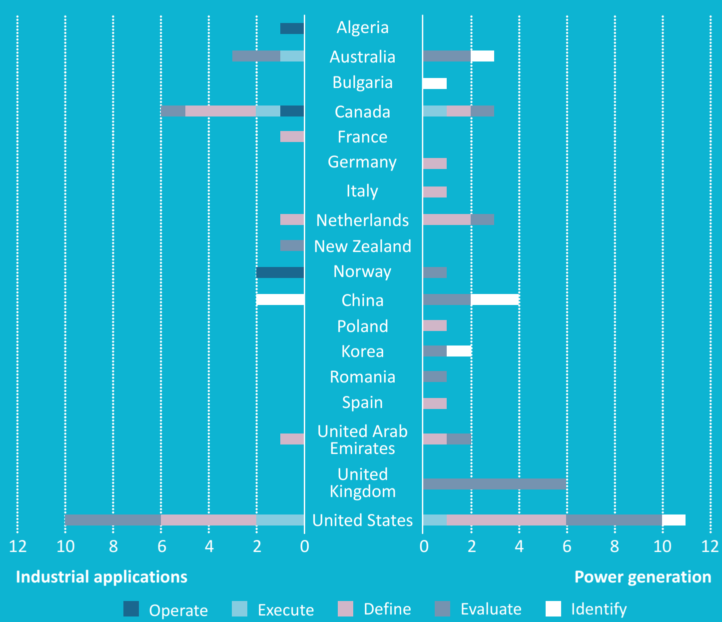
16

GW OF POWER GENERATION FITTED WITH CCS IN 2020

196

MT OF CO_2 CAPTURED IN INDUSTRIAL APPLICATIONS IN 2020

1.40: Large-scale integrated project status, 2011



Source: GCCSI

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PART 2

Financing the Clean Energy Revolution

Part 1 concludes that most clean energy technologies are currently not on track to achieve the *ETP* 2DS objectives. Policy actions are required to scale-up the development and deployment of clean energy technologies, which will in part aim to shift capital from traditional fossil fuel technology investments, to clean energy alternatives. The power, transport, buildings and industry sectors will all require additional investments over the next decade to achieve the 2DS. This section reviews the scale of additional investments required, but also the fuel saving benefits from transitioning to a low-carbon energy sector. In addition, the potential sources of finance and tools to unleash this capital are highlighted.

Low-carbon energy investments to 2020

Over the next decade, an estimated USD 24 trillion will need to be invested in power, transport, buildings and industry sectors in the 2DS. Investments in the transport sector represent the largest share, accounting for 34% of total investments, and globally will exceed USD 8 trillion over the next decade. Over this period, a projected 1.7 billion new vehicles will be purchased globally. Building investments to 2020 will reach over USD 6 trillion of which just half is needed in OECD regions with significant investments for the retrofit of existing building envelopes and improvements in energy efficiency of HVAC systems, appliances and other equipment.

Investments in the power sector are estimated at USD 6.4 trillion under the 2DS, of which China will account for nearly 30% of investments – equal to the combined investments of the United States and Europe. China's economic growth is expected to remain strong over the next decade resulting in increased investment needs across all sectors, but particularly in the power and transport sectors to meet growing demand for electricity and higher vehicle penetration rates. In OECD member country regions, investments are dominated by buildings and transport, which combined make up between 65% and 70% of total investments in the next decade.

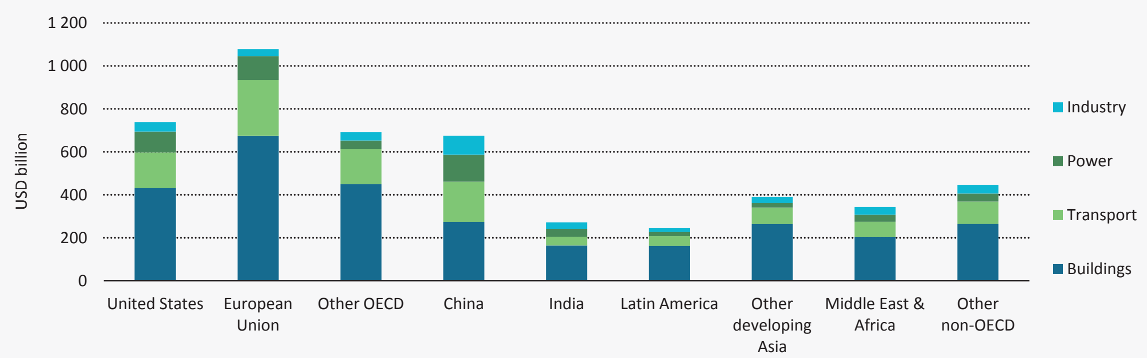
Compared to the investment requirements over the next decade under the 6DS of USD 19 trillion, total additional investment needs to achieve the 2DS is projected to be USD 5 trillion or 25% above investments needed in the 6DS. OECD member countries represent over half (USD 2.5 trillion) of these total additional investments, with the European Union accounting for the largest share of any region at 22% or USD 1.1 trillion (Figure 2.1).

Table 2.1 Total investment needs in the 2DS 2010 to 2020

USD billion	Power	Transport	Buildings	Industry	Total
United States	850	1 300	900	250	**3 300**
European Union	950	1 800	1 300	250	**4 300**
Other OECD	650	1 150	900	250	**3 000**
China	1 800	1 450	900	850	**5 000**
India	500	300	300	300	**1 450**
Latin America	300	350	300	200	**1 100**
Other developing Asia	250	600	450	300	**1 600**
Middle East and Africa	450	550	400	500	**1 900**
Other non-OECD	600	650	700	250	**2 200**
Total	**6 350**	**8 100**	**6 100**	**3 100**	**23 700**

The largest share of additional investments needs in 2DS compared to 6DS over the next decade are required in the building sector, representing more than half at USD 2.9 trillion globally. On a regional basis, buildings represent by far the largest share of the additional investment needs for all countries, accounting for 70% (Other Developing Asia) to 40% (China) of the share of total additional investments. Early investments in low-carbon building options are critical to achieving the high share of energy efficiency outlined in the 2DS. Delays in implementing these investments will result in the need for additional investments for new power generation capacity, as well as higher fuel costs in buildings and an increase in the number of people without access to reliable and affordable energy.

Figure 2.1 Cumulative additional investments in the 2DS compared to 6DS, 2010 to 2020



Note: United States and Canada LDVs include light-commercial vehicles, SUVs and passenger vehicles.
Source: Enacted and proposed targets: GFEI, 2011; IEA analysis and data.

Key point *Additional investments in buildings dominates in all countries, accounting for 40% (China) to 70% (Other Developing Asia) of additional investments.*

The importance of implementing energy efficiency measures over the next decade cannot be over-emphasised. In many cases these options have short payback periods with low or negative abatement costs. Investments with longer payback periods (such as deeper renovations in buildings) will also be needed to avoid technology lock-in. For new buildings mandatory building codes with stringent minimum energy performance requirements (standards) aiming to zero-energy buildings need to be implemented. For existing buildings governments should implement mandatory annual renovation rates; and each time renovation undergoes energy requirements should be based on life cycle cost analysis. There is also a need to enforce building codes and energy requirement at the design, the construction and operation stage of the building; and stringent penalties in case of non-compliance should be defined and implemented by governments. New financing mechanisms will need to be explored.

The diverse nature and large number of individual transactions in the building sector means that transaction costs associated with investment in individual energy efficiency projects in buildings can be prohibitive. A mechanism to pool individual transactions into a portfolio of energy-efficiency projects could help to overcome this barrier and governments could play an important facilitation role.

Benefits of a low-carbon energy sector

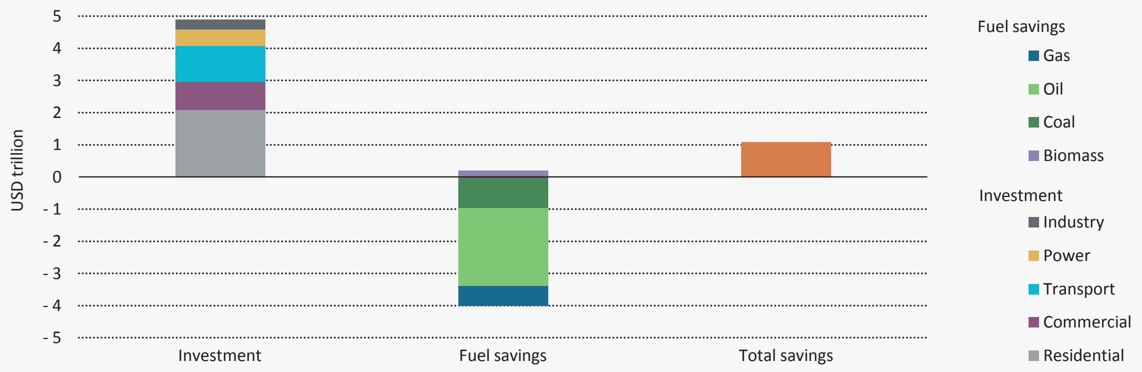
The additional investment needed to transition to a low-carbon sector will have significant benefits, not only in terms of reduced environmental damage, but also improved global energy security, as dependence on fossil fuels is reduced. Improvements in energy efficiency will reduce the growth rate of energy consumption. The amount spent to purchase fuel will decline sharply with the switch from fossil fuels to renewables. For countries that import oil and gas, this will improve current account balances and allow foreign reserves for other uses. In addition, the transition to a low-carbon energy sector will also yield significant health and employment benefits.

Fuel savings

The move away from traditional fossil-based energy technologies will result in significant fuel savings with reductions in the purchase of oil, gas and coal. An estimated USD 4 trillion will be saved in the 2DS from lower fossil fuel use and an additional USD 0.2 trillion will be spent on additional biomass for a net fuel savings of USD 3.8 trillion between 2010 and 2020. In energy terms, this represents a 10 600 Mtoe reduction in fuel purchases to 2020.

Over the longer term higher fuel savings will significantly offset the additional investment requirements in 2DS. An important challenge will be to shift investment patterns towards higher capital-intensive technologies with lower fuel inputs. In the buildings and transport sector, individual consumers often do not adequately value the benefits of reduced fuel costs in the future and focus more on the higher upfront costs (Figure 2.2).

Figure 2.2 Additional investment and fuel savings in the 2DS compared to 6DS, 2010 to 2020



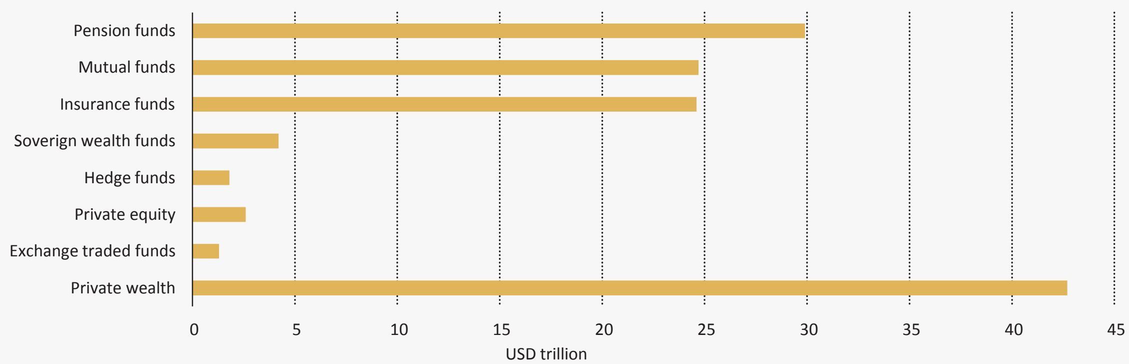
Note: Investment and savings are undiscounted, based on fuel price assumptions consistent with the 6DS.

Key point *Fuel savings would offset much of the additional investment costs needed to begin decarbonising the energy sector.*

Unlocking trillions from institutional investors

Of the USD 212 trillion in global capital markets, more than half are assets of the global fund management industry (McKinsey, 2011). The industry can be split into conventional fund assets, typically managed by pension, mutual and insurance funds, and unconventional fund assets comprised of wealthy individuals, sovereign wealth funds and hedge funds. These investors had combined assets of USD 117 trillion at the end of 2010, with conventional assets rising 10% to reach USD 79.3 trillion and unconventional assets

Figure 2.3 Global assets under management, 2010



Note: Approximately one-third of private wealth is invested in pension and mutual funds.
Source: OECD Global Pension Statistics and Institutional Investors database.

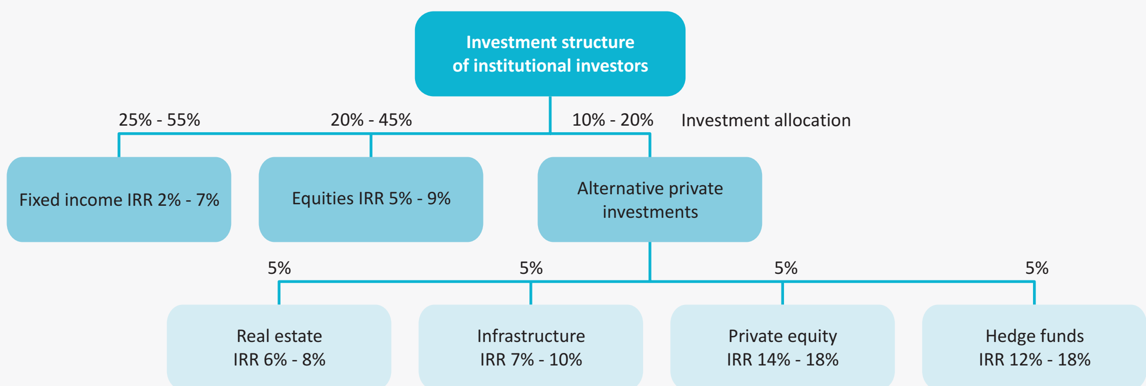
Key point *Availability of capital does not appear to be a major obstacles to funding the energy technology revolution.*

rising 12% to USD 37.7 trillion (Figure 2.3). Since 2000, assets under management of conventional funds have risen at a compound annual growth rate (CAGR) of over 7%, while unconventional funds (including private wealth) have risen at a CAGR of 6%.

Conventional funds generally have low appetites for risk and invest primarily in liquid (*e.g.* exchange listed and freely tradeable) equities, fixed-income and other securities, seeking average annual returns of 4% to 8%. Pension and insurance funds invest pension contributions and insurance premiums to fund future long-term and statistically determinable liabilities. Pension funds and insurance companies have greater flexibility in making long-term, illiquid investments. Mutual funds invest capital for capital appreciation and their time horizons range from short to long-term. Because mutual funds must be ready to redeem shares on a daily basis, they have large cash reserves and are nearly fully weighted to listed equities and bonds. These investors are major shareholders in listed companies and hold significant positions in government and corporate debt. Public pension funds, like private pension funds, seek adequate risk-adjusted returns for their investments and require stable inflation-adjusted income streams.

Investments in low-carbon power generation technologies, which often offer stable income streams through long-term power purchase agreements, appear to offer a good fit for these investors with relatively low appetites for risk. The average returns which these investors target vary depending on the associated risks of the different investment vehicles (Figure 2.4). It is important to note that the expected average return is based on variable performance of different investments so the actual target investors will strive for will need to be higher to achieve the indicated average returns. For example an infrastructure fund which expects returns of 7% to 10% will generally invest at 10% to 15% as some returns will be lower then their expected target.

Figure 2.4 Asset allocation and expected returns from institutional investors



Note: Significant ranges exist in different countries for asset allocation; figures shown above represent current allocations across various countries. IRR or internal rate of return is a rate of return used to measure and compare the attractiveness of different investments. In the figure above it is used to illustrate the expected average net returns from investors of different investment vehicles. For alternative private investments which are made via private unlisted funds fund there is a differential of 2% - 5% between the gross returns from the investment and the net returns to an investor to cover the cost of the fund manager. In the case of the infrastructure "asset class", there is a wide range of assets with varying risk profiles and return expectations. The 7% - 10% returns noted above are generally expected for what is known as "core infrastructure", which refers to mature "brownfield" operating assets with long-term inflation linked cash flows and concession or monopoly like status, such as transmission lines. New "Greenfield" infrastructure projects that entail construction risk, or where revenues are more variable or linked to GDP growth (e.g, ports, toll roads), or that have volume risks (*e.g.* wind production) or pricing risks, generally require higher returns to attract investors.
Source: Brown J. and M. Jacobs, 2011 and OECD, 2011.

Key point *Investors require signficiant returns on investments.*

Allocation of pension funds to clean energy technologies is currently very low, at less than 1% (Della Croce R *et al*, 2011) with little data currently available on allocation by other investors. In contrast, fund holdings in traditional energy companies (most of which are primarily fossil fuel based) are estimated to be approximately 5% to 8%. Raising adequate financing for clean energy will require attracting a much greater portion of funds under management by pension funds, and other conventional and unconventional fund investors.

The increased allocation of pension funds and other institutional investors to clean energy investments will occur only if the investment opportunities in these sectors offer adequate risk-adjusted returns. Pension funds cannot and should not be expected to invest in clean energy simply because it is needed by society. Government policies can correct market failures through regulations and policies aimed at filling the gap between investment risks and market barriers. They can also ensure that adequate domestic frameworks covering energy, climate and investment policies are in place to attract sufficient capital to this sector.

Understanding investment risks

Prior to investing in any project, investors will undertake a risk assessment of the project. A number of different risks will be evaluated by investors and cover regulatory and policy risks through to construction and markets risks (Table 2.2). Investors seek conditions in which risks can be understood, managed and anticipated (Hamilton, 2009). Policies can help to address both investment risks and market barriers to create suitable environments for low-carbon energy technologies to attract private sector finance.

The ability to evaluate and manage the above risks will differ depending on the stakeholder and their experience and capabilities to properly support these risks. For example, in the case of offshore wind, one of the largest risks for these projects comes with construction. Offshore wind farms are still at a relatively early stage in development, and can face many

Table 2.2 Risk analysis for investments in low-carbon energy technologies

Type of risk	Description
General political risk	Concern about political stability and the security of property rights in country, along with generally higher cost of working with unfamiliar legal systems.
Currency risk	Concern about loss of value of local currencies.
Regulatory and policy risk	Lack of long-term low-carbon development strategies; concern about the stability and certainty of the regulatory and policy environment, including longevity of incentives for low-carbon investment and reliability of power purchase agreements; instability in the price of carbon, such as weak or unstable environmental regulations; existence of fossil-fuels subsidies that make such investments more attractive to investors.
Construction/ execution risk	Local project developers or firms lacking the capacity and experience to execute the project efficiently; general difficulty of operating in a distant and unfamiliar country; level of risk subject to the maturity of the technology and the track record of the technology provider.
Technology risk	Whether a new or relatively untried technology or system will perform.
Unfamiliarity risk	Amount of time and effort needed to understand a project of a kind that has not been undertaken by the investor previously.
Public acceptance risk	Opposition from the public to low-carbon technologies, such as wind farms, CCS and nuclear.
Market risk	More competitors entering the market; change in consumer preferences and demand; technological advances.

Source: Adapted from Brown J. and M. Jacobs, 2011.

different challenges during the construction and operational phases. Companies that have significant experience in developing wind farms and, in particular, offshore wind farms, are particularly well placed to support the construction risk of developing offshore wind farms. Once the project construction is completed and operating, it can be sold (either in part or in its entirety) to a different actor that is equally adept at owning these assets and managing the market risks of projects in their operating phase.

Mechanisms and financing vehicles to leverage private-sector investment

A range of public finance mechanisms and financing vehicles has been identified that can be used to overcome these barriers (Table 2.3). Public finance should be used to underpin and develop early investment-grade projects to allow the private sector to move into new markets, thus helping build up the technical capacity of a country. Early public-private partnerships should be encouraged, as they can help demonstrate technologies and create new markets.

Table 2.3 Public finance mechanisms to leverage private-sector investments

Mechanism	Description and context	Estimated leverage ratio	Technology stage
Debt funds	Credit lines for senior or mezzanine or subordinated lending incentives.	n.a.	Demonstration, deployment and commercial roll out.
Loan guarantees	Pledge by a government or government-supported entity to protect the lender from technology, business model or other proof of concept risk (suitable for countries with high political risk, dysfunctional energy markets and lack of policy).	6-10 times	Demonstration, deployment and commercial roll out.
Export credit	A lending or guarantee line intended to promote exports of domestic clean energy manufacturers.	n.a.	Diffusion and maturity.
Risk insurance	Indemnity coverage for investors, contractors, exporters and financial institutions intended to spur investment in developing countries.	n.a.	Diffusion and maturity.
Energy service company funds	Financing vehicle for energy efficiency.	n.a.	Diffusion and maturity.
Policy insurance	Countries with strong regulatory systems, but where specific policies are at risk of destabilising.	10 times and higher	Diffusion and maturity.
Equity pledge fund	Projects with strong internal rate of return, but where equity cannot be accessed.	10 times	Diffusion and maturity.
Subordinated equity fund	Risk projects, with new or proven technologies; public sector first loss.	2-5 times	Demonstration, deployment and commercial roll out.
Publicly-backed Green or Climate bonds	Typically issued by a government agency or multinational institution, publicly-backed bond programmes offer tax incentives or rind-fenced funds suitable for smaller developers or in markets with high capital costs.	n.a.	Commercial roll out.

Source : WEF (2010); Caperton (2010) and CBI (2012).

The current economic crisis has reduced the amount of public finance available to support low-carbon energy technologies. Public finance must be used as efficiently as possible and should be targted at mechanisms that can leverage high levels of private sector finance. Well-designed public finance mechanism can leverage between three and fifteen times their amount in private-sector investments (IIGCC, 2010).

Well-targeted public finance mechanisms will help create an investment track record and thereby offset some of the perceived investment risk that private investors are not currently willing to support. For certain less-mature technologies such as CCS or for those which are not currently cost effective (some building technologies), where there is a larger public good aspect to developing or deploying these technologies, the role of public finance and regulation will be particularly important.

Different financing models will emerge in different countries, depending on the market structure of the energy sector and maturity of the financial market. In many emerging countries, such as China and Brazil, the prevalence of state-owned development banks and state-owned enterprises will mean that the role of public finances will be much greater than in more liberalised energy markets and mature financial markets such as the United Kingdom and United States.

Green or climate bonds

Green bonds offer the largest potential to attract funding from institutional investors in the next decade. Bonds represent roughly 50% of holdings by institutional investors, making this asset class particularly attractive. With a value of USD 95 trillion, the global bond market offers plenty of opportunities to raise large amounts of finance for clean energy technologies.

The current market size of self-labelled climate change-related thematic bonds (labelled anything from green, climate to clean energy) is, at USD 16 billion (Table 2.4), far below what is needed to create a liquid asset class that institutional investors could easily access.

Table 2.4 Green bond market (USD billion)

Multilateral development bank bonds	7.2
United States municipal clean energy / energy efficiency bonds	0.8
Renewable energy project bonds	8.5
Total	**16.5**

Note: As of March 2012.
Source: CBI database and Bloomberg database.

The largest green bond issuances to date have come from green or clean energy bond programmes by multilaterial development banks, such as the World Bank and European Investment Bank, totalling USD 7.2 billion. These bonds have received the highest AAA rating and have helped establish early confidence in the green bond market. The United States government has allocated USD 2.4 billion under a Clean Renewable Energy Bonds program to allow municipalities to finance public sector renewable energy projects[22]. In addition, a number of large bond issuances ranging from USD 500-850m in the United States have raised capital for wind and solar farm construction, and renewable energy manufacturers are increasingly turning to the bond markets in the absence of restricted bank lending.

An estimated USD 200 billion of bonds have been identified that could be classified as climate change investment-related bonds, once asset-backed and corporate bonds are included (CBI and HSBC, 2012). Climate bonds are defined as those issued to fund *or refinance* climate change mitigation, adaptation or resilence projects (Climate Bonds Initiative). Included investments would range from clean energy and grid development to water adaptation and flood defense.

Bonds can be issued by banks, governments or corporations. They can be asset-backed securities linked to a specific project or they can be treasury-style bonds issued to raise capital to fund a portfolio of projects. For a specific bond to have sufficient liquidity, it needs to be issued with a size of at least USD 300-400 million. Below this threshold, climate bonds will have difficulty attracting sufficient interest from mainstream markets.

Institutional investor appetite for bonds is largely in the investment grade area and in large-scale issuance. A liquid market requires issuance upwards of USD 200-300 billion, made up of bonds rated BBB or higher.

Qualifying as investment grade is an issue for clean energy investments, with ratings agencies typically awarding BB or lower ratings for wind and solar project bonds. A focus on issuing bonds for refinancing rather than project funding is one way of addressing this, with established projects likely to achieve higher ratings than pre-development project bonds; this would involve banks maintaining current bank debt to bond ratios of 20:1, but securitising loans within two years of development in order to avoid liquidity ratio issues involved in long-term holding of lower grade debt.

Another strategy would be to bring rating agencies, investors and governments together to determine optimal means to overcome barriers. The lack of track record for large-scale climate change related bonds means that risk is seen as greater than with existing investments; this is compounded by policy being seen as the main (and volatile) sector risk by investors.

Governments can help bring institutional investors into the market by:

- Providing insurance and other guarantees in relation or policy risk. For example the German government currently provides guaratees for power purchase agreements in Germany and in some other European countries, such as Greece.
- Providing legislative or tax credit support for qualifying bonds. The United States for example provides tax credits for clean energy bonds and the United Kingdom derisks securitised energy efficiency loan portfolios through the legislated repayment collection mechanisms in its Green Deal legislation.
- Issuing government climate bonds, as Australia is doing for its Clean Energy Finance Corporation, to lend to intermediary banks to direct to energy developers.

The last option is also a means of addressing problems of lack of scale, with large sovereign or multilaterial bank bonds raising funds for distribution across a portfolio of projects (CBI, 2012).

22 Of the USD 2.4 billion allocated under the US government programme only USD 600 million of bonds have been issued. Many developers who have won consent to issue the bonds have not yet done so.

Banks can issue asset-backed securities that effectively aggregate portfolios of smaller loans into institutional investor sized offerings. The market for asset-backed securities is still weak, but investment grade ratings can for the moment be achieved with partial or even full guarantees, all the while educating investors about the underlying projects in anticipation of the recovery of an asset-backed securities markets.

Like utilities, large corporations can do the same, contributing to developing an investment track record for underlying assets by linking their bond issuance to low-carbon projects, while providing full and later partial credit rating through the corporate balance sheet. Over time this will allow utilities to better focus their balance sheet on the need for development of new energy infrastructure.

Acronyms, Abbreviations and Units

Acronyms

AUD	Australian dollar
BAT	best available technology
BEV	battery electric vehicles
CAGR	compound annual growth rate
CCS	carbon capture and storage
CCUS	carbon capture use and storage
CEM	Clean Energy Ministerial
CFL	compact fluorescent light bulb
CHP	combined heat and power
CSP	concentrated solar power
DECC	Department of Energy and Climate Change (United Kingdom)
DOE	Department of Energy (United States)
EPA	Environmental Protection Agency (United States)
ETP	*Energy Technology Perspectives*
ETS	Emissions trading scheme
EU	European Union
EV	electric vehicle (including plug-in hybrid electric vehicles and battery electric vehicles)
EVI	Electric Vehicles Initiative
FIT	feed-in tariffs
FYP	five-year plan
GBP	Great Britain pound
GCCSI	Global Carbon Capture and Storage Institute
GFEI	Global Fuel Economy Initiative
GHG	greenhouse-gas
GSHP	ground source heat pumps
GWEC	Global Wind Energy Council

HELE	higher-efficiency, lower emissions (coal)
HEV	hybrid electric vehicles
HVAC	heating, cooling and ventilation
ICE	internal combustion engine
ICT	information and communications technology
IEA	International Energy Agency
IGCC	integrated gasification combined cycle
IPEEC	International Partnership on Energy Efficiency Cooperation
ISGAN	International Smart Grid Action Network
LDV	light-duty vehicle
LCIP	large-scale integrated project
MEPS	minimum energy performance standards
MVE	monitoring, verification and enforcement
NDRC	National Development and Reform Commission (China)
OECD	Organisation for Economic Co-operation and Development
PEPDEE	Policies for Energy Delivery of Energy Efficiency Initiative
PV	photovoltaic
R&D	research and development
RD&D	research, development & demonstration
RHI	Renewable Heat Incentive
SC	supercritical
SEAD	Super-Efficient Equipment and Appliance Deployment Initiative
S&L	standards and labelling
SMR	small modular reactors
SUV	sub-urban utility vehicle
USC	ultra-supercritical
USD	United States dollar

Abbreviations

CO_2	carbon dioxide
2DS	2°C scenario
4DS	4°C scenario
6DS	6°C scenario

Units of measure

EJ	exajoule
Gt	gigatonne
Gtoe	gigatonnes of oil equivalent
GW	gigawatt
GW_{th}	gigawatt thermal capacity
km	kilometre
kW	kilowatt
kWh	kilowatt-hour
kW_{th}	kilowatt thermal capacity
L	litre
L/100km	litre per 100 kilometres
lge	litres gasoline equivalent
m^2	square metre
MJ	megajoule
Mt	megatonne
Mtoe	million tonne of oil equivalent
MW	megawatt
MWh	megawatt-hour
TWh	terawatt-hour

Technology Overview Notes

Unless otherwise sourced, data in the two-page graphical technology overview is from IEA statistics and analysis. Additional notes below provide relevant details related to data and methodologies

Higher-efficiency, lower-emissions coal overview (page 18)

Figure 1.3: "OECD 5" is a weighted average of the efficiency of coal-fired power plants installed over the five-year period in Australia, Germany, Poland, the United Kingdom and the United States

Figure 1.4: Costs refer to overnight investment costs. Overnight cost is the present value cost of total project construction, assuming a lump sum up-front payment and excluding the cost of financing.

Figure 1.5: Total investments calculated are based on capacity additions, and cost and construction time estimates from the IEA. Total investment is allocated to the year in which the plant is assumed to have begun construction. This method was chosen to allow for consistency of comparison between different technology areas.

Figure 1.6: Capacity in 2014 is calculated based on plants under construction as of 2010 year-end.

Nuclear power overview (page 22)

Figure 1.8: France data is 2009. South Africa data is 2008. The South Africa and Brazil RD&D trend from 2000 to 2010 is excluded as no historical data exists for this period.

Figure 1.10: Cost estimates from NEA, 2010. The total investment is allocated to the year in which plant construction began. This method was chosen to allow for consistency of comparison between different technology areas.

Figure 1.11: The post-Fukushima 2025 estimate takes into account changes to government nuclear policies, expected project completions by that date, existing capacity with an assumption of a 60-year plant lifetime in the United States, and a 55-year lifetime in all other countries.

Renewable power overview (page 28)

Figure 1.15: Public RD&D spending includes data from IEA member countries, as well as Brazil (data is from 2010), India, Russia and South Africa (data is from 2008).

Figure 1.16: Annual capacity investment from non-hydro renewables from the BNEF database; large hydropower investment is based on Platts, 2010. Costs are based on IEA estimates.

Figure 1.18: Market concentration is calculated based on the Herfindhal-Hirschman Index (HHI), to assess current renewable market concentration and required concentration

under the *ETP 2012* 2DS by 2020. The HHI is a commonly-accepted measure of market concentration. It is calculated in this case by squaring the market share of each country competing, or expected to compete in the market (taking the 50 largest countries in terms of market share), and summing the resulting numbers. A total of <0.15 means that the market is un-concentrated; 0.15-0.25 represents moderate concentration; and >0.25 represents high concentration.

Electric vehicles overview (page 50)

Figure 1.31: January 2012 data are estimates.

Biofuels overview (page 54)

Figure 1.33: Biofuels yields are indicated as gross land use efficiency, not taking into account the land demand reduction potential through co-products, such as cattle feed, heat and power.

Figure 1.35: The United States is omitted from this figure as their biofuels target is not a blend percentage, as it is in other cases. The target is: 78 billion litres in 2015, of which 11.4 billion litres is cellulosic-ethanol; 136 billion litres in 2022, of which 60 billion litres is cellulosic-ethanol.

Carbon capture and storage overview (page 58)

Figure 1.37: Public RD&D data includes all IEA countries with the exception of Finland, Greece, Hungary, Ireland, Luxembourg, Poland and Sweden.

Figure 1.40: Project numbers are as of November 2011. The graph includes only operating projects that demonstrate the capture, transport and permanent storage of CO_2, with sufficient measurement, monitoring and verification systems, and processes to demonstrate permanent storage. Given frequent updates to the GCCSI database, project numbers may have been updated since publication.

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