Clean energy Progress Report

IEA input to the Clean Energy Ministerial

International Energy Agency

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Update June 2011

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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International Energy Agency

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Foreword

Less than three years after fossil fuel prices hit an all time high and the world plunged into its deepest recession since the Great Depression, geopolitical events are driving prices steadily higher. The short-term risks to political stability and economic activity posed by the world's dependence on fossil fuels are again as manifest as its long-term threat to environmental sustainability. To break this dependency, the world needs a clean energy revolution. Such a revolution would enhance global energy security, promote enduring economic growth and tackle environmental challenges such as anthropogenic climate change. It would break the long-standing link between economic growth and carbon dioxide (CO_2) emissions once and for all. But to succeed, it must also be truly global in scope. Even if countries belonging to the Organisation for Economic Co-operation and Development (OECD) somehow drove their emissions to zero, on today's path emissions from non-OECD countries would still lead to environmental disasters on an epic scale.

Such a sweeping revolution will require unprecedented investments in research, development, demonstration and deployment (RDD&D) of clean, low-carbon technologies of all sorts for decades to come. However, these investments will provide equally unprecedented benefits. The IEA estimates an internal rate of return on the investment of a bit more than 10% per year from the fuel savings alone. The enormous benefits to political and economic stability, as well as to environmental quality and human well-being, that we also expect would add immeasurably to this financial return.

But is such a revolution really possible? Can societies mobilise the huge amounts of capital needed in time? The good news is that there is already ample evidence that when governments provide a sustained strategic framework for a clean energy future, the private sector invests rapidly in clean technologies. Several countries, within the OECD and outside of it, have already achieved tremendous clean energy deployment, leading the way for others to follow. Many governments have announced targets for shifting their energy systems onto a cleaner, more sustainable path.

However, are announced policies sufficient? Which policies are approaching the rates of deployment needed? Where are the biggest challenges to our clean energy revolution? To answer such questions, this report analyses – for the first time – progress in global clean energy technology deployment against the pathways needed to achieve shared goals for sustainable, affordable energy. It provides an overview of technology deployment status, key policy developments and public spending on RDD&D of clean energy technologies.

We find that the past decade has seen a dramatic rise in global investment in renewable energy, led by wind and solar. The rate of energy-efficiency improvement in OECD countries is starting to accelerate again, after many years of modest gains. In transport, major car companies are adding hybrid and full-electric vehicles to their product lines and many governments have launched plans to encourage consumers to buy these vehicles. Public investment for RD&D in low-carbon technology reached an all-time high in 2009.

Unfortunately, the news is not all good. The growth of fossil fuels has matched — or even outpaced — that of clean energy globally. We are entering a period of uncertainty for nuclear power after the natural disasters in Japan. As incomes rise, consumers naturally demand more products leading to a growth in per-capita energy consumption. Smarter, more ambitious policies are clearly needed, ones that build upon the positive examples we have seen in a number of countries. This report offers a series of recommendations as input to the discussions that will take place among the ministers attending the second Clean Energy Ministerial (CEM) in Abu Dhabi. Working together, we still have time to address these recommendations and achieve a sustainable energy future. But we must not become complacent; time is running out.

Nobuo Tanaka
IEA Executive Director

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Key findings

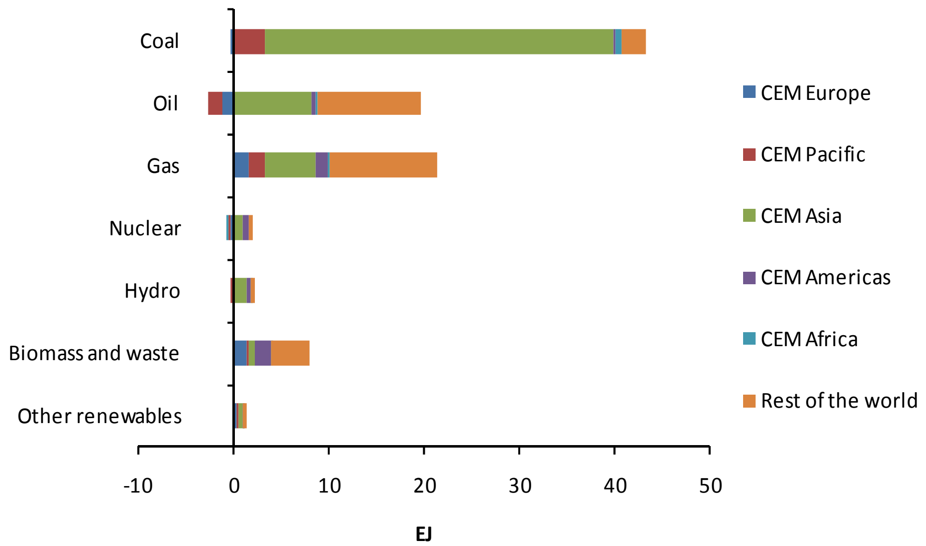
- Clean energy technologies are making clear progress globally, but fossil fuels continue to outpace them. More aggressive clean energy policies are required, including the removal of fossil fuel subsidies and implementation of transparent, predictable and adaptive incentives for cleaner, more efficient energy options.
- Thanks to favourable policy support, solar PV and windpower are achieving strong growth. However, achieving sustainable energy goals will require a doubling of all renewable energy use by 2020. There are also signs that policy support is weakening due to government austerity plans. Instead of eliminating successful policies, governments need to put in place dynamic schemes that respond to technology markets.
- For the past decade, coal has been the fastest-growing global energy source, meeting 47% of new electricity demand. Extensive deployment of CCS is critical to achieve climate change goals: around 100 large-scale projects are needed by 2020, but countries must accelerate their policy and funding support for the large-scale CCS demonstrations.
- Progress has been made to transform the market for some key energy-efficient products, including compact fluorescent light bulbs. However, in the buildings and industry sectors, significant under-investment remains, resulting from an array of market financial, information, institutional and technical barriers. Much more policy effort is needed to capture the near-term profitable and low cost energy savings opportunities.
- Biofuels have shown steady growth, but still only represent 3% of global road transport fuel consumption. A sound policy framework is required to ensure the sustainable growth of biofuel production by ten-fold to reach climate change targets in 2050. Commercialisation of advanced, sustainable biofuels will be particularly critical to meet targets, and will require significant expansion of production capacity.
- Electric vehicles are poised to take off. Major economies have announced targets that together would reach about 7 million vehicle sales per year by 2020. If achieved, this will result in over 20 million electric vehicles on the road by that year, taking into account all sales over the next 9 years. However, this will only account for about 2% of light-duty vehicle stocks worldwide; continued strong growth after 2020 will be important to ensure market transformation. Fuel economy of conventional light-duty vehicles has also been improving recently, but will need to improve faster to achieve a global target of 50% improvement by 2030 compared to 2005 levels.
- While nuclear capacity has remained nearly flat for the past decade, countries are currently constructing 66 nuclear reactors that should add 60 Gigawatts by 2015. However, the recent earthquake in Japan and resulting damage have led countries to review nuclear safety and investments across the board. As a result, nuclear expansion is likely to be slower than planned.
- An increased level of systems thinking is needed to integrate the broad range of individual clean energy technologies into the energy system. Increased attention and resources are required to expand smart grid pilot projects on a regional level.
- International collaboration is key to ensuring that momentum is maintained and gaps are addressed. The Clean Energy Ministerial offers an unique opportunity to accelerate technology deployment through government and corporate pledges and tracking progress toward shared global energy goals.

Growth in clean energy has been strong ... but needs to expand and accelerate

Clean energy technologies came into their own during the last decade. Implementation of energy -efficiency (EE) measures is improving. Renewable energy has seen 30% to 40% growth rates in recent years, due to market-creating policies and cost reductions. Carmakers are releasing the first set of a new wave of electric vehicles (EVs) and are attracting customers.

But formidable challenges remain. These developments show that many clean energy technologies are gaining momentum. However, not all of the news is good. Despite the tremendous growth seen in this sector, demand for traditional fossil-based energy has outpaced demand for clean energy (Figure 1). To achieve the clean energy revolution that has been called for, the current double-digit growth seen by renewable energy must be sustained for the long term. Energy-efficiency efforts must provide the right incentives for utilities, industry and consumers to invest, and must verify savings through improved monitoring and reporting. Advanced biofuels and electric vehicles must ramp-up dramatically. Government funding commitments to large-scale demonstrations for CCS and smart grids must be allocated. In short, achieving a sustained clean energy pathway on the global scale will require significant scale-up and acceleration.

Figure 1. Incremental total primary energy supply in CEM and the world, 2000-08



Note: CEM Europe is Denmark, Finland, France, Germany, Italy, Norway, Spain, Sweden and United Kingdom. CEM Pacific is Australia, Indonesia, Japan and Korea. CEM Asia is China, India, Russia and United Arab Emirates. CEM Americas is Brazil, Canada, Mexico and United States. CEM Africa is South Africa.

Source: Unless otherwise indicated, material in figures and tables derive from IEA data and analysis.

Table 1 includes an updated assessment of the current gaps faced by key clean energy technologies in terms of deployment requirements compared against the BLUE Map scenario and public investments in RD&D.

Table 1. Recent deployment growth compared with clean energy targets

Technology	Current rate	Required annual growth to 2020	Current status	Blue Map target 2020
Biofuel	18%	7%	2.54 EJ	5.04 EJ
Biomass power	7%	4%	54 GW	82 GW
Hydropower	5%	2%	980 GW	1219 GW
Solar PV	60%	19%	21 GW	126 GW
Wind power	27%	12%	195 GW	575 GW
Energy intensity of manufacturing	-1.30%	-0.60%	3.73 MJ	3.81 MJ
Geothermal power	4%	7%	11 GW	21 GW
Nuclear power	3%	4%	430 GW	512 GW
CSP	8%	50%	0.6 GW	42 GW
Electricity generation with CCS	Zero projects	3 GW per year	Zero projects	28 GW
Electric vehicles	-	Doubling of sales each year from 10 000 EV/PHEV sales in 2011 to reach Blue Map target	-	7 million sales in 2020

Green	Achieving or exceeding levels, maintain the course
Yellow	Progress but more concerted effort needed
Red	Sizeable gap between deployment and goals

Note: Table compares recent rate of improvement/growth in a technology area against the rate of improvement/growth required to reach the ETP BLUE Map scenario in 2020. Due to gaps in data, different time periods were used. The current rate for wind and biofuels is the annual average growth rate from 2005 -2010. For solar PV, biomass, geothermal, and CSP this period is 2004-2009. The observed trend in energy intensity is from 2005 – 2008. The current rate and status of nuclear includes capacity under construction up to 2015; the required rate is calculated for 2015 to 2020. Required rates are measured from the year of the last complete global data set. The Energy intensity is measured in MJ per USD PPP 2009. Biofuel is measured in energy use from all biofuels in EJ. Electricity generation with CCS includes generation from biomass, coal and gas. Assumes 10 000 EV/PHEV sales in 2011.

Source: based on ETP 2010 BLUE Map scenario and country submissions.

Energy efficiency

Energy efficiency is often referred to as an important fuel of the future. By reducing energy demand, improvements in energy intensity are estimated to deliver 30% of primary energy consumption. Public policy has successfully transformed markets for an array of energy-efficient products, including compact fluorescent light bulbs (CFLs), refrigerators, motors and key building components. These successes have been delivered by a set of well-designed and implemented energy-efficiency policies, including building codes, standards and labelling (S&L), energy certification schemes and utility programmes. Nevertheless, significant under-investment in energy efficiency globally results from an array of market, financial, information, institutional and technical barriers. More effort is needed to advance integrated building design and performance, strengthen appliance standards globally in all markets, improve monitoring and verification of labelling and certification schemes, incentivise utilities to invest more in energy efficiency, and provide a competitive framework for industry to invest in the best available technology (BAT).

Higher-efficiency coal use and CCS

For the past decade, coal has been the fastest-growing energy source, meeting 47% of new electricity demand globally. This growth has been accompanied by a move toward more efficient, cleaner coal plants worldwide. However, to meet global climate change goals at lowest cost, extensive deployment of CCS is critical: around 100 large-scale CCS projects are needed by 2020, and over 3 000 by 2050. While there are over 70 projects currently planned, it is uncertain how many of them will be realised. The currently available public funding for large-scale demonstration projects (USD 25 billion) is not enough. Delays in funding decisions are caused by a number of factors that governments must address, including the high cost of CCS, lack of public support for CCS, and a need for adequate regulatory frameworks for CO_2 transport and storage.

Nuclear power

While nuclear capacity has remained nearly flat for the past decade, 15 countries are currently constructing 66 nuclear reactors that together should add 60 GW of capacity by 2015; these and other countries have ambitious plans to further expand global nuclear capacity by 2020. However, the recent earthquake and tsunami in Japan, and the resulting damage to nuclear reactors, will lead many countries to review the safety and siting of their existing and planned nuclear plants. As a result, nuclear expansion may be slower than previously announced plans suggest.

Renewable energy

Renewable energy market success has been driven by policy support, which has grown considerably in the last decade. Policies continue to evolve to address market developments and reduce costs. In the case of solar energy, at least ten countries now have sizeable domestic markets. Both utility-scale and rooftop solar photovoltaic (PV) generation have seen a major scale-up in the past few years, resulting from market-creating policies that led to an extraordinary decline in the cost of PV modules. Wind power also experienced dramatic growth over the last decade; global installed capacity at the end of 2010 was around 194 GW, up from 17 GW at the end of the year 2000.

Despite this good news, worldwide renewable electricity generation since 1990 grew an average of 2.7% per year, which is less than the 3% growth seen for total electricity generation. While 19.5% of global electricity in 1990 was produced from renewable sources, this share fell to 18.5% in 2008. This decrease is mainly the result of slow growth of the main renewable source, hydroelectric power, in OECD countries. Achieving the goal of halving global energy-related CO_2 emissions by 2050 will require a doubling (from today's levels) of renewable generation by 2020. Non-hydro renewables will have to increase at double-digit rates; wind power must see an annual average growth rate of 17% and solar power 22%. While these levels have been exceeded in the past few years, this level of high growth must be sustained for the long term.

Biofuels

Biofuels have seen steady growth during the last 10 years. Driven by policy support, most prominently in Brazil and the United States, and more recently in the European Union and Southeast Asia, global production grew from 16 billion litres in 2000 to more than 100 billion litres in 2010. Further, many countries are accelerating their investments in advanced biofuels, with large-scale demonstration plants under construction in many regions. Even with this growth, biofuels represented around 3% of global road transport fuel consumption in 2010. To stay on target, governments and industry will have to ensure the large-scale deployment of sustainable biofuels. More specifically, for biofuels to reach in 2050 a 27% share in total transport fuel, their production will need to increase more than tenfold over the next 40 years.[1] It will be particularly important that advanced biofuels reach commercial scale in the next 10 years, with a 30-fold capacity increase until 2030.

Electric vehicles and vehicle efficiency

Major economies have announced targets that together would reach about 7 million vehicle sales per year by 2020. If achieved, this will result in over 20 million electric vehicles on the road by that year, taking into account all sales over the next nine years. There has been a strong growth in the number of new car models announced, and more importantly, models being sold. Most of the large markets now offer incentives and support schemes to accelerate consumer adoption. However, vehicle sales are only beginning, and even if targets are met in 2020, this will still only represent 2% of vehicles. It will take even longer sustained efforts to achieve substantial impacts on light-duty vehicle (LDV) energy use and CO_2 emissions. To ensure successful ramp-up of EVs, governments must accelerate grid integration through standards development and programmes that invest in recharging infrastructure.

Vehicle efficiency continues to improve, with average global new LDV fuel economy reaching about 8 litres per 100 km (L/100km). Planned tightening of fuel economy standards in most major economies should accelerate this trend. In order to lock in the long-term improvements, and reach the Global Fuel Economy Initiative (GFEI)[2] target of halving new LDV fuel use by 2030, these standards must be extended beyond 2020 and other countries must adopt strong fuel economy policies.

[1] This is the target of the IEA Biofuels roadmap (forthcoming 2011).

[2] For more information about the Global Fuel Economy Initiative, visit www.globalfueleconomy.org.

Smarter, more ambitious strategies are needed

The last decade has seen some renewable energy technologies become competitive with conventional energy technologies. Most clean energy technologies, however, still cost more than incumbent fossil-based technologies that have received (and continue to receive) subsidies from government in the form of tax credits, infrastructure development and funding for large-scale demonstration. Fossil fuels currently receive USD 312 billion (2009) in consumption subsidies, versus USD 57 billion (2009) for renewable energy (IEA, 2010g). The competitiveness of clean energy technologies lags behind fossil-based technologies due to their level of maturity, as well as the lack of a price for external environmental impacts, including greenhouse-gas (GHG) emissions. Moreover, the deployment of technologies is hampered by non-economic barriers such as administrative burdens, grid integration issues, lack of awareness and public acceptance problems. Clean energy technology deployment will therefore require a concerted public and private commitment, supported by more ambitious policies. It is clear that setting a CO_2 price will not be enough to achieve the revolution. Governments need to take action on each of the following policy measures:

- Increase public investment in innovation through support for research and development (R&D), as well as large-scale demonstration.
- Implement smarter energy policies, including removing non-economic barriers and providing transparent, predictable and adaptive incentives for cleaner options.
- Facilitate the uptake of clean energy technologies into energy systems by supporting integration of technologies such as smart grids.
- Phase out subsidies for fossil fuels.
- Establish a price on CO_2 emissions.

A growing body of experience shows that a clean energy revolution can be achieved through a comprehensive policy approach. Over the last two decades, several countries have achieved dramatic changes in their energy markets. A key to success has been to create a strategic, comprehensive approach that communicates to the public the energy security, economic growth and environmental benefits of clean energy investment.

Successful national strategies also work with the private sector to identify a set of priority technologies, and provide a package of co-ordinated, predictable policies to accelerate technology development. This involves designating lead institutions, providing sustained funding and reducing duplication by improving lines of communication and co-ordination. It also requires providing smart interventions along the technology development chain from research to demonstration, large-scale integration and market commercialisation, and pulling technologies into the market using targeted policies (Box 1).

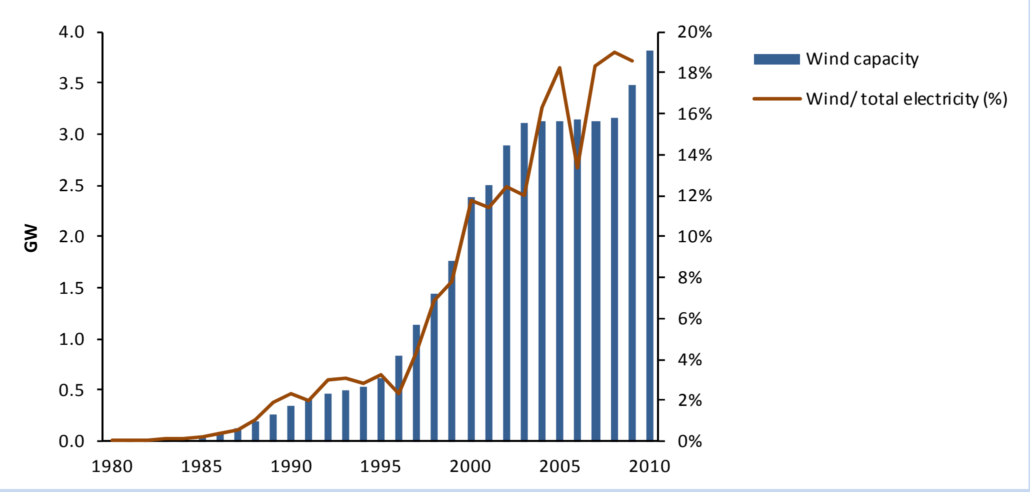
Other countries benefit in a number of ways from the success of these pioneering countries: testing policy tools and approaches; creating a small initial market for technologies, which sets a path for future cost reductions; and exporting their expertise and technology to the rest of the world. This success required a high-level political commitment, private sector support and, in most cases, a substantial commitment of funds from governments or electricity customers. In the case of renewable electricity, several countries are currently revising policies and tariff rates, given unexpected growth that has resulted in escalating policy cost. However, it is clear that by building on these successful national examples, countries can accelerate technology learning and diffusion, achieve cost reductions and become world leaders in clean energy technologies.

Box 1. Wind power: building momentum through national policy leadership

Starting in the late 1980s, Denmark aimed to reduce fossil fuel imports and address climate change concerns by developing a local renewable energy industry, with a focus on biomass and wind. Today, nearly 20% of electricity is produced from wind, and Denmark is one of the leading exporters of wind energy technology and expertise around the globe (Figure 2). Energy products and equipment (including wind turbines) accounted for over 11% of total goods exports in 2009. Further, Denmark has done this while reducing oil imports and CO_2 emissions. Key factors of this success were:

- Reliable public support and private commitment to the goals of the technology strategy.
- A set of market introduction mechanisms, including loan guarantees for large turbine export projects and feed-in tariffs (FIT) that required utilities to purchase all generated wind energy at a consistent, above-market price.
- Provision of financial incentives for the public to become supporters of the wind energy economy through wind co-operatives.
- Supporting industry wind R&D by developing guidelines and standards for wind turbines while leading research collaboration on the exploration and exploitation of wind resources.

Figure 2. Danish wind power capacity growth

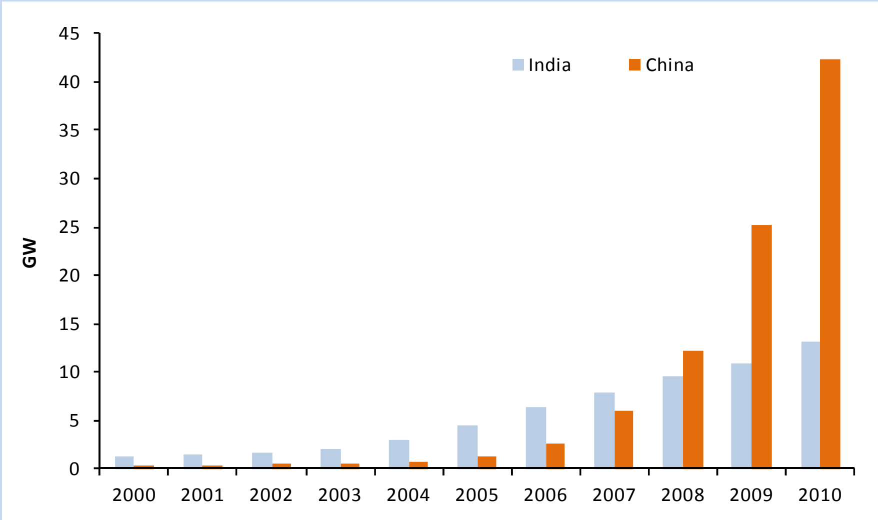


Source: Global Wind Energy Council (GWEC), and Danish Energy Agency, 2010.

In the past decade, India now has the fifth-largest installed wind power capacity in the world, more than three times the installed capacity of Denmark (Figure 3). As in Denmark, this growth was driven by a set of stable policies and support mechanisms, including:

- Effective legislation such as India's Electricity Act of 2003, which requires state energy regulatory commissions to encourage electricity distributors to procure power from renewable energy sources; this led the states to develop aggressive renewable energy targets and policy support mechanisms.
- Support for development of domestic wind manufacturing capability through Suzlon, an Indian-owned company that holds over 50% of the Indian wind turbine market share and has also captured a large share of the global market.

Figure 3. China and India's growth in wind power capacity



Source: Global Wind Energy Council (GWEC) and country submission.

China began installing wind power capacity in 2005, but has since become the world's largest domestic wind market, achieving three times the installed capacity in India (or ten times the capacity in Denmark) in just give years (Figure 3). As in Denmark and India, China created strong incentives and drivers for private investment through a comprehensive mix of support, including:

- The 11th Five-Year Plan (2006) included renewable energy scale-up to meet growing electricity demand and achieve energy security and pollution reduction goals. The plan included national targets for wind: 5 GW installed in 2010; and 30 GW installed in 2020.
- These targets are implemented by the provinces and by electricity producers through mandated shares of renewable energy. The policy combines market instruments (*e.g.* bidding on concessions and mandated market share) with government intervention (*e.g.* price controls and technology targets).
- Support for state-owned companies to invest in wind R&D.

Notably, China's central government (through the National Development and Reform Commission (NDRC)) replaced the tender system, which had granted on-grid prices that varied significantly. Recognising that the bidding system's low tariffs were a key barrier to profitable wind development, the NDRC established in mid-2009 a fixed FIT, differentiated by regional wind resource. As a result of this pragmatic, integrated approach, China's installed wind capacity exceeded the 2010 target by 320% (China Electricity Council, 2010). The 12th Five-Year Plan (published in late March 2011) will likely contain a further increase of the 2020 targets above 100 GW.

Recommendations for energy ministers

Make the Clean Energy Ministerial an international forum for commitment, action and shared learning

The reality of the clean energy challenge is such that individual and isolated actions will not enable the rapid and large-scale transition required. Increased collaboration among countries, stakeholders and initiatives that seek to achieve the shared benefits of clean energy technology deployment is imperative to rapidly scale-up investment, replicate the positive steps that are being taken, and enhance the cost-effectiveness and efficiency of action. Several examples demonstrate that when one (or more) country sets a pioneering pathway in clean energy technology development, it increases the potential for domestic scale-up, with associated cost reductions in the technology. This shared learning needs to accelerate if countries want to remain on track to realise the full potential of clean energy technologies. One strategy would be to create a forum within the Clean Energy Ministerial for common pledges to develop new markets for clean energy technologies.

The Clean Energy Ministerial provides a unique opportunity for governments to translate dialogue into concrete action, in order to collectively enhance energy technology development and deployment. Through agreement to a set of far-reaching and ambitious goals, this group of key governments can make a significant difference to the global deployment of clean energy technologies. The initial successful establishment of the CEM process, with its related technology initiatives, is a positive step that clearly demonstrates the shared interest in learning together and in accelerating the transition to clean energy. There are a number of actions that the CEM could promote, in close collaboration with existing international technology initiatives.[3]

Clean energy ministers should:

- Utilise the regular CEM meetings to make shared government and corporate pledges to invest in targeted clean energy technologies, through the launch of new financial mechanisms, targeted policies and/or procurement. Track progress in fulfilling these pledges.
- Working with the IEA, collect and share data on technology deployment, policy implementation and investments in clean energy RD&D.[4] Initiate discussion among CEM countries on a common set of data that will be collected on a regular basis, and provide training and other support to countries that require it. Utilise CEM meetings as an opportunity to provide updated data on deployment, policy implementation and RD&D investment thereby providing the evidence base for policy announcements and activities.
- Identify the most promising products and technologies for common standards and develop projects to map existing harmonisation efforts in specific technology areas; develop harmonised approaches based on these efforts.
- Engage the corporate sector on best practices in energy technology RD&D policy and innovation. Create a mechanism through which companies can report RD&D expenditures in a

[3] Including the International Low-Carbon Technology Platform, the European Union Strategic Energy Technology Plan, and a number of other multilateral and bilateral efforts.

[4] This report includes data from the following countries: Australia, Brazil, Canada, Denmark, Finland , France, Germany, Italy, Korea, Japan, India (Policies only), Mexico, Norway, Spain, Sweden, UK, USA, UAE. Future data collection efforts need to expand to include all major economies.

manner that maintains their competitiveness while offering government guidance as to gaps and priorities for government spending. Explore ways to create innovative financing mechanisms that reduce the cost of clean energy financing.

Continue to increase public investment in technology innovation

Governments have a clear role in technology innovation. Technologies ranging from rail transport and nuclear energy to the Internet and global positioning systems (GPS) were all invented by government-supported researchers, developed with public funding or first deployed through government purchasing and incentives. Public investments are needed to train the human capital and build the enabling infrastructures required for the widespread deployment of many technologies.

In 2009, governments recognised that clean energy is a driving force for economic recovery. A number of major economies invested recent stimulus funds in clean energy RD&D projects such as high-speed rail, CCS demonstration projects and smart grid pilot projects. As a result, public sector energy RD&D in 2009 rose to its highest level ever, eclipsing the previous high achieved during the oil crisis of the 1970s. Annual global public RD&D spending on energy in CEM countries now exceeds USD 21 billion. This is likely the minimum level needed to achieve the rate of technology deployment required to attain climate change targets (IEA, 2010c). However, indications for 2010 show that spending levels once again dropped – marking the end of stimulus spending –and were closer to 2008 levels.

To achieve the necessary clean energy targets, higher spending levels must be sustained over the long term and spending priorities need to shift. During the last decade, countries spent USD 56 billion on nuclear energy research and USD 22 billion on fossil research, but only USD 17 billion on renewable energy and energy-efficiency research combined.

Clean energy ministers should:

- Realign government subsidies for fossil fuels to support clean energy.
- Use market mechanisms, such as carbon taxes or proceeds from GHG auctions, to generate dedicated funding for RD&D.
- Provide incentives for greater private sector investment in clean energy through tax credits and market-creating mechanisms, and through innovative public/private partnerships.
- To address the impact of continued fossil fuel use, provide immediate allocation of announced funds for large-scale CCS demonstration projects.

Unleash the potential of energy efficiency

Global energy intensity is improving but leaves no room for complacency; much cost-effective energy-efficient potential is not yet tapped and energy demand is growing. Energy efficiency can and should be improved across all sectors. Carbon prices are essential but will not alone address all the barriers to energy efficiency, other policies targeting energy efficiency are needed.

Clean energy ministers should:

- Develop policy packages that target energy-efficiency actions in all sectors and strive for sustained efficiency improvements.
- Use the CEM process to track and deliver more detailed data on energy-efficiency technology deployment and RD&D spending to identify priorities for action and collaboration.

- Use the CEM process to identify significant end-use technology areas as priorities for improved energy-efficiency market transformation, including domestic cold appliances, domestic lighting, electric motors, air conditioners and network standby power, among others.

Sustain the momentum of innovation in renewable energy

Several countries have successfully triggered the sustainable, large-scale deployment of renewable energy technologies. This success has been the result of smart support policies that these leading countries have developed and applied. Their experience points to a number of key design principles that policy makers should follow to arrive at "investment grade" policies. If policy makers adhere to these basic design principles, the vast potential renewable energy technologies have to meet global energy needs can be unlocked.

Clean energy ministers should:

- Remove non-economic barriers, such as administrative hurdles, obstacles to grid access, poor electricity market design, lack of information and training, and social acceptance issues.
- Develop adaptive, predictable and transparent support frameworks to attract investment.
- Develop and implement transitional incentives guaranteeing specific – but decreasing – levels of support as different technologies advance in their degree maturity and move towards market competitiveness.
- Give due consideration to the impact of large-scale penetration of renewable energy technologies on the overall energy system, especially in liberalised energy markets, with regard to overall cost efficiency and system reliability.
- Expand the use of renewable energy for off-grid and mini-grid applications.
- Ensure synergies with climate change policy frameworks.

Foster electric vehicle market introduction

In order for EVs to succeed, governments must make commitments to building sustained markets that last for at least the next 10 years. This should include price incentives for consumers (and adequate and stable funding to pay for these incentives over at least the next 5 years, followed by a phase-out period); support for construction of adequate recharging infrastructure; working with cities to ensure cohesive regional and national systems; funding for RD&D, including pilot programmes and consumer education campaigns.

Clean energy ministers should:

- Ensure that sufficient recharging infrastructure is put in place not only for the initial wave of vehicles (*e.g.* a few thousand within a country, through 2012) but also the second phase of market ramp-up (*e.g.* potentially up to hundreds of thousands or even a few million vehicles, through 2015-20).
- Send clear signals that vehicle price incentive support will not suddenly disappear. At the same time, governments need to avoid exposure to large potential subsidy costs. One option is to allocate an annual limit on incentive expenditures, and keep that amount each year through 2020, reducing the amount per vehicle as sales rise. This has the benefit of automatically lowering the support level per vehicle as sales increase.

Develop integrated clean energy systems

The year 2000 marked an important historical moment, as the share of global population living in urban environments surpassed 50%. This proportion will continue to grow over the next few decades. The energy infrastructures on which communities depend will therefore need to be adapted and upgraded to meet increasing demands for energy services. This provides the opportunity for local government leaders to encourage increased deployment of clean energy systems and gain the benefits that they offer.

The development of smart grids is an essential step to enable and integrate the clean energy technologies needed to support demand, supply and transport. Smart grids are needed to provide the information and tools to allow electricity consumers to decrease costs and increase efficiency of energy use. Several concepts are emerging that extend the reach of the smart grids from electricity systems to broader energy and societal contexts. One of these is the smart community or smart city.

A smart community integrates energy supply and use systems within a given region in an attempt to optimise operation through customer energy management while also allowing for maximum integration of renewable energy resources, from large-scale wind farms to micro-scale rooftop PV systems. Smart communities include existing infrastructure systems, such as electricity, water, transportation, gas, waste and heat, as well as future systems such as hydrogen and EV charging. The goals of such integration through the use of information and communication technology (ICT) include increased sustainability, security and reliability, as well as societal benefits such as better services, reduced capital investment and job creation (IEA, 2011c).

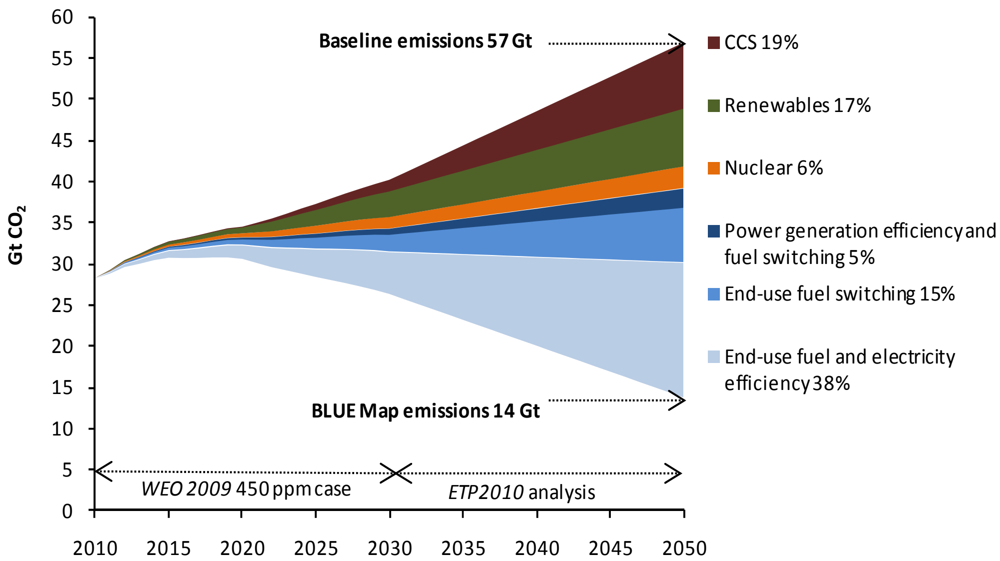
Clean energy ministers should:

- Commit to scale-up existing small-scale smart grid pilot efforts to carry out several regional large-scale and system-wide demonstrations that identify technology, regulatory and customer solutions.
- Provide assistance to local governments to develop tailored approaches that engage and educate energy customers by supporting technologies, developing regulations and helping industry to create business models for smart grids roll-out.

Clean energy progress report

The BLUE Map scenario sets a goal of halving global energy-related CO_2 emissions by 2050 (compared to 2005 levels) and sets out the least-cost pathway to achieve that goal through the deployment of existing low-carbon technologies (Figure 4). This can serve as a vision for shared global goals to reduce GHG emissions while enhancing energy security and advancing economic growth.

Figure 4. Key technologies for reducing CO_2 emissions under the BLUE Map scenario, 2010



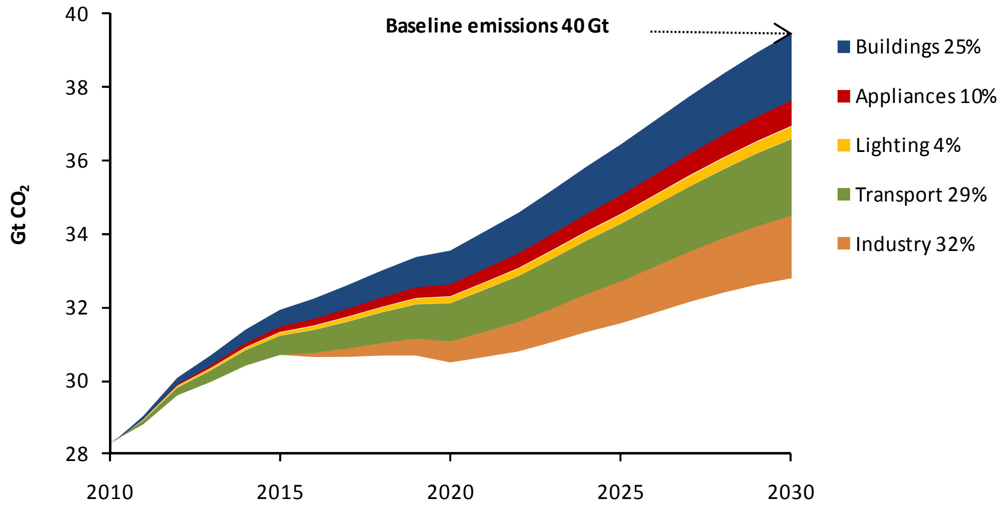
The BLUE Map scenario, together with IEA technology roadmaps, provides clear pathways for deploying clean energy technologies. These can be compared against current deployment, as reported in IEA statistics and in data collected from countries that participate in the CEM process, thereby providing a preliminary assessment of global progress toward the clean energy transition. The following section provides a more in-depth discussion of deployment status, policy implementation and public spending on RD&D for six categories of clean energy technologies: energy efficiency; higher-efficiency coal use and CCS; nuclear power; renewable energy; biofuels; and EVs and vehicle efficiency.

Energy efficiency

Since the early 1970s, global energy intensity has improved at an average rate of 1.7% per year, but this improvement must be measured against overall increases in CO_2 emissions and energy consumption resulting from economic growth. Without energy-efficiency improvements, final energy use in 2006 would have been 63% higher in the OECD-11 than it was in the early 1970s (IEA, 2010d). It has been estimated that global savings from energy productivity improvements was 3.6 gigatonnes of oil equivalent (Gtoe) in 2008, or almost 30% of primary energy consumption (WEC, 2010). However, energy efficiency's potential has barely been tapped. The economic crisis and resulting stimulus programmes, as well as rising fuel costs, have acted as strong drivers of recent energy efficiency, yet these are offset by increased consumer demand and willingness to invest and lend in times of economic recession.

Under-investment in energy-efficiency results from an array of market, financial, information, institutional and technical barriers; carbon pricing alone will not be enough to overcome these. The IEA has developed 25 policy recommendations to help governments achieve the full potential of energy-efficiency improvements across all energy-consuming sectors. If implemented globally without delay, proposed actions could cumulatively save around 7.3 gigatonnes (Gt) of CO_2/year by 2030 (Figure 5).

Figure 5. Estimate of potential CO_2 emissions savings through implementation of IEA 25 energy-efficiency policy recommendations



The consolidated set of recommendations covers seven priority areas: cross-sectoral activity, buildings, appliances, lighting, transport, industry and power utilities. The 2009 progress report showed that IEA member countries had implemented 57% of the 25 IEA energy-efficiency policy recommendations (IEA, 2010d). No single policy can overcome the energy-efficiency gap. Policies are required in all sectors to achieve significant improvements in energy efficiency. Effective approaches that reflect the diffuse and incremental nature of energy-efficiency actions are needed. Policies also need to include a systemic rather than individual component approach. This section provides a snapshot of the energy-efficiency landscape across key consuming sectors and end-uses, highlighting key technologies, policy developments in CEM countries, and RD&D spending trends.[5]

Energy-efficient buildings deployment

The energy consumption of the buildings sector is projected to grow from 2 759 Mtoe (2007) to over 4 400 Mtoe by 2050, with more than half of this consumption in residential buildings and a significant increase of the non-OECD countries share of the total energy consumption in the buildings sector (IEA, 2010a). Deep cuts in building energy consumption are achievable by implementing stringent requirements for both new and existing buildings and deploying the existing technologies on a global scale. Achieving significant energy reduction in the buildings sector is feasible with existing technologies if the investment costs are lowered and efficient designs are employed in an integrated way. However, in order to reduce energy consumption of the buildings sector to the levels that are needed for the longer term, new buildings will need to

[5]Vehicle efficiency is covered separately in the last section of this report.

be zero-energy and deep renovation of existing buildings will be required. Therefore, the challenge for the next decades is to put in place policies that target improvements in the technical efficiency of building components as well as efficiency improvements in the design of the new buildings and the design of systems, especially heating, ventilation and cooling systems.

During the last three decades, improvement has been made on the energy performance of insulating material and windows; key components of the energy efficiency of the building shell. Most IEA member countries now use high-performance insulating materials; double glazing windows are becoming standard. The increase of the sales of high-performing windows and insulating materials show the positive steps that are being taken to ensure improved efficiency of buildings envelope and shell technologies.

Policy developments

Major economies use a variety of policies to make their buildings more energy efficient, including building codes, building certification and standards and labels (S&L) for buildings and building components. However, these policies lack verification of the performance in the field. Building codes that include energy-efficiency standards for new buildings are used in all IEA member countries. Many CEM countries have introduced minimum energy requirements for new buildings, with 13 IEA countries including mandatory energy-efficiency requirements in codes for new buildings, as well as the UAE and India. Building code standard stringency varies widely. The United Kingdom's minimum energy performance standards (MEPS) for buildings are set to tighten so that, by 2016, all new dwellings will be zero-carbon. Germany's current strong efficiency standards are expected to be raised 30% in 2012. Denmark also has strong requirements that will rise by 2015. Once these amendments are in force, it is expected that Germany's and Denmark's building codes for new buildings will be close to the level of stringency recommended by the IEA. Other countries—including the Netherlands are moving to implement more ambitious requirements.

In the case of existing buildings, many CEM countries have introduced energy certification schemes that analyse energy use and recommend improvements. Eight IEA member countries have successfully implemented mandatory certification schemes for buildings. There are also several voluntary certification schemes. A number of nations also implement voluntary standards and labelling schemes and energy requirements windows.[6]

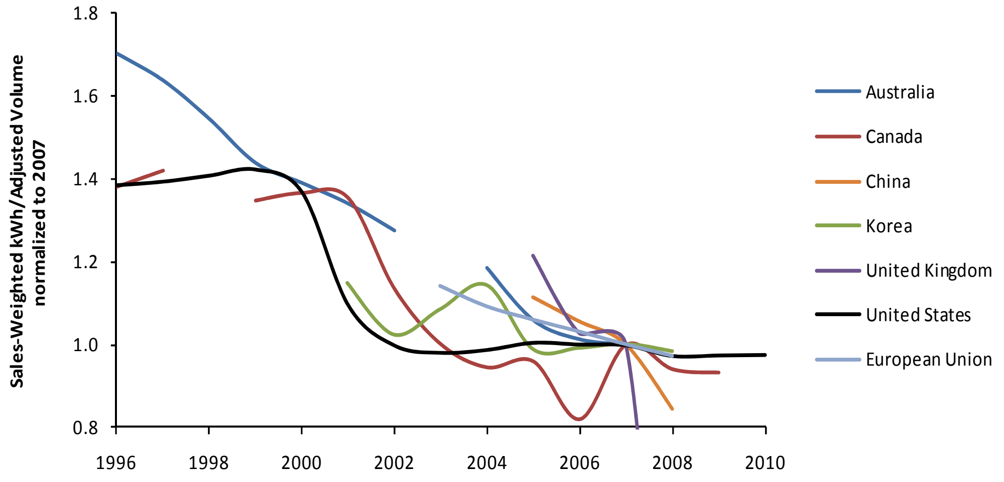
Deployment of energy-efficient household appliances

The use of electricity by appliances in IEA countries grew by 53% over the period 1990-2006, accounting for 15% of total electricity consumption (IEA, 2010d). In all countries electricity use by household appliances — *e.g.*, refrigerators, air conditioners, washing machines, stoves — is forecast to rise, and particularly in emerging markets. A key issue will be strengthening and broadening the appliance standards and labelling programmes in countries that manufacture and import these appliances.

Household appliances represent the best example of how government policies and public-private partnerships can transform consumer purchasing of energy-consuming equipment. In the case of refrigerators, energy consumption has steadily improved while purchase prices have decreased. Figure 6 shows the increased efficiency for new refrigerator/freezer combination units in each country, resulting from improved product performance.

[6] Additional details on national energy-efficiency policy implementation can be found at www.iea.org/textbase/pm/?mode=pm

Figure 6. Change in energy efficiency of new refrigerator/freezer combination units in select countries



Note: This data has been normalised to 2007 to highlight the trend. US data prior to 2005 is estimated.
Source: IEA 4E Implementing Agreement and country submissions.

These trends in efficiency improvements are, however, offset increased global sales and resulting energy demand.

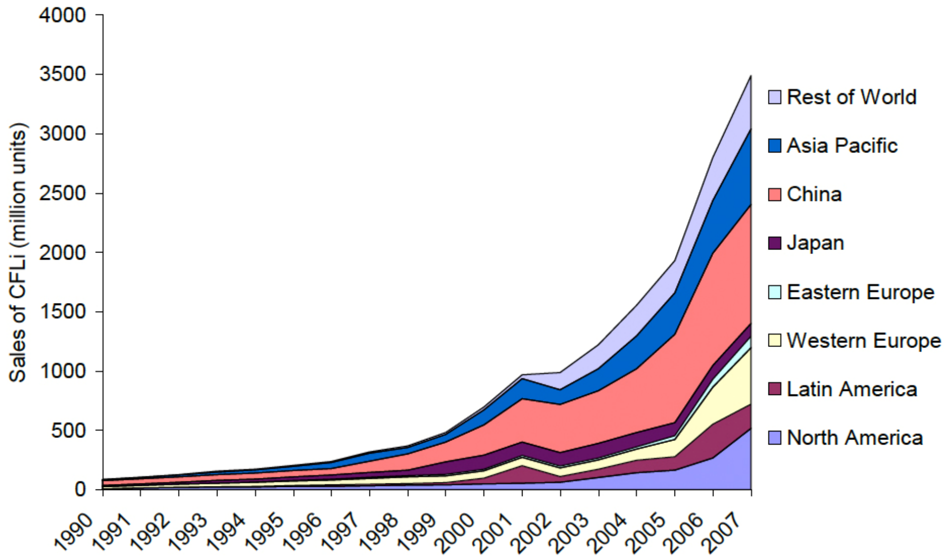
Policy developments

Major economies actively implement energy-efficiency policies for appliances, with 73% of CEM countries implementing MEPS and labelling for a growing list of appliances. Over 50 nations implement end-use equipment programmes which seek to improve energy efficiency for electrical appliances and equipment in the residential, commercial and industrial sectors (CLASP, 2010). Product energy labeling takes one of two forms – endorsement labeling, such as the US ENERGY STAR label, and comparative labeling, as found in Australia, Korea and the EU. Government standards and labelling programmes have transformed the market for many appliances by increasing their functionality and efficiency while reducing unit cost. However, non-compliance is a major factor which limits S&L programmes in achieving their potential energy efficiency. Better monitoring, verification and enforcement (MVE) of S&L programmes is needed. International co-ordination and collaboration can assist in lowering the costs of such programmes (IEA, 2010f).

Energy-efficient lighting deployment

Lighting is one of the main energy-consuming sectors, consuming a fifth of global electricity. For most of the 20th century, incandescent light bulbs were the only cost-effective technology to provide artificial indoor lighting. However, since the early 2000s the production costs of more efficient technologies such as CFLs dropped, making them a cost-effective alternative. In recent years there has been a rapid increase in global CFL sales. Between 2000 and 2007, the average growth rate in IEA countries was 34%, 22% in China, 23% in Latin America, 33% in Eastern Europe and 26% in Asia Pacific (Figure 7). China is now not only the dominant producer but is also comfortably the largest single market, accounting for sales of about 1 billion lamps in 2007. Another 1.5 billion lamps are sold in the rest of the world. These sales trends illustrate that the last decade has seen a global market transformation in lighting. (IEA, 2010e).

Figure 7. Estimated CFL sales by region



In addition, more efficient lighting technologies are becoming available, namely solid state lighting (SSL) technologies such as light-emitting diodes (LEDs) . Potential improvements hold the promise of more cost-effective energy savings in the lighting sector after the phase-out of incandescent lights is complete.

Policy development

The high purchase cost held back the market penetration of CFLs initially. To overcome this market barrier, almost all major economies have introduced MEPS for lamps which have had the effect of a ban on incandescent lights. Examples of these policies include:

- **European Union**: progressive phase-out of incandescent light bulbs from 2009 to 2012.
- **Japan**: progressive phase out of incandescent light bulbs to 2012.
- **Brazil**: progressive phase-out of incandescent light bulbs starting in 2010.

Canada, Australia, Korea and Switzerland have also announced a policy of phasing out incandescent lamps; China and India are considering a phase-out. To realise the full potential energy savings resulting from the switch to energy-efficient CFLs, the phase-out policies passed worldwide need to be enforced in the coming years.

Box 2. The role of utilities in delivering energy efficiency

Energy providers have distinct advantages in delivering energy-efficiency improvements for a range of residential, commercial and industrial customers. They enjoy ready access to capital, an existing relationship with end users, extensive information about customers and markets, a familiar brand name, and a ready-made service network within their jurisdiction. Utilities play a major role in delivering energy efficiency in many IEA member countries. For example, in 2008 utility-delivered energy-efficiency programmes in the United States and Canada saved 105 TWh of electricity and more than 367 million therms of gas, reducing GHG emissions by an estimated .06 Gt of CO_2 (ACEEE, 2010).

Policy developments

Certain enabling conditions are needed before energy providers can embrace the role of energy-efficiency implementer, namely the ability to recover programme costs, compensation of foregone revenues owing to lower sales, and acceptable levels of regulatory and other risk. Establishing these conditions requires tailored institutional, regulatory and market mechanisms. If the energy provider is a for-profit but regulated entity, there must be a mechanism to adjust prices or rates in order to recover programme costs and make a profit. For retail energy providers operating in fully competitive markets, obligations to deliver carbon emissions reductions or energy savings have proved effective. State-owned energy providers will need other enabling conditions depending on organisation, autonomy and funding needs.

These enabling conditions have been achieved in many jurisdictions, notably In North America and parts of Europe, where energy providers play a central role in the funding and implementation of energy efficiency. Recent studies on ratepayer-funded energy-efficiency programmes for gas and electricity in the United States and Canada put 2009 spending at USD 6.1 billion and forecast that US spending alone would top USD 10 billion by 2015 (Barbose and Goldman, 2009)(CEE, 2010). In some US jurisdictions, utilities spend as much as 3% of collected revenue on energy efficiency. Utilities in Brazil collect 1% of electricity revenues, which is used to fund EE programmes as well as R&D. In the United Kingdom, energy provider spending on energy efficiency is about USD 3 billion under the Carbon Emissions Reduction Target (CERT) supplier obligation. This obligation has a target CO_2 emissions reduction of 0.19 Gt between 2008-12 (Energy Savings Trust, 2009). The French and Italian White Certificates programmes, which give energy providers the choice between implementing energy-efficiency programmes and purchasing energy-efficiency offsets in a secondary market, together account for about USD 700 million in annual spending on energy efficiency.

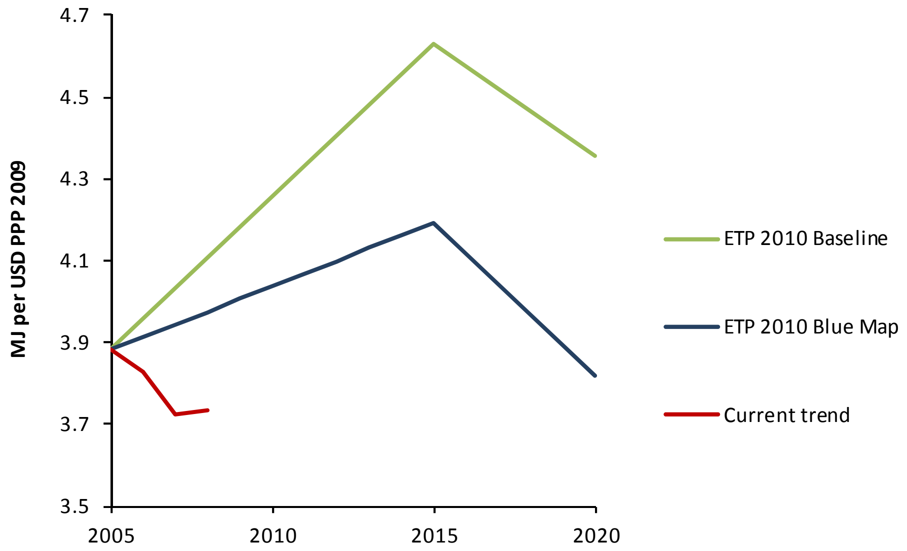
The success of programmes and policies that mobilise energy providers to deliver energy efficiency has led to increased interest in this sector. Most recently, the 2011 the EU Energy-Efficiency Plan proposes legislation that will oblige energy regulators and energy companies to take steps that enable their customers to cut their energy consumption. This could take the form of obligations to cut customer energy consumption, as is currently the case in the United Kingdom, or requirements to implement certain types of efficiency investment programmes, either directly or through Energy Service Companies (EC, 2011).

Energy-efficiency deployment in industry

Between 1990 and 2006, the overall energy efficiency of manufacturing industry in 21 IEA member countries improved by 1.6% per year. Without the energy savings resulting from these improvements, manufacturing energy consumption in the IEA would have been 21% higher in 2006. This represents an annual energy saving of 9.5 exajoules (EJ) in 2006, equivalent to almost 600 Mt CO_2 emissions avoided. The effect of these savings is significant: despite a 45% increase in output, final energy in the manufacturing sector decreased by 0.6% between 1990 and 2006. The rate of improvement in energy efficiency during this period was much lower than in previous decades. However, there are indications that the rate of improvement has accelerated in the recent past. Both process and individual component energy efficiency are important in determining the energy intensity of industry. Across all industrial sectors electric motor-driven systems (EMDS) have an important role in the energy efficiency of the system.

The IEA BLUE Map scenario estimates that industrial energy intensity will increase in the next few years, peak between 2015 and 2020, and then start decreasing. In reality, global energy intensity of the manufacturing industry has decreased 1.3% per year since 2005 and is a sign that countries may be on track to achieve longer-term climate change goals (Figure 8). However, this trend may hide important fluctuations that are caused by factors beyond energy efficiency, including the 2008-09 economic recession.

Figure 8. Current trend in global manufacturing energy intensity compared to Baseline and BLUE Map scenarios



Deployment of electric motor-driven systems

Electric motor-driven systems comprise the largest single end use in the industrial sector, consuming more than 40% of electricity consumption. They are fundamental components and their application ranges widely in systems as varied as large industrial equipment and processes to small household appliances. The market share of more efficient motors has been increasing in many regions and countries. A least life-cycle cost (LLCC) savings potential exists of 20% to 30%, accounting for 10% of global electricity consumption, using BAT (IEA, 2011b).

Policy developments

Even though energy costs typically account for over 95% of an electric motor's life-cycle cost, most companies' organisational structures separate equipment procurement from operation and maintenance, giving little reason to look beyond the lowest purchase price. A lack of awareness among motor purchasers of the potential savings from using more efficient motors is another barrier to uptake of more efficient motors. One way to overcome this is to introduce mandatory minimum energy performance standards (MEPS). The United States and Canada are leaders in setting motor energy-efficiency standards, as they introduced MEPS regulations for motors in the late 1990s followed by many countries such as China, Australia, Korea, Brazil, Mexico, and

Taiwan. The European Union also passed MEPS legislation for electric motors in 2009 as an implementing measure under the Eco-design Directive. India, Japan and Russia have not yet adopted MEPS, but are currently considering their implementation. Global co-operation will be important for motors, as they are among the most highly traded goods and many motors are integrated into equipment before being sold. Recently the the International Electrotechnical Commission (IEC) completed the task of aligning the existing national and regional efficiency classification for electric motors. Global co-operation is needed to accelerate similar alignment in regulations such as MEPS for electric motors.

Energy-efficiency deployment in energy-intensive sectors

The rapid expansion of production capacity has generally had a positive effect on the energy efficiency of the **iron and steel industry**. Additional capacity has reduced the average age of the capital stock. New plants tend to be more energy-efficient than old plants, although not all new plants have introduced BAT. Energy-efficiency equipment has been retrofitted to existing furnaces and ambitious energy-efficiency policies have led to the early closure of inefficient plants in several countries. The decrease in steel demand (and production) resulted in a lower capacity utilisation of the plants; which in turn resulted in loss of economies of scales. The iron and steel industry was on track to achieve the outcomes outline in the BLUE Map scenario until 2007. However, the recent economic crisis has had a noticeable impact: the sector's intensity in 2008 increased to the Baseline level for CEM countries.

The thermal energy consumption of the **cement industry** is strongly linked to the type of kiln used. Vertical shaft kilns, of which there are three main types, consume between 4.8 GJ/t and 6.7 GJ/t clinker. The intensity of wet kilns varies between 5.9 GJ/t and 6.7 GJ/t clinker. The long dry process requires around 4.6 GJ/t clinker, whereas adding pre-heaters and pre-calciners further reduces the energy requirement to between 2.9 GJ/t and 3.5 GJ/t clinker. Since 1990, dry technologies have exhibited a marked increase in all the regions for which data are available.

As in the iron and steel sector, the cement industry was also greatly impacted by the economic downturn. Initial assessments for 2008 indicate that while intensity increased by more than 5%, the sector's intensity is still on track with the BLUE Map scenario.

It is difficult to measure the physical production of the organic **chemical industry** given the large number of products. Polymer production represents both the largest and the fastest-growing segment of the chemical and petrochemical sector, representing approximately 75% of the total physical production and rising nearly 6% per year to approximately 300 Mt in 2006 (PlasticsEurope, 2008; SRI Consulting, 2008). While growth has levelled off in industrialised countries, polymer production in China and some other emerging economies has continued to increase rapidly. However, worldwide growth has been negatively affected by the recent economic turmoil. Data that are available to 2007 for CEM countries show that while energy intensity has been at the level of the Baseline Scenario, there are signs that the sector is slowly moving in the right direction.

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 the upper limit may be closer to 60%. Pulp and paper mills in the CEM countries have dramatically improved their energy intensity since 2005, improving by 1.2% per year. Globally, the sector achieved a 1.8% per year improvement.

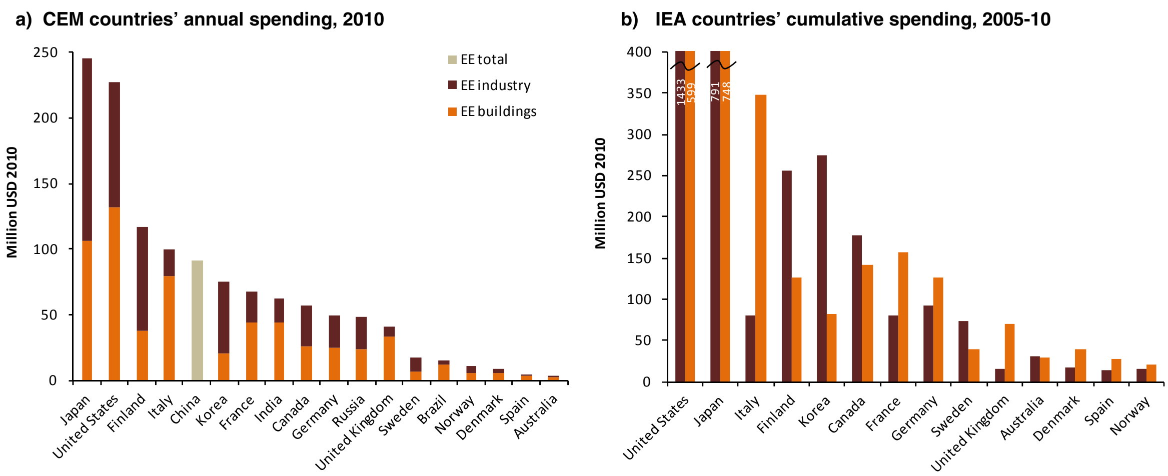
Policy developments

Many countries have introduced tax and other fiscal incentives to encourage energy-intensive sectors to purchase efficient equipment. Many countries provide lists of eligible energy-efficient equipment which act as an information or benchmarking tool for company or public sector procurement (IEA, 2011a). In addition, several nations are expanding their promotion of energy management in industry by providing energy management tools, training, energy manager certification and quality assurance. Nevertheless, with under half of the CEM countries implementing energy management support programmes, significant room for improvement remains. Since a global carbon market is not imminent, international agreements covering some of the main energy-intensive industrial sectors is a transitional step to secure sectoral reductions in energy consumption.

Public spending on research, development and demonstration for energy efficiency in buildings and industry

Energy efficiency in industry encompasses techniques and processes as well as industrial equipment and systems in manufacturing, construction and mining industries. Energy efficiency in the buildings sector comprises advanced design and buildings envelope components, building equipment and operation systems, appliances and lighting as well as heating, cooling and ventilation technologies.[7]

Figure 9. Public spending on energy efficiency in buildings and industry



Notes: China is 2008 data, France and Russia is 2009 data. Data for India are from the Office of the Principal Scientific Adviser to the Government of India ; amounts are estimated on a yearly basis as one fifth of total budgets.

Source: Country submissions, Kempener *et al.*, 2010

Between 2005 and 2010, the United States and Japan spent more on energy-efficiency RD&D than most other major economies, followed by Italy, Finland and Korea (Figure 9b). Japan has the largest budget for energy efficiency in buildings and industry with fairly equal shares between the two

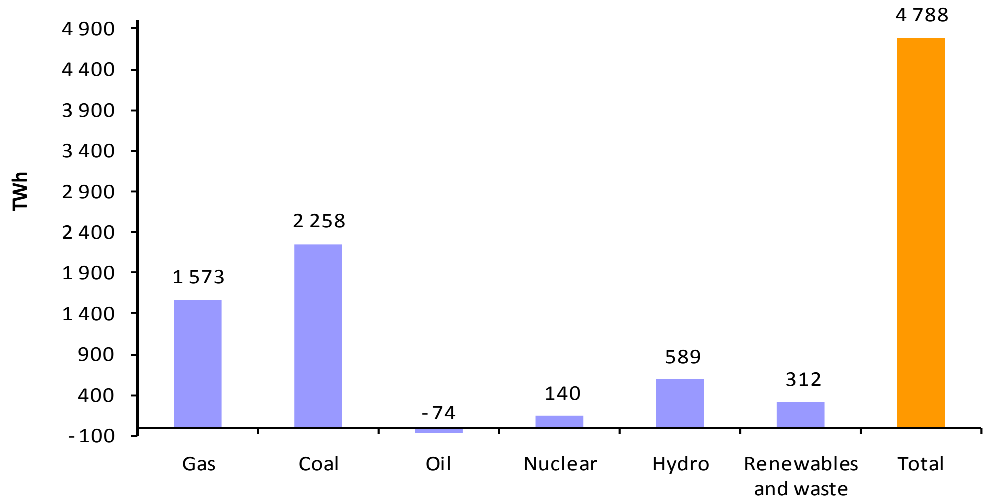
[7] Solar heating and cooling is included in renewable energy RD&D.

sectors in 2010, although spending has steadily declined since 2001. Data were not available for large emerging economies other than Russia, which spent USD 120 million between 2007 and 2009, split evenly between industry and buildings efficiency. Figure 9a identifies CEM country spending in 2010, based on IEA statistics and country data submissions. Figure 9b compares select IEA member countries' spending between 2005 and 2010, showing that most countries do not split spending evenly between buildings and industry. Korea and Finland spend much higher amounts on energy efficiency in industry, the United States, Italy and France spend more on buildings. The United Kingdom spent slightly less than USD 16 million on energy efficiency in industry during this time period.

Higher-efficiency coal use and CCS

The world continues to rely heavily on coal as an energy source; for the past decade, coal has met 47% of new electricity demand globally (Figure 10). There is also a growing difference between the use of coal for power generation between OECD and non-OECD regions. Though contributions from hydropower, nuclear and natural gas use are increasing, growth in energy demand in these countries is largely being fed by coal. By contrast, in OECD countries new power demand is being met by natural gas and new renewable energy, especially wind power; and coal is contributing substantially less.

Figure 10. World incremental growth in electricity generation, 2000-08



Note: Renewables and waste category excludes hydropower

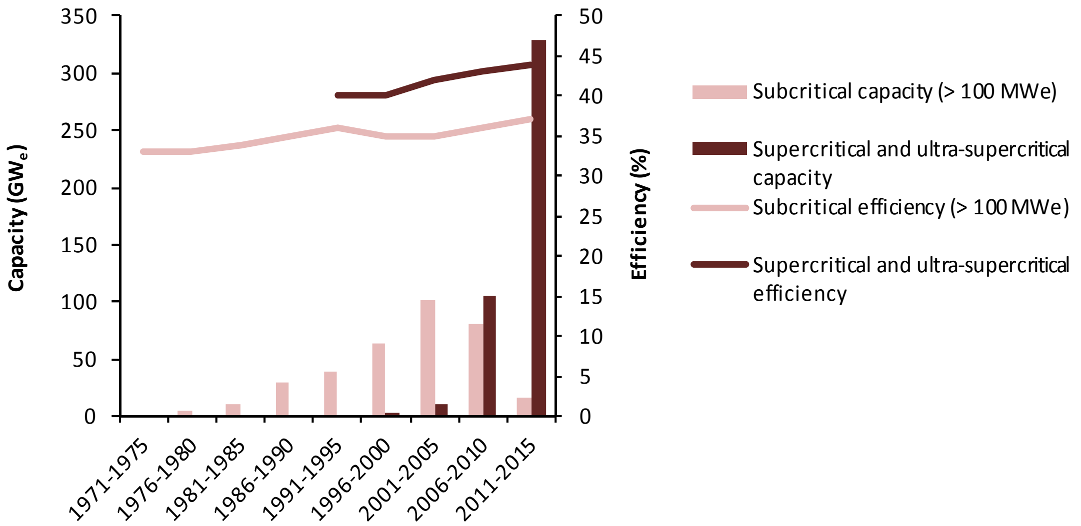
In the Blue Map scenario the amount of relatively less efficient subcritical coal capacity begins to decline between 2010 and 2015 and the share of supercritical, ultra supercritical and combined heat and power (CHP) plants increases. This process has already begun. China has begun the phase out of subcritical plants and all new construction is supercritical or ultra supercritical. Between 2010 and 2015 it is estimated that around 250 GW of super critical and ultra supercritical capacity will be installed in CEM countries alone. In 2008, whereas coal accounted for 41% of total generation, it produced 73% of power-related CO_2 emissions. Though more recently constructed coal plants are highly efficient, even the best plants emit more than 750gCO_2/kWh. And globally, the average coal-fired power plant emits a little over 1 000gCO_2/kWh, or more than 1 MtCO_2/TWh.

For this reason, raising the efficiency of existing and new coal-fired plants is important. Switching to less carbon-intensive fuels (*e.g.* from coal to natural gas) and improving the efficiency of coal plants will achieve significant reductions in CO_2 and should be a top priority. However, improving efficiency alone will not meet the reductions needed to satisfy the BLUE Map scenario. For deep cuts in emissions at lowest overall cost, CCS must be deployed. As a result of the additional energy requirements of CCS, improving the efficiency of existing coal-fired power plants and ensuring that new plants meets high efficiency standards will be a critical first step to deployment.

High-efficiency coal deployment status and policy developments

The last decade's growth in coal use has been driven by a move toward more efficient, cleaner coal plants. New plant construction is generally based on the latest, most efficient technology. The oldest, least efficient plants are being phased out of operation and remaining, inefficient plants are systematically being upgraded, with aging components replaced and more effective operational practices introduced. The majority of coal-fired generation capacity in China is less than 10 years old, while in the United States and Europe, most of the fleet is between 31 to 40 years old (IEA CCC, 2011). China has been routinely closing down old, inefficient coal-fired plants (less than 200 GW capacity) and replacing them with modern, efficient technology, for example, in 2010, more than 11 GW of small plants were taken out of operation. Figure 11 shows the estimated capacities and thermal efficiencies of Chinese hard coal fired units expected to be operating in 2015.

Figure 11. Modernisation of the Chinese coal fleet



Notes: Capacities and thermal efficiencies are on a gross generation and fuel lower heating value basis. The year ranges at the base show the years of first operation of these plants. Note that the 2011-15 date range, for supercritical and USC plants, includes some commissioned from 2006. Plants that have already closed or are due to close before 2015 are excluded. Data consists of early estimates from a study that is still in progress.

Source: IEA Clean Coal Centre, using information from the Centre's power station database and additional data from Dr A. Minchener.

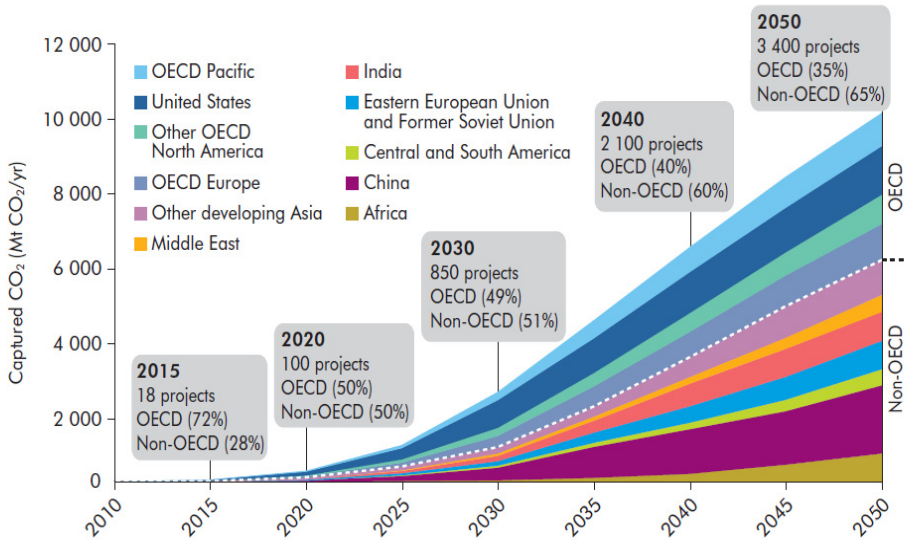
This illustrates the rapid modernisation of the Chinese coal fleet through the introduction of supercritical and ultra-supercritical units in the last decade. With these developments, the average efficiency of Chinese coal-fired plant is likely to outstrip the current average efficiency of plant in the OECD. Coal is also fuelling India's economic growth, providing almost 70% of the country's power needs. Like China, India also has plans to reduce the carbon intensity of its coal-fired fleet of power plants. India has a total coal-fired capacity of more than 80 GW, more than half of which is at least 20 years old. India's plants have low efficiency, the result of a variety of technical and institutional factors such as poor quality of coal, electricity grid conditions, low plant load factor, degradation due to age, lack of proper operation and maintenance at power plants, ineffective regulations and lack of incentives for efficiency improvements (Chikkatur, A., 2008).

There is a promising opportunity to improve the efficiency of existing power plants by at least one to two percentage points. The retrofit of plants built during the last 30 years is considered a cost-effective measure to improve operational efficiency and provide additional capacity (Remme *et al.*, 2011). In its 11th Five-Year Plan (2007-12), India plans to renovate and modernise 26 GW of coal capacity, while the 12th Five-Year Plan (2012-17) proposes to modernise a further 17 GW. In addition, while 1.1 GW of old, inefficient plant has already been retired, closure of 4 GW is to be written into both the 12th and 13th Five-Year Plans (Mathur, 2010). In OECD countries, on the other hand, coal consumption is projected to decrease, with ageing plants and higher costs expected to result in the retirement of significant coal-fired capacity over the coming years. The growth in demand for electricity is also likely to be modest over this period, due to expected stable population and modest economic growth. The shortfall resulting from the reduced coal capacity will likely be replaced by renewable energy, nuclear and gas-fired generation (IEA, 2010a).

CCS technology deployment status

To meet global emissions reduction goals at lowest cost, extensive deployment of CCS is required. Figure 12 shows that around 100 large-scale CCS projects will be needed by 2020 to meet the BLUE Map goal, and over 3 000 by 2050. This represents a significant scale-up from the five large-scale CCS projects that are in operation today.

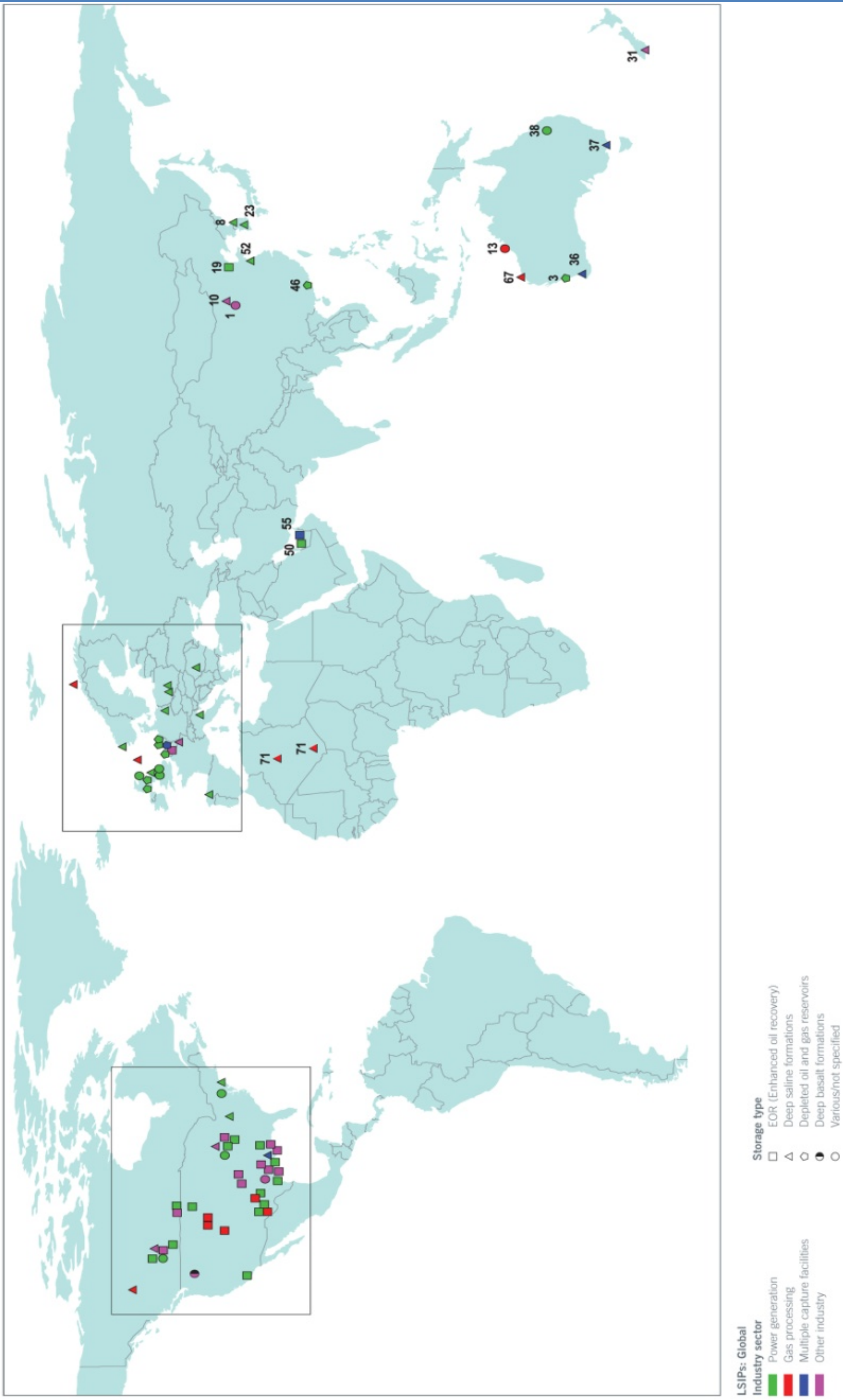
Figure 12. CCS deployment by region, 2010-50



Governments recognise the critical role of CCS in mitigating the growing fleet of power and industrial plants powered by fossil fuels, and have made a number of public commitments to fund the first set of large-scale[8] demonstration projects. Figure 13 shows the current set of 77 operational and planned large-scale demonstration projects. North America and Europe contain 68% of the active or planned projects--31 and 21 projects respectively - followed by Canada (eight projects), Australia (six projects) and China (five projects). There are currently no large-scale projects in Japan, India and Russia.

[8]"Large scale" is defined as storing more than 1 millon tonnes of CO_2 annually.

Figure 13. Global status of large-scale CCS demonstration projects

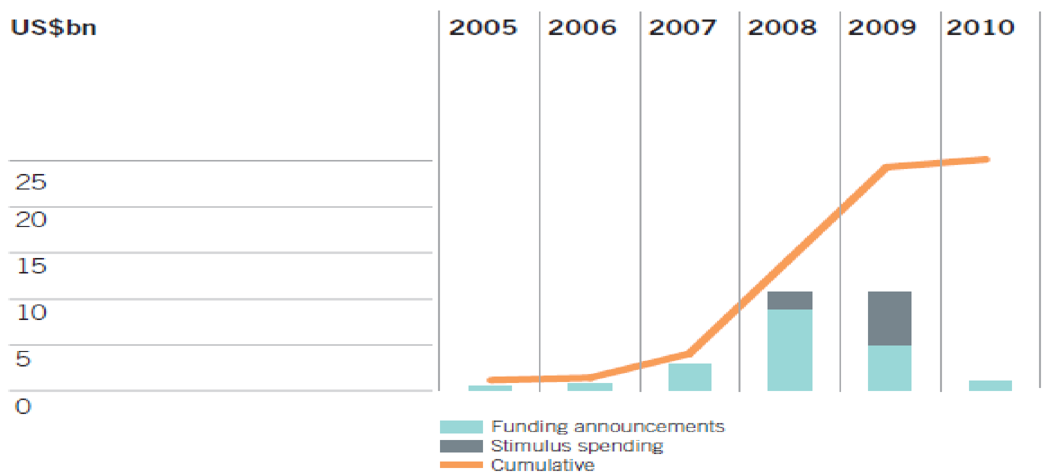


Source: GCCSI 2011

Approximately two-thirds of the planned projects are in the power generation sector. Industry and upstream projects are also well represented, in particular in natural gas processing. There are also projects related to the cement, aluminium and iron and steel industries, but these sectors are underrepresented. Many of these projects are still in the early stages of development.

As of 2010, government funding commitments totalled around USD 25 billion (Figure 14). However, only USD 13 billion of these commitments have been allocated to specific demonstration projects. The countries with the largest amounts allocated are the United States (USD 6.1 billion), Canada (USD 3 billion) and Norway (USD 1.3 billion). 2010 also saw a worrying gap between funding needs and new commitments that must be addressed if CCS is to succeed. (Figure 14).

Figure 14. Status of public funding support to CCS (USD billion)



Source: GCCSI 2011

Further, funding is often contingent on industry and may be susceptible to review depending on government priorities and financial constraints. Financial incentives for non-OECD CCS deployment are also crucial.

Developing policy frameworks and engaging the public

Important progress is being made towards developing national CCS legal and regulatory frameworks. Although developments are generally concentrated in OECD regions, including Europe, Australia, the United States and Canada, non-OECD countries such as South Africa and the UAE are beginning CCS regulatory discussions and framework development (GCCSI, 2011). This progress must continue, in particular in non-OECD countries which will play a significant role in global CCS deployment.

Currently, CO_2 mitigation incentives are insufficient to cover the additional costs and risks associated with building and operating first-of-a-kind, CCS demonstration plants. Accordingly, additional financial incentives are required in the near-term where CCS activities are not supported by other mechanisms such as a sufficient CO_2 price[9] or additional revenue streams (enhanced hydrocarbon recovery). While global understanding of CO_2 storage opportunities is improving, there is limited practically usable and characterised storage capacity at the level needed to support large-scale project investment. CO_2 storage site characterisations, including suitable pathways for transport and storage, need to accelerate.

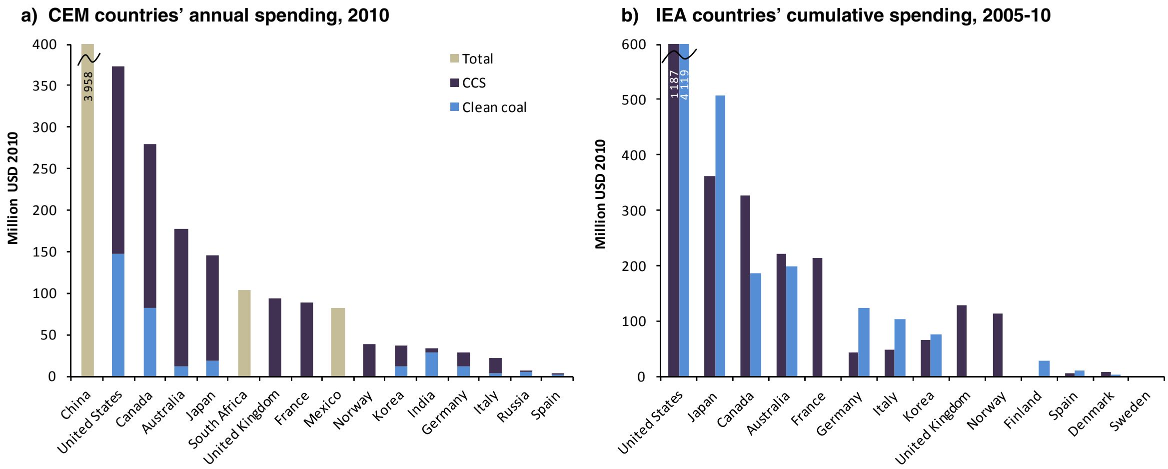
[9] Norway has a carbon tax on offshore oil and gas operations which has incentivised the Sleipner and Snøhvit operations.

Public outreach is critical to CCS deployment but has not received sufficient attention. Projects such as Barendrecht in the Netherlands, which was recently cancelled due to public opposition, emphasise this point. Governments and developers must engage the public in the development of CCS projects in a timely and transparent manner. Work is ongoing internationally to better manage public engagement processes, drawing on lessons learnt. This development is also starting to be visible outside OECD countries. For example, South Africa has recently launched a new Centre for CCS that will focus on accelerating CCS demonstration, raising awareness and ensuring public engagement; more such efforts in key fossil-based economies are needed.

Public spending on research, development and demonstration

Higher-efficiency, cleaner coal technologies comprise coal conversion and combustion technologies such as integrated gasified combined cycle (IGCC), as well as coal production, preparation and transportation. RD&D spending on CCS includes CO_2 capture/separation, transport and storage. Figure 15 shows most recent data on RD&D expenditures on clean coal and CCS: in 2010 for IEA countries, 2009 for Russia, 2008 for China, India and South Africa and 2007 for Mexico. [10]

Figure 15. Public spending on energy efficiency in CCS and clean coal



Notes: China and South Africa is 2008 data, France and Russia is 2009 data. Data for India are *R&D budgets* from the Office of the Principal Scientific Adviser to the Government of India ; amounts are estimated on a yearly basis as one fifth of total budgets.

Source: Country submissions, Kempener *et al*., 2010

Between 2005 and 2010 the United States had the largest budget dedicated to clean coal and CCS, spending USD 1.2 billion on CCS RD&D, the lion's share of which was on several large-scale demonstration projects; with USD 4.1 billion on clean coal. Japan also recently focused more on clean coal technologies. During this period, Australia and Canada increased their expenditures significantly, especially on CCS for which Australia will spend USD 169 million in 2011 (up from USD 55 million in 2009) and Canada USD 455 million in 2011 (up from USD 66 million in 2009). France has also showed strong interest in CCS, with USD 214 million invested between 2005 and 2010. China spent nearly USD 9.9 Billion between 2005 and 2008 (Kempener *et al.*, 2010) on fossil fuel technologies; however some of this was for the oil and gas sector.

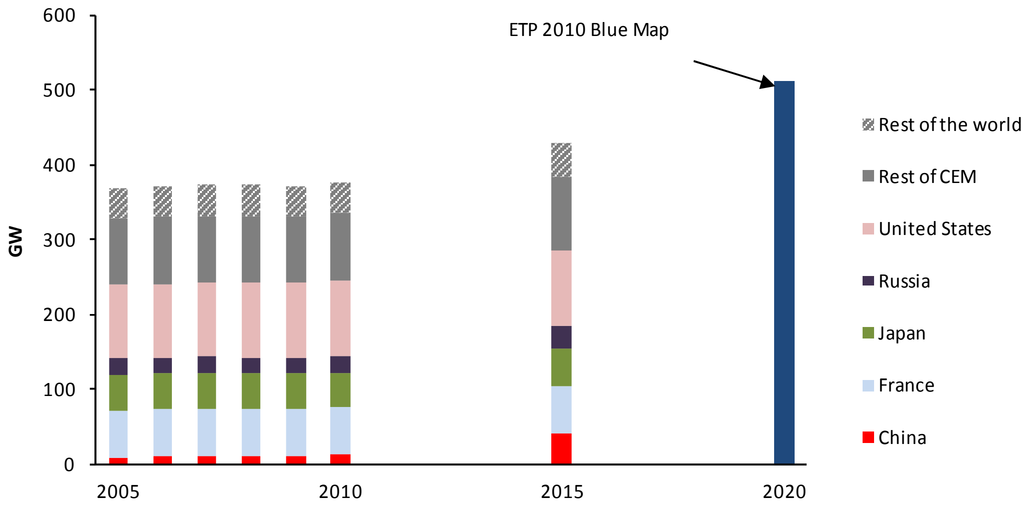
[10]The split between clean coal and CCS for the latter group of countries was not available. The total shown for non-IEA countries comprises technologies related to other fossil fuel technologies than coal, including enhanced oil and gas production, refining, non-conventional oil recovery and other technologies. More work is needed to improve RD&D spending statistics for non-IEA countries.

Nuclear power

Technology status

For the past five years, nuclear power growth has remained nearly flat—worldwide operational installed nuclear capacity increased from 370 GWe at the end of 2005 to 375 GWe by the end of 2010 (Figure 16). This slow growth reflects the low number of new construction starts during the past two decades. Worldwide electricity generation from nuclear power plants has also remained flat at around 2 600 TWh. Nuclear power production in OECD countries peaked in 2006 at 2 259 TWh and declined to 2 136 in 2009; a further fall is indicated by preliminary 2010 data. Meanwhile, non-OECD nuclear production rose from 390 TWh in 2005 to 423 TWh in 2009. This trend towards non-OECD countries is expected to strengthen over the coming years, partly due to the retirement of older plants in OECD countries.

Figure 16. Global nuclear capacity vs. BLUE Map scenario, 2005-20



Source: IAEA PRIS database, 2011.

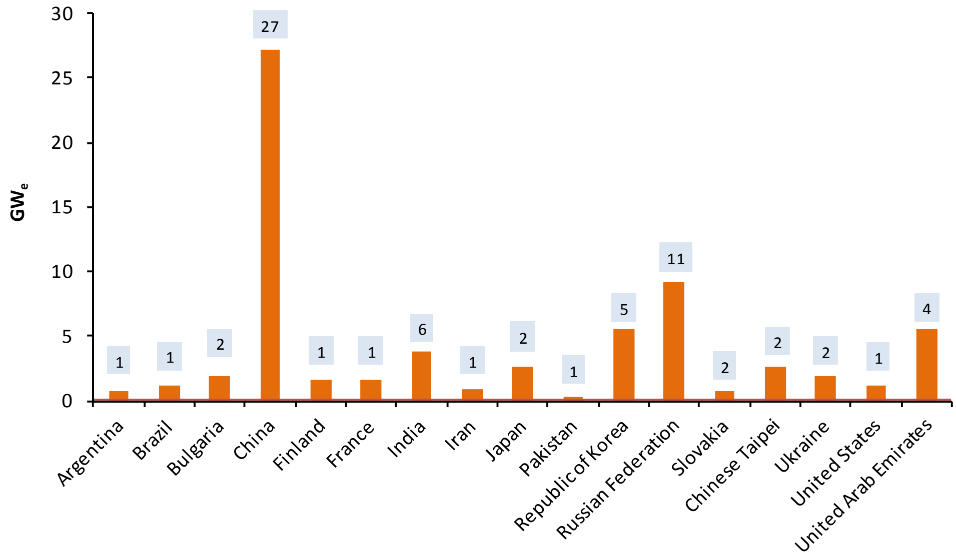
In the IEA BLUE Map scenario illustrated in Figure 16, by 2015 444 GW of nuclear capacity should be installed globally. If all the capacity currently under construction is installed by then, this target will very nearly be achieved. It is uncertain, however, whether all current constructions will be completed by 2015. The real challenge exists when looking at the 2020 milestone. Given the relatively lengthy construction period needed, a significant number of new construction starts would have to take place over the next four to five years if the capacity is to reach 512 GW by 2020. A number of countries have announced ambitious targets for 2020 including China (80 GW), the United States (111 GW), Japan (62 GW), Russia (51 GW) and India (20 GW).

A severe earthquake and tsunami in March 2011 that ravaged the Pacific coast of northern Japan resulted in a major incident at the Fukushima Daiichi nuclear power plant. Following these events, several countries have announced safety reviews of their nuclear programmes. The impact on the growth of nuclear generating capacity will only become clear in the coming months and years, but it could result in some countries delaying, scaling back or cancelling the planned nuclear expansion that is described below, and also lead to earlier than expected closure of some older nuclear plants.

Nuclear expansion plans and policy developments

Fifteen countries are currently constructing new nuclear capacity (Figure 17). Given the lengthy construction period compared to other electricity generating plants, capacity under construction provides a good indication of expected growth over the coming years. Assuming that plants currently under construction will be complete by 2015, they will add some 60 GW to the present 375 GW of capacity. Allowing for 3 to 4 GW of older plants being closed, plus some additional capacity from power uprates at existing plants, that installed capacity would be about 430 GW by the end of 2015.

Figure 17. Nuclear capacity under construction and number of reactors



Source: IAEA PRIS database, 2011 and country submissions.

Of the 66 units under construction at the end of 2010, 27 were in China. In contrast, China had only three units under construction at the end of 2005 (all now in operation). Hence, the upturn in nuclear construction that is evident in recent years is largely due to the rapid expansion of the Chinese nuclear programme. Most of the Chinese units now under construction are the established CPR-1 000 design. The next phase of expansion is expected to be based on the more advanced AP-1 000 design, the first of which are now under construction in the country. Current plans are for more than 30 additional units, beyond those now under construction, to start building in the next few years.

Among other countries, Korea plans to continue its expansion, with at least four additional units beyond those now under construction. France has announced that a new unit is to start construction in 2012, and Finland is also actively planning for a further new unit to follow the unit that is presently under construction. The UAE has plans to build a 5 600 MW plant, with four reactors slated between 2017 and 2010. Russia has announced plans to launch construction of two new units each year, which has been achieved for the last three years. This is expected to continue, although some of this new capacity will be offset by retiring older plants before 2020. India has to date largely relied on its indigenous nuclear designs, and plans have often suffered delays. Nuclear agreements with the United States and other countries in the last few years mean that India is now able to import nuclear technology more easily, having agreed to place much of its nuclear programme under international safeguards. More rapid expansion of its nuclear capacity is now expected, but plans are still taking shape.

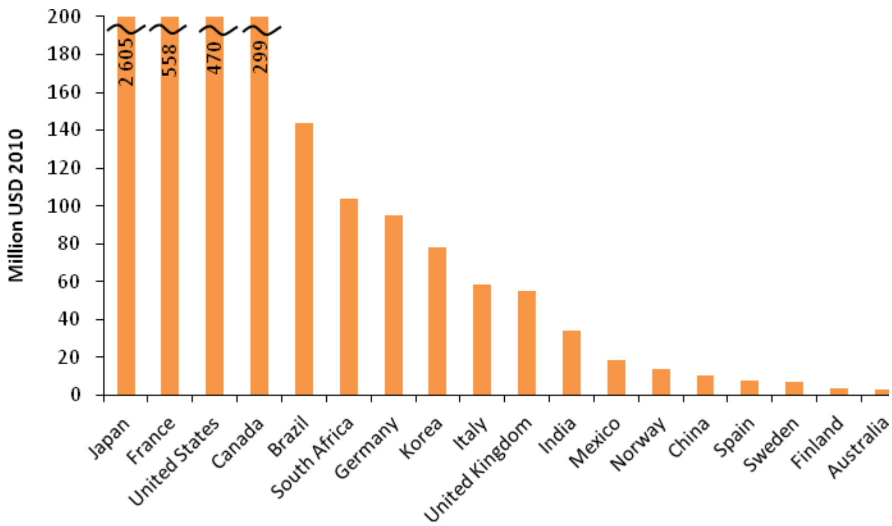
New nuclear construction in the United States after a 30-year hiatus would be a significant development. License applications for 17 units have been submitted, and plans are being developed for over 30 new units. However, some of these may be put on hold given the increase in recoverable gas reserves in recent years. Nevertheless, government incentives seem set to ensure the construction of at least a few new units before 2020. One long-suspended construction project was reactivated in 2007, to come on-line in 2013. The first government loan guarantee for a nuclear plant was awarded in 2010; site works are already well advanced and the plant should be on-line by 2017.

The United Kingdom has one of the oldest nuclear fleets, based on gas-cooled reactors that have proved to have shorter operating lives than water-cooled reactors used elsewhere. As a result, many of its early plants have already closed and most of the others will follow by 2020 or soon after. The government is now encouraging electricity companies to invest in several new nuclear units to be in operation by 2020 but is committed to avoid any public subsidy. At present, siting and licensing activities are underway.

Public spending on research, development and demonstration

Nuclear fission RD&D comprises research on light and heavy water reactors, breeder reactors, fuel cycle and other nuclear fission technologies. Japan has consistently had the highest RD&D investment rates, and contributed about 70% of the total amount spent by major countries in the last decade (Figure 18).

Figure 18. Public spending on nuclear fission RD&D in 2010



Note: Mexico is 2007 data ; data is from 2008 for other non-IEA countries. France is 2009 data. Given the lack of detail, data for non-IEA countries might include amounts spent on nuclear fusion.

Source: Country submissions, Kempener *et al*., 2010

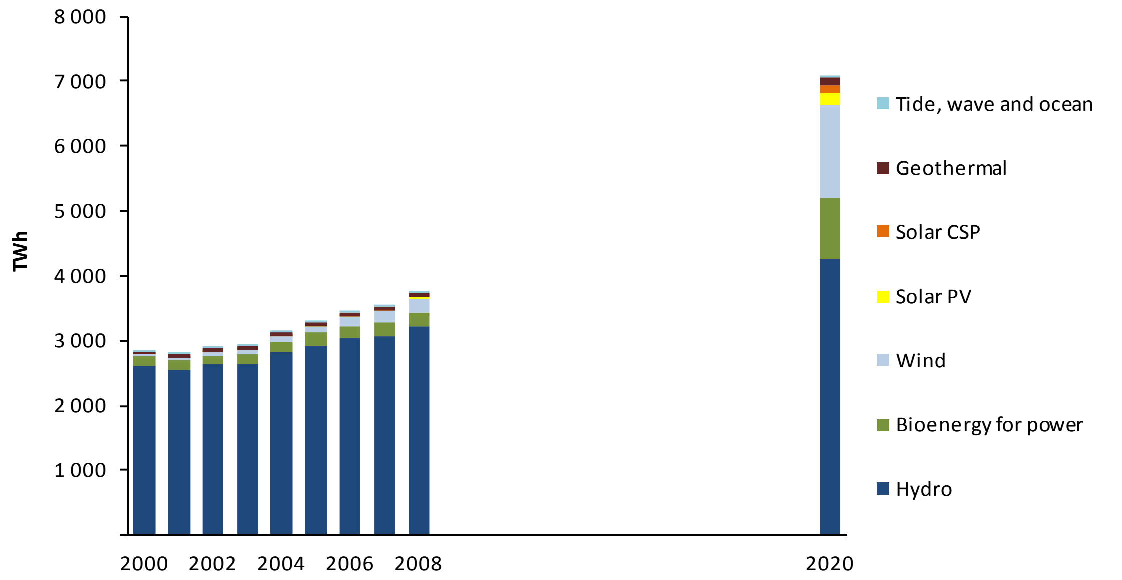
Between 2002 and 2010, Japan is the only country that reduced its expenditures in this sector (by 26%). Among non-IEA countries, Brazil spent most with over USD 144 million, followed by South Africa with over USD 100 million estimated expenditures in 2008, more than Germany and Korea together for that year. India was next with USD 33 million and China spent over USD 10 million. Russia has a large programme underway that focuses on next-generation nuclear technology; they have announced a budget of USD 3.6 billion for the next decade (Kempener *et al.*, 2010).

Renewable energy

Renewables have been the driver of much of the growth in the global clean energy sector for the past decade. Recent years have seen a major scale-up of wind and solar technologies. Other renewable technologies—including hydropower, geothermal and biomass—continued to grow from a strong established base, adding thousands of megawatts of new capacity worldwide. During the past decade, renewable energy growth has been uneven across the world, driven by government support. In wind power, China became the global leader in terms of new yearly installed capacity in a very short time, overtaking the United States in 2010. Germany continues to lead the world in solar PV capacity, followed by Spain and Japan. The United States has the largest geothermal power capacity with the Philippines, Indonesia, Mexico and Italy following. China is the leading hydropower producer, followed by the United States, Brazil, Canada and Russia. In bioenergy for power, the Unites States leads and is followed by Germany, Sweden, Finland and the United Kingdom.

In order to achieve the goals of halving the global energy-related CO_2 emissions by 2050, as assumed in *ETP 2010* BLUE Map scenario, a significant effort in deployment of renewable electricity is needed. In 2008, over 3 700 TWh of power was produced globally using renewable sources of energy. To meet the BLUE Map scenario, this production will need to almost double to over 7 000 TWh by 2020 (Figure 19).

Figure 19. Global power generation from renewable sources vs. BLUE Map scenario



While hydropower will remain the largest source of renewable power, revolutionary growth in the deployment of wind, solar, geothermal and bioenergy technologies will be needed: wind power must see an annual average growth rate of 17% and solar power 22% to meet their 2020 targets. These sorts of levels are achievable. Since 2005, we have observed comparable growth rates both for wind and solar technologies, averaging at 26% and 50%, respectively. The challenge will be to maintain this high growth for the longer term. This will require manufacturing cost reductions, driven by stable and predictable policy support that adapts to market conditions. Renewable energy RD&D investment also needs to continue to expand in all major economies.

Renewable energy policy

Policy support for renewable energy has increased considerably over the last decade; there has been a proliferation in policy tools and a strong growth in the number of countries using these policies. Countries pursue renewable energy to improve their energy security by diversifying the energy mix with locally available resources and to achieve climate goals.

Renewable electricity policy has undergone a continual evolution over the past 10 years. As countries gain experience in renewable energy deployment, they learn from their own and other nations' experiences, and adapt schemes to meet their policy goals in an effective, cost-efficient manner. Table 2 presents this evolution in CEM countries for the following technologies: wind, solar PV, Concentrated solar power (CSP), geothermal power, bioenergy for power (details for biomass and biogas) and hydropower.

Renewable electricity policy

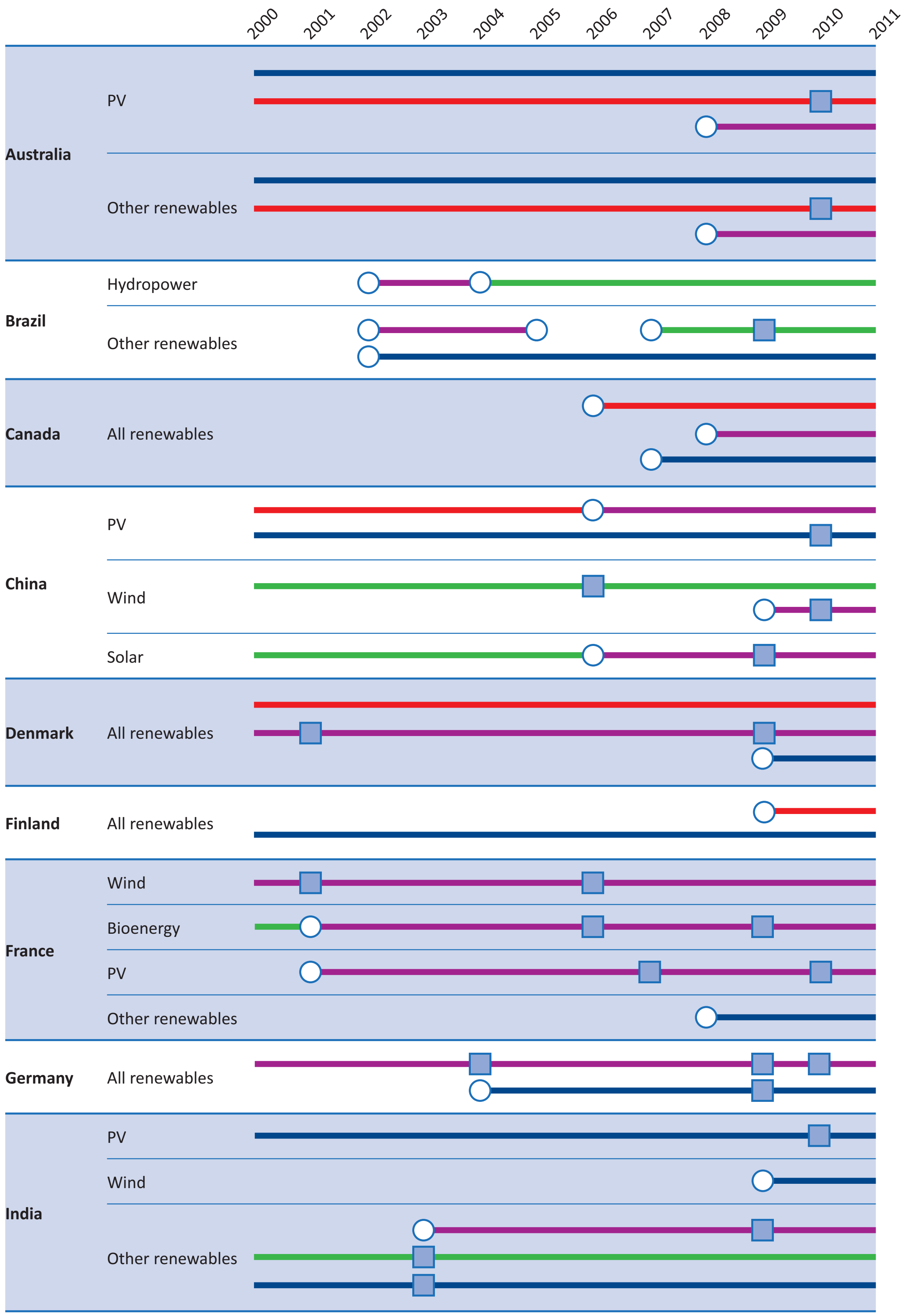
In 2010, almost all major economies had some form of support scheme for renewable electricity; this stands in contrast to 2000, when only 16 countries provided targeted support. Seventeen countries currently have FIT schemes, ten countries implement quota obligation systems with tradable green certificates, and four countries have tender systems in place.[11] The table also illustrates the growing number of changes in policy support and adaptations to existing schemes. In 2010 and in the beginning of 2011, a number of countries adapted PV FIT schemes, with the Czech Republic, Spain, France, Italy and Germany revising policies and tariff rates given unexpected rapid growth that resulted in escalating policy cost. Brazil has also shifted from a FIT support scheme to capacity tenders in an effort to use a more adaptive policy framework. Japan is considering extending its current FIT scheme to include solar PV, wind, small hydro, geothermal and biomass. Australia passed legislation to extend its mandatory renewable energy target for electricity to 2020, with the objective of achieving 20% of electricity from renewables. A number of governments introduced new policies, with India planning to launch a renewable quota obligation system at the beginning of 2011. South Africa has made significant progress in plans to advance its Solar Park, which will build 5GW of solar capacity by 2020.

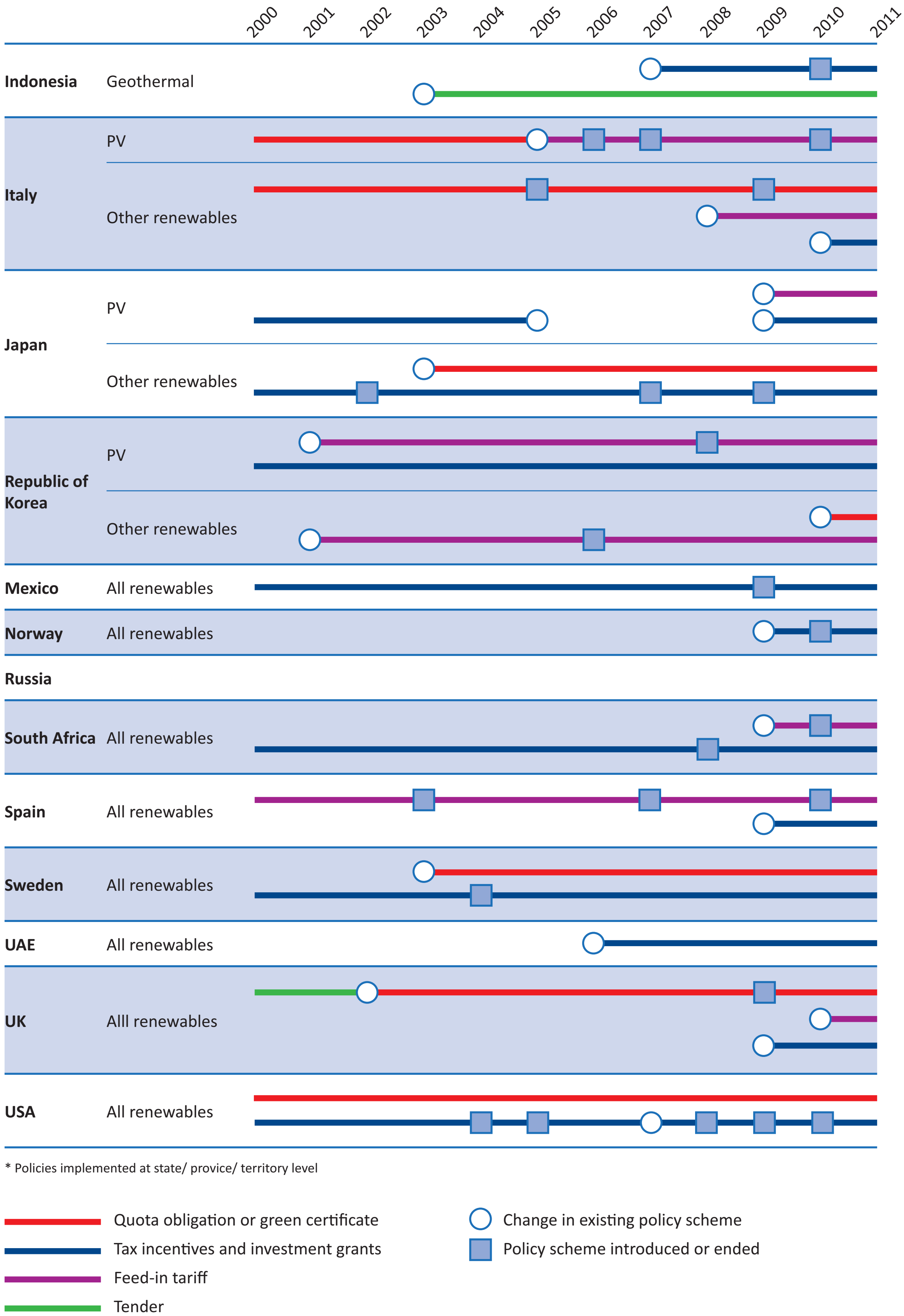
Renewable heat policies

Government support for renewables-based heat is low compared to renewables-based electricity or biofuels for transport. Policy design for renewable heat raises different issues as compared to renewable electricity policy design due to a number of differences between the delivery of heat and electricity (Connor *et al.*, 2009). The heterogeneous nature of heating fuels means that there is a diverse group of companies supplying the market. The demand side is also is fragmented and difficult to target: heat is produced on site by millions of building owners and developers, district heating operators and industries. Moreover, installers, heating engineers and architects often act as crucial gatekeepers between supply and demand.

[11] A "feed-in tariff" refers to a fixed guaranteed price at which power producers can sell renewable power into the electric power network; quota obligation systems require a minimum percentage of electricity sold or generation capacity installed to be provided by renewable energy, which utilities must meet. They can also set obligations that a minimum percentage of electricity purchased comes from renewable energy sources; A tradable green certificate represents the certified generation of one unit of renewable energy, generally one megawatt-hour (MWh). Certificates can be traded and used to meet renewable energy obligations among consumers and/or producers, and can also be used for voluntary renewable energy power purchases.

Table 2. Evolution in renewable electricity support policies in Clean Energy Ministerial countries




2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Indonesia
Geothermal
Italy
PV
Other renewables
Japan
PV
Other renewables
Republic of Korea
PV
Other renewables
Mexico
All renewables
Norway
All renewables
Russia
South Africa
All renewables
Spain
All renewables
Sweden
All renewables
UAE
All renewables
UK
Alll renewables
USA
All renewables
* Policies implemented at state/ provice/ territory level
Quota obligation or green certificate
Tax incentives and investment grants
Feed-in tariff
Tender
Change in existing policy scheme
Policy scheme introduced or ended

To date, the most widely adopted mechanisms for the support of renewable heat are direct capital grants and tax credits for the purchase of a renewable heating system. Direct capital grants for solar thermal systems exist in many European Union countries. However, subsidy schemes often depend directly on the public budget; as such, conditions change regularly and schemes suffer from stop-and-go support, depending on the political agenda. Another disadvantage is the absent guarantee of producing renewable heat, as grants or tax credits are often provided without verifying whether heat equipment has been properly installed. Still, grant and tax credit schemes continue to stay in force, as they are popular with individual consumers and have low transaction costs relative to other schemes.

A number of countries have deviated from financial incentive schemes to introduce use obligations for renewable heat systems. The Spanish government developed a national solar heat obligation policy in 2006; Portugal and cities in Italy, Brazil and India followed. Since a solar obligation incentivises one specific technology, such a policy should be introduced only where there is no competition with other renewable technologies for the same market. The procedure for checking compliance and the absence of an incentive to exceed the required level of the obligation are weaknesses of the solar obligation. The German Marktanreizprogram aims to increase renewable heat in general, including geothermal heat from hot sedimentary basins used in district heating systems. Moreover, the German Renewable Energy Sources Act guarantees a bonus of EUR 3 cent/kWh to the FIT for geothermal (binary) power plants if the waste heat is made useful. In March 2011, the United Kingdom announced the Renewable Heat Incentive (RHI), the first heat market feed-in tariff. The RHI is designed to provide a continuous income stream over twenty years upon installation of an eligible renewable heating system. In 2011, the scheme will introduce premium payments for the non-domestic sector. In 2012, the scheme will expand to the domestic sector. Solar thermal systems are rewarded a premium payment of GBP 0.085/kWh_{th} (EUR 0.099/kWh_{th}) for systems < 200 kW_{th}.

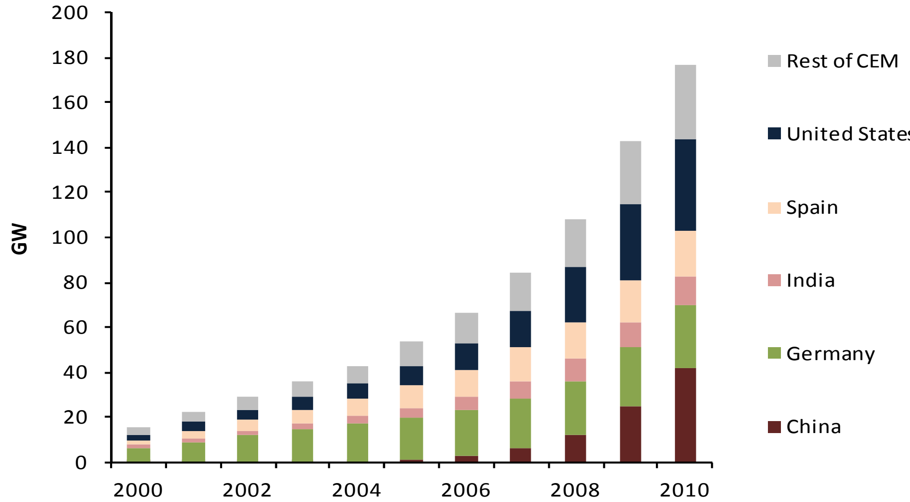
Wind Power

Technology deployment

Wind power experienced dramatic growth over the last decade. Global installed capacity at the end of 2010 was around 195 GW, up from 18 GW at the end of the year 2000. Nearly 36 GW were added in 2010 alone. Clean Energy Ministerial countries accounted for over 90% of total installed capacity in 2010, corresponding to some 175 GW (Figure 20).

Over the last couple of years wind's centre of growth moved from Europe and North America to Asia, which emerged as the global leader. In the year 2010, China added roughly 17 GW of capacity and became the global leader in terms of installed capacity. While China is at present very fast in building new wind capacity there is a lag of several months in connecting this capacity to the grid. As a result, a relatively low capacity factor is seen in China. While China's wind growth has been impressively rapid, windpower only provides just 1% of total electricity output in China. Contributing to the large Asian growth, India added over 2 GW of new wind power in the 2010. Growth in Europe and North America has slowed somewhat, the result of the economic downturn, which resulted in reduced access to financing. In addition, rising materials costs and turbine and component shortages have contributed to rising wind costs.

Figure 20. Clean Energy Ministerial countries' wind power capacity (GW)



Source: Global Wind Energy Council and country submissions.

In the United States these effects were amplified by the weak dollar. Offshore developments were concentrated mostly in Europe, where 883 MW were installed in the year 2010, bringing the total installed capacity to roughly 3 GW.

Policy developments

A number of recent important policy measures and programmes have emerged in support of expanded wind markets. Many of the new policy developments concern offshore wind:

- Offshore wind is now a Chinese priority with the publication of its Offshore Wind Development Plan in 2009 and with the establishment of a new FIT. The official target for wind deployment was increased to 150 GW.
- The United Kingdom emphasised onshore and offshore wind in its National Renewable Energy Action Plan, with funding allocated by the newly created Green Investment Bank. Up to 33 GW of offshore renewable generation is targeted via a maximum of GBP 15 billion invested in offshore infrastructures.
- In the United States, the USD 1 billion Cape Wind project, the country's first offshore wind farm, was successfully approved by the Department of Interior. The Department of Energy is currently reviewing the loan guarantee application. In December 2010, the DOE also finalised a deal for the Caithness Shepherds Flat project, the world's largest wind project to date, by providing a partial loan guarantee of USD 1.3 billion for the 845 MW facility located in eastern Oregon.
- Spain continues its focus on onshore wind deployment, issuing a new FIT in December 2010 for new wind power capacity to 2012.
- The European Union launched a 10-year European Wind Initiative that will provide EUR 6 billion in partnership with industry to advance wind RD&D.

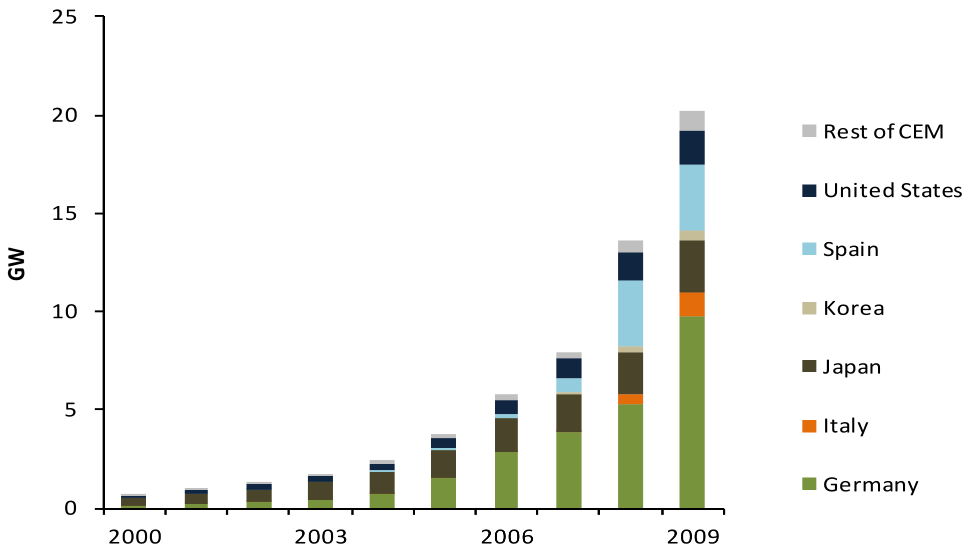
Solar energy

Solar photovoltaic deployment

From 2000-10, solar PV was the fastest-growing renewable power technology worldwide. Estimates suggest that cumulative installed capacity of solar PV reached roughly 40 GW at the end of 2010, up from 1.5 GW in 2000 (Figure 21). At least 17 GW were added in 2010, roughly half in Germany. In the year 2009, the last year for which a full data set is available, Germany, Spain, Japan, the United States, Italy and Korea accounted for over 90% of global cumulative capacity. Based on first available data for 2010, Germany maintains its massive lead of the market. Italy and the Czech Republic also saw a solar PV boom resulting from generous FITs and rapidly decreasing PV module costs.

Spain experienced rapid growth in 2008, followed by a significant slowdown after a new regulatory framework was introduced in 2009. The government has sought to rationalise deployment and control the impact of the FIT by establishing a quota of 500 MW of new capacity per year, a relatively modest target, comparing to the 2 500 MW added in 2008. Growth in the United States remained stable, while Japan continues to lead the way in Asia, adding almost 500 MW in 2009. China has announced ambitious targets and we can expect that China will transform its role from a leader in PV manufacturing to accelerate domestic deployment over the next few years.

Figure 21. Solar PV electric capacity in CEM Countries (GW)



Source: Country submissions and China Electricity Council, 2010.

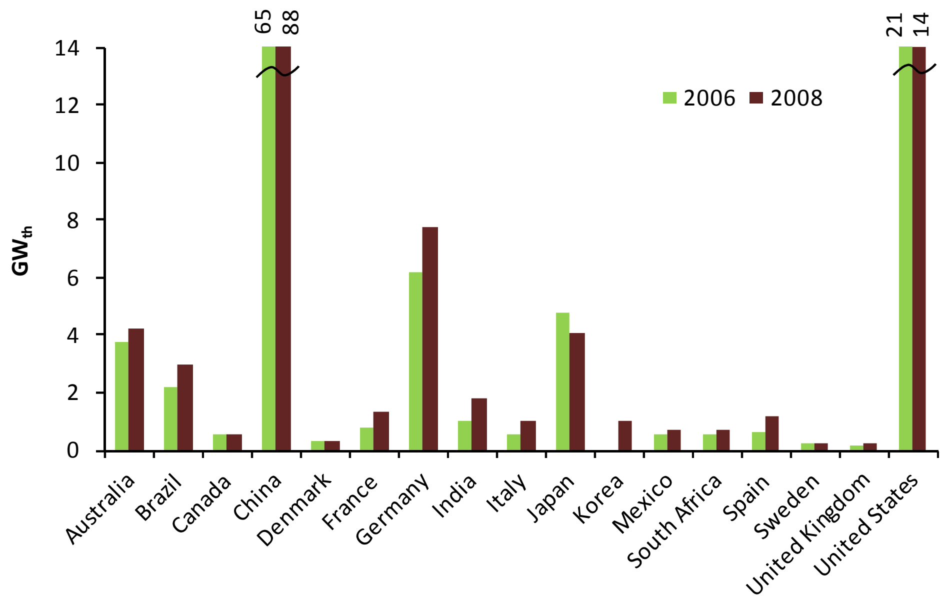
Concentrated solar power deployment

Concentrated solar power is a re-emerging market. Roughly 350 MW of commercial plants were built in California in the late 1980s; activity started again in 2006 in the United States, (473 MW at the end of 2009) and Spain (632 MW at the end of 2010). At present, Spain and the United States are the only two countries with significant CSP capacity. As CSP requires strong direct irradiation, future developments are expected in a handful of key countries in semi-arid, hot regions. Projects are under construction or planning in a number of developing and emerging economies, including Algeria, Egypt, Morocco, Australia, China, India, Israel, Jordan, Mexico, South Africa and the United Arab Emirates.

Solar heat deployment

By the end of 2008, worldwide installed solar thermal capacity totalled 152 GW_{th} corresponding to 217 million square meters (Figure 22). Of total solar thermal capacity installed in 2008, 132 GW_{th} consist of flat-plate and evacuated tube collectors. Unglazed plastic collectors accounted for 19 GW_{th}, which are the dominant application in the United States and Australia, mainly used for swimming pool heating. The remaining 1 GW_{th} comes from solar air collectors. The main markets are in China (87.5 GW_{th}), Europe (28.5 GW_{th}) and the United States and Canada (15.1 GW_{th}). Leading countries in flat-plate and evacuated tube collectors are China (87.5 GW_{th}), Turkey (7.5 GW_{th}), Germany (7.2 GW_{th}), Japan (4.1 GW_{th}) and Greece (2.7 GW_{th}). Apart from solar thermal systems operating on individual buildings, some 150 large-scale solar thermal plants (≥ 500 m^2; 350 kW_{th}) are in operation in Europe, functioning as multifamily building systems or contributing to district heating.

Figure 22. Solar heat capacity in leading countries (GW_{th})



Note: Figures are for low and medium temperature.
Source: Weiss, *et al.,* (2010).

Annual installed glazed collector area worldwide was more than four times higher in 2008 than in 2000, with an average annual growth of 20.1% (Weiss, 2010). The estimates for 2009 show that capacity has increased significantly again to 189 GW_{th} with complete data available for Europe and China (Weiss, *et al*., 2010).

Solar energy policy developments

Most countries with favourable solar deployment have adopted an integrated policy approach by establishing national Solar Missions or Programmes to set targets and drive co-ordination. Photovoltaic policies faced major challenges in 2010 and beginning of 2011. While expansion in global PV capacity has been a positive development, in that it has delivered significant cost reductions, this boom was larger than expected. As a consequence, escalating policy costs raised the question of financial sustainability of policy schemes. As a result, 2010 and the beginning of 2011 saw a number of countries reducing FIT tariff rates for solar PV development, and in some cases halting capacity expansion (Table 2 above). A key need is to design policies that adjust support to follow rapid reductions in the cost of solar technology. For solar heating, the most widely adopted support mechanisms are direct capital grants and tax credits for the purchase of a solar thermal system; these are offered by a number of European Union countries.

Other noteworthy policy developments include:

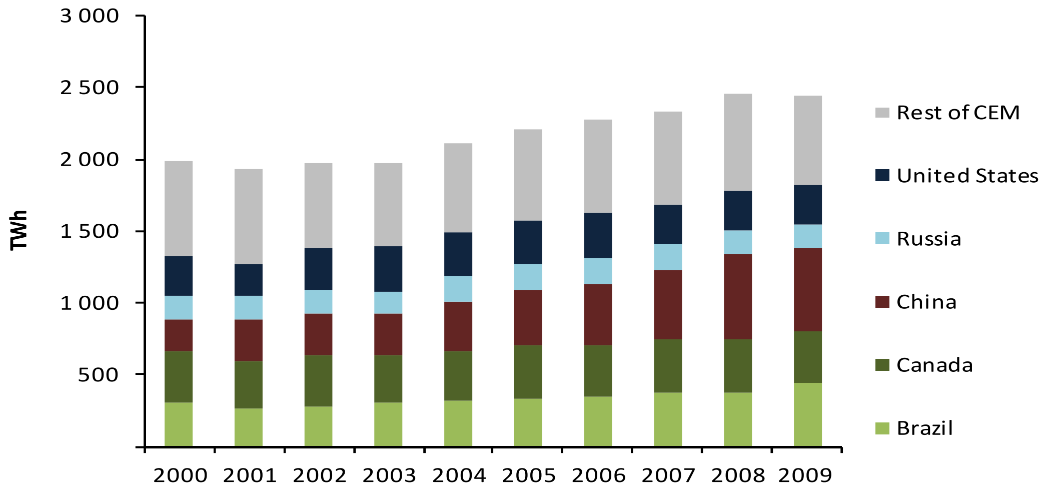
- India launched its Solar Mission in 2009 with an objective of 20 GW of installed capacity by 2022, supported by the use of renewable purchase obligation and preferential tariff rates.
- China established the Golden Sun programme in 2009 to expand solar production in China, with subsidies for 50% of the cost of investment in projects and related transmission and distribution systems. For remote, non-grid connected regions, subsides could amount to 70%. In 2010, China also implemented the Building Integrated Solar PV programme that provides incentives and grants. The China Energy Conservation and Environmental Protection group completed one of the largest building integrated PV installations in the world at over 6.5 MW.
- In South Africa, plans for the Solar Park were approved by the Department of Energy, with the objective of building 5 GW of solar capacity.
- The United States saw progress in 2010 in the permitting of large CSP plants which will lead to expansion of the industry in 2011. The DOE also finalised a USD 1.45 billion loan guarantee for the world's largest parabolic trough CSP plant—it will be 250 MW in capacity.
- Israel pioneered solar heating obligations in the 1980, mandating solar collectors in all new residential buildings. Today, solar thermal systems are a mainstream technology in the Israeli water heater market without any financial support.
- Deployment of solar thermal technologies can also be encouraged in energy-efficient building regulations. Germany's 2009 building regulations require a defined share of a new building's heat demand to be supplied by renewable energy.

Hydropower

Hydropower deployment

Hydropower remains the world's largest source of renewable energy. Much of the growth in recent years can be seen in developing countries with China leading the way (Figure 23). China ended 2009 with nearly 200 GW of installed capacity, an enormous increase on 2005 when it had an installed capacity of 117 GW. Over this period of rapid economic expansion in China and surging demand for energy, hydropower has maintained its share in total electricity output.

Figure 23. Hydropower electricity production in CEM countries (TWh)



Notes: Excludes pumped storage. Some 2009 numbers are estimates.
Source: Country submissions and China Electricity Council, 2010.

New hydropower development is concentrated in emerging economies. Many OECD countries have successfully tapped into their large hydro potential, and are now focusing on smaller applications. The world leaders in hydropower production are China, Canada, Brazil, the United States and Russia. For Brazil and Canada hydro represents a very large share of national power generation, roughly 80% and 60%, respectively, depending on weather conditions in a given year.

Policy developments

While hydropower represents the largest share of renewable electricity production, development of large hydropower slowed over the last decade due to concerns related to its environmental and social impacts. Life-cycle assessments and other policies are being developed to ensure that projects are sustainably developed. In 2010, the IEA Hydropower Implementing Agreement updated its *Recommendations for Hydropower and the Environment*[12] and the International Hydropower Association released an updated Hydropower Assessment Sustainability Protocol (IEA Hydropower IA, 2010). These efforts aim to provide a broadly supported sustainability assessment tool to measure and guide hydropower performance. While large hydropower is generally competitive, most hydropower financial support policies aim to address costs of generation for small installations.

Geothermal energy

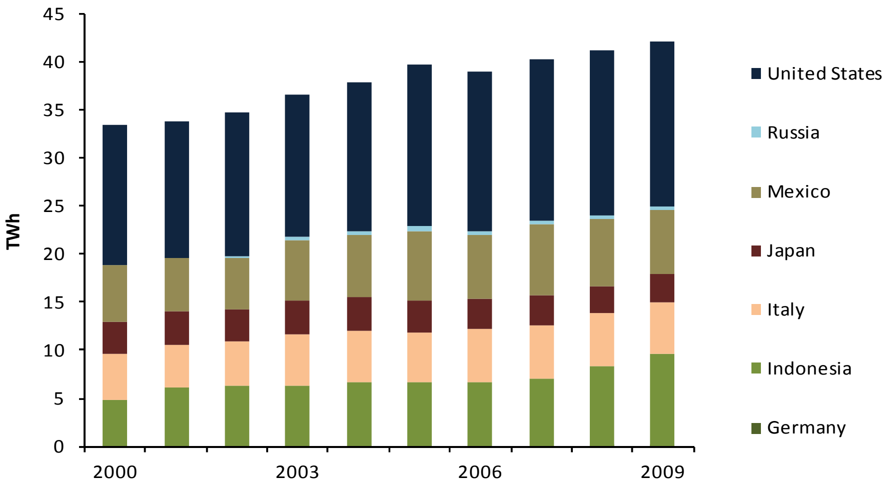
Geothermal power deployment

High-temperature geothermal energy resources suitable for power generation are concentrated in a small number of countries. Due to the uniqueness of the geothermal resource, the technology is considered relatively risky; as a result, growth has been slow over the last decade.

[12] The IEA Hydropower Implementing Agreement led work in this field since 2000. Within its current activities, Brazil is leading the work on the management of the carbon balance in freshwater reservoirs.

In 2009, global installed power capacity was nearly 11 GW, generating over 67 TWh of electricity. Much of this was generated outside of the CEM group of countries in places such as the Philippines (10 TWh), Iceland (4.5 TWh) and New Zealand (4 TWh).

Figure 24. Geothermal electricity production in CEM countries (TWh)



Source: Country submissions and Bertani, 2010.

Global leaders in geothermal power generation include the US, the Philippines, Indonesia, Mexico and Italy (Figure 24). Capacity has grown steadily in the United States and Indonesia over the last decade. Both of these countries have extensive experience with geothermal power; with a large additional potential, they aim to expand development. Geothermal power will be able to deliver even more significant contribution and on a global scale if efforts to develop technologies tapping into hot dry rock resources like enhanced geothermal systems prove to be successful (IEA, 2010b).[13]

Geothermal heat deployment

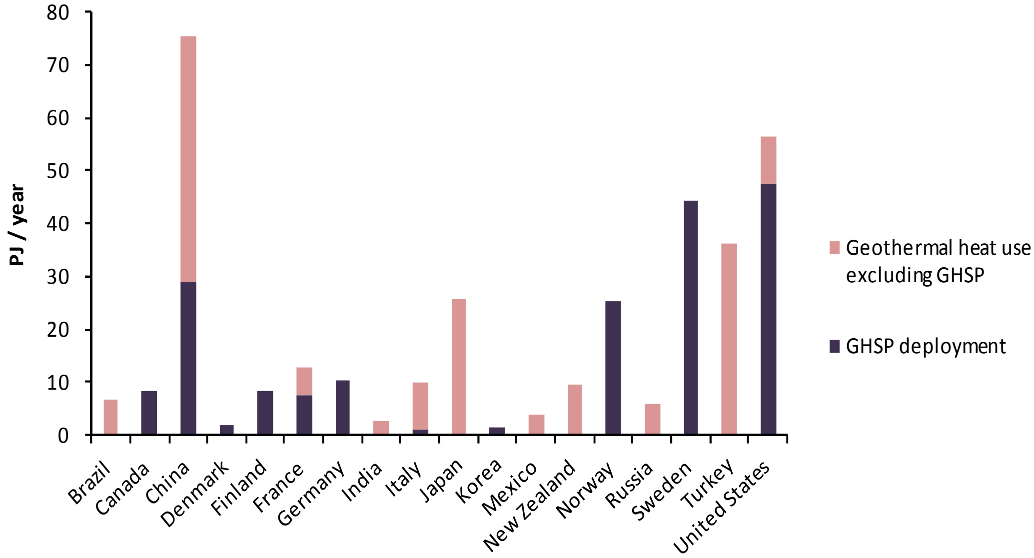
Geothermal heat resources can be used for a wide range of heat applications such as space and district heating, spa and swimming pool heating, greenhouse and soil heating, aquaculture pond heating and industrial process heating. Total global installed capacity of geothermal heat (excluding heat pumps) equalled 15 GW_{th} in 2009 with a yearly heat production of 223 PJ (5.3 Mtoe) (Figure 25). This increases from 139 PJ in 2000 and 175 TJ in 2005 (Lund *et al.*, 2010; Lund and Freeston, 2000; Lund *et al.*, 2005).

Ground source heat pumps are sometimes ranked under geothermal heat production.[14] Deployment of geothermal ground source heat pumps accounted for rapid acceleration of production levels from 23 PJ in 2000 to 215 PJ (5.1 Mtoe) in 2010 (Lund *et al.*, 2010; Lund and Freeston, 2000; Lund *et al.*, 2005).

[13] The IEA Geothermal Roadmap will be published in May 2011.

[14] This is not the practice in IEA statistics.

Figure 25. Top 15 countries using geothermal heat, excluding heat pumps, 2009



Source: Lund *et al.*, 2010.

Policy developments

Achieving the potential of deployment of geothermal power will require policy support to overcome the barriers of high initial capital cost, resource development risk, lack of awareness about geothermal energy and environmental issues. The most widely adopted mechanisms for geothermal heat are direct capital grants and tax credits for consumer purchases of a ground source heat pump.

A number of recent policy developments show progress:

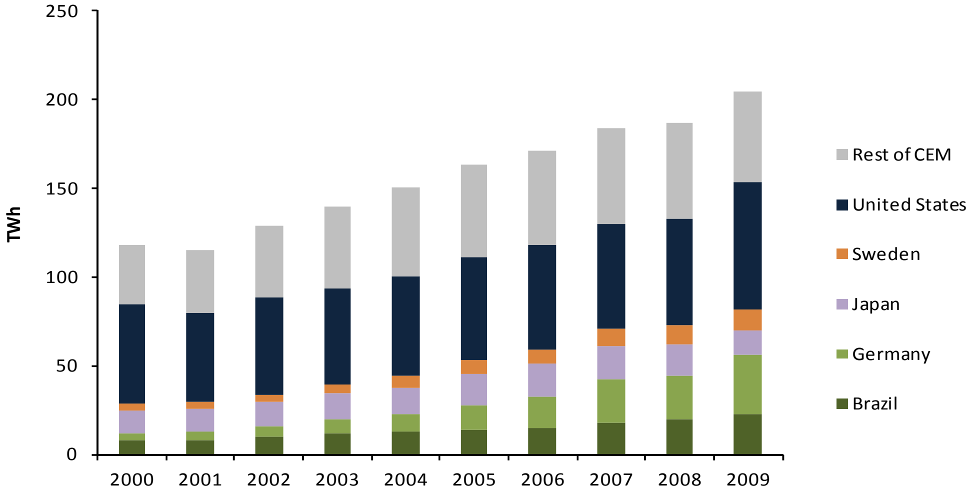
- US federal tax incentives for geothermal power were expanded through the 2009 economic stimulus legislation. USD 350 million was provided to the DOE Geothermal Technologies Programme, with 2010 seeing the approval of many new projects.
- The Indonesian government has objectives to develop over 12 GW of new geothermal power capacity by 2025, and will support this with tax incentives.
- Kenya hopes to achieve 490 MW of geothermal power by 2012 and 4 GW within 20 years, and has amended its FITto include geothermal energy.
- Germany amended its Renewable Energy Sources Act in 2009 to increase the tariffs for geothermal facilities, with a FIT bonus for the use of EGS technologies of EUR 0.04/kWh. Funds from the Market Incentive Programme are available for installations harvesting deep geothermal energy for electricity and heat generation.
- In the United Kingdom, the Deep Geothermal Challenge Fund awarded GBP 5.1 million through 2010 in support of six demonstration projects. Starting in April 2011, an expansion to the renewable feed-in tariffs is planned to low-carbon heating technologies, including ground source heat pumps'.
- In 2010, Australia committed AD 1.1 billion in the form of tax credits and rebates to geothermal development. The largest global project under development is in the Cooper Basin, with the potential to support up to 10 GW in capacity.
- The European Deep Geothermal Energy programme test site for EGS in France began electricity production in 2010.

Bioenergy

Bioenergy power deployment

The growth in electricity production from solid biomass, biogas and renewable municipal waste and liquid biofuels has been steady since the beginning of the decade. In 2000, over 130 TWh of power was produced from bioenergy, with Clean Energy Ministerial countries accounting for 88% of this output. By 2009, CEM countries had increased their output to over 200 TWh (Figure 26).

Figure 26. Bioenergy for electricity production – CEM countries



Note: Some 2009 numbers are estimates.

Growth in some countries has been more rapid than in others. The United States is the leader, followed by Germany, whose output has grown over 22% per year during the last decade. Brazil is also steadily growing; it has increased its capacity from less than 4 GW in 2005 to nearly 8 GW in 2010, with plans to reach 11.5 GW by 2015.

Biomass for heat deployment

The progress in biomass for heat over time is difficult to characterise, as it is disguised by extensive use of biomass as a source of heat in the residential sector in developing countries. This "traditional biomass" includes wood, charcoal, crop residues and animal dung and is mostly used for cooking and water heating and space heating.[15] In 2008, 746 Mtoe of traditional biomass was consumed in the residential sector in developing countries, with consumption in sub-Saharan African countries accounting for 32%; demand for traditional biomass worldwide increased by 12% between 2000 and 2008 (IEA, 2010g).

Modern biomass for heat consists of biomass used in efficient stoves or installations. In modern renewable heat, biomass dominates over solar thermal and geothermal heat; in OECD countries 89% of renewable heat came from biomass in 2008. The global use of modern biomass for producing heat reached 278 Mtoe in 2008 (including wood products, such as pellets and briquettes that have been made to burn efficiently, industrial biogas and bioliquids) (IEA, 2010g).

[15] The use of these biomass resources is considered traditional because they are most often burned at very low efficiencies and release many pollutants that have a serious health impact.

Policy developments

Biomass is the only renewable source that is suitable for producing power, heat and transport fuels but only about 20% of biomass is used on an industrial scale for these productions. Most biomass is currently used for traditional small-scale domestic heating and cooking, mostly in developing countries. Biopower is supported by targeted FIT schemes, renewable portfolio standards and tax incentives. Many governments provide support for bioenergy in CHP; some countries also support biomass co-firing in coal power plants. Given that reducing CO_2 emissions is an important driver for bioenergy support, much of the debate has focused on ensuring that bioenergy applications generate a net CO_2 benefit across their entire life cycle.[16] The most widely adopted mechanisms for the support of small-scale biomass heat are direct capital grants and tax credits for the purchase of a biomass heating system, mainly in buildings. Direct capital grants for biomass heating systems can be found in several European Union countries. Modern biomass for heat can also be encouraged through energy-efficient building regulations. Germany's 2009 building regulations require a defined share of a new building's heat demand to be supplied by renewable energy.

- In 2010, the Chinese National Development and Reform Commission announced a new national FIT for biomass power of CNY 0.75/kWh (USD 0.11/kWh), together with a national biomass capacity target of 30 GW by 2020.
- The Argentinian Ministry of Federal Planning, Public Investments and Services launched the Renewable Energy Generation (RENGEN) programme to have 8% of total electricity come from renewable sources by 2016. The public utility ENARSA will implement tenders for a total of 1 000 MW of electricity produced from renewable sources, out of which 150 MW are expected to come from thermal biocombustion, 120 MW from urban renewable waste and 100 MW from biomass.
- In Germany, the FIT has recently been adjusted to increase tariffs for biomass generated electricity and to emphasise CHP generation through additional bonuses.
- France reduced their biomass CHP tariffs in January 2011. In 2010 and 2011, the government tendered 450 MW of biomass capacity, and targets a total installed capacity of 2300 MW by 2020.
- In January 2011 the Finnish government approved the first national feed-in-tariff for electricity generated from wind, biogas and wood chips. The regulation implements a fixed tariff to biogas electricity producers, for a 12-year period, and an additional capital premium for CHP plants. This policy will be key to achieve Finland's strategy to meet a target of 38% of energy consumption from renewables by 2020, growing from 28% today.
- The German Marktanreizprogram is one example of a policy looking into encouragement of renewable heat in general; modern biomass for heat is included in the policy for all these market segments.

Public spending on research, development and demonstration for renewable energy

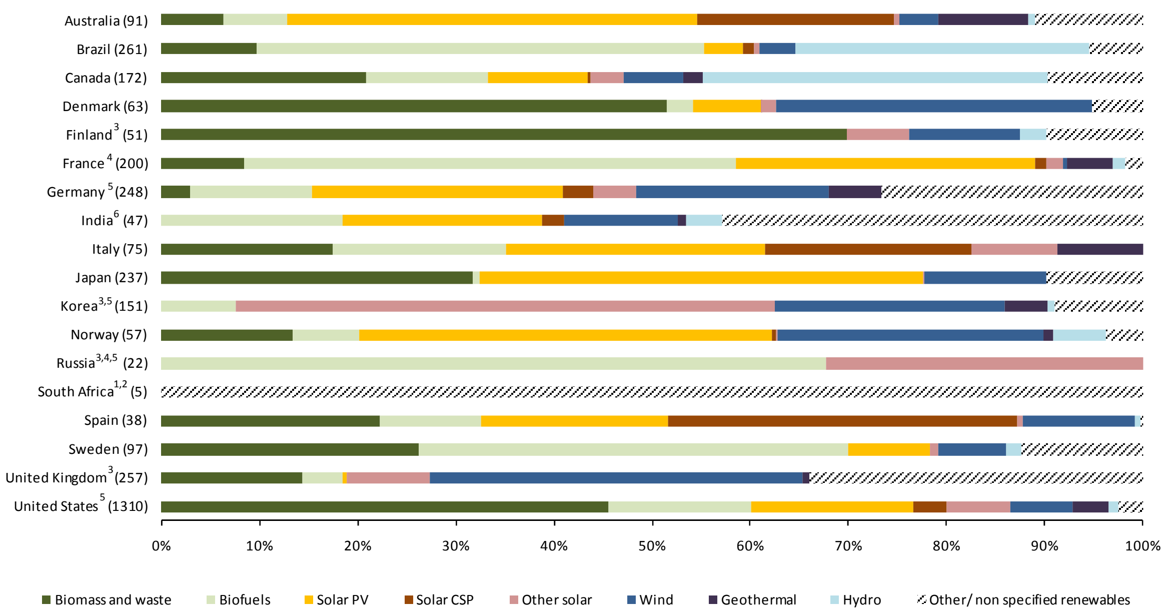
Renewable energy RD&D comprises solar PV, CSP, solar heating and cooling, wind, hydropower, geothermal electricity and heat, production and use of biomass and waste (including liquid

[16] The IEA Bioenergy Implementing Agreement and the Global Bioenergy Partnership are leading efforts to develop analysis and common definitions for bioenergy lifecycle estimates.

biofuels and biogas), and other renewable technologies such as ocean and wave/tidal power.[17] Overall, there was a significant threefold increase in CEM countries' RD&D expenditures on renewable energy between 2000 and 2010. In 2010, there was a large decrease to USD 3.1 billion total spending from 2009's all-time high of USD 3.8 billion due to reductions in stimulus spending. However, estimates for 2011 indicate that spending regains momentum as more data become available from a wider range of countries. Between 2000 and 2010, countries spent USD 56 billion on nuclear energy and USD 22 billion on fossil fuels RD&D, this compares to renewable technologies for which CEM countries spent only USD 16 billion over the same time period.

The United States is the largest spender on renewable energy RD&D among CEM countries. Between 2005 and 2010, the United States spent USD 4.9 billion, representing 40% of the total spent by all countries. In addition, the US spending amount increased significantly compared to the first half of the decade, when the country spent USD 1.4 billion (2000-05). In 2011, the United States has made a significant increase in solar energy RD&D, especially CSP (USD 141 million) which represents as much as 12% of total renewable technologies RD&D for this year. Japan and Australia increased expenditures on solar energy; each country spent about USD 145 million in 2011.

Figure 27. Public spending on renewable energy RD&D (2010 USD million)



Sources: Country submissions, Kempener *et al*., 2010.

Notes:

[1] Data is 2008.

[2] Source: Kempener *et al.*, 2010.

[3] Official data does not include a split between the different solar technologies.

[4] Data is 2009.

[5] Official data suggests only a number for total biomass, the split between solid biomass, waste and liquid biofuels is estimated.

[6] Data are *R&D budgets* and were taken from the Office of the Principal Scientific Adviser to the Government of India, together with hte submission by the Ministry of New and Renewable Energy. The Office of the Scientific Advisor amounts were estimated on a yearly basis as one fifth of total budgets.

For total biomass, the United States also leads RD&D expenditures with USD 2.6 billion between 2005 and 2010, followed by Brazil, Japan and Canada, who spent together more than USD 1 billion in this time period. For non-IEA countries other than Brazil, Russia spent some

[17] Liquid biofuels are described separately in the next section of this report.

estimated USD 46 million on biomass between 2007 and 2009 (including biofuels). India spent around USD 100 million between 2000 and 2008 on solar, wind, small hydro and biogas technologies RD&D but no specific rates are officially available (Kempener *et al.*, 2010). Approximately India plans to spend USD 43 million on bio-energy between 2007 and 2011 out of a total renewable energy RD&D budget of USD 237.

Generally, there are no detailed data breakdowns available for large emerging countries on renewable energy RD&D spending. As these countries develop a growing number of initiatives to increase renewable energy, it will be important to improve RD&D spending data for these countries. Brazil, Korea, Japan, Russia, the United Kingdom and the United States have made special efforts to submit more detailed RD&D data on sub-sectors. This allows for important insights upon priorities and trends in these countries.

Biofuels

While biofuels have been produced commercially in both the United States and Brazil for several decades, the sector has seen its fastest growth rate during the last 10 years. Driven by policy support in both OECD and more recently, non-OECD countries, global biofuels production grew from 16 billion litres in 2000 to more than 100 billion litres in 2010 (Figure 28). Today, biofuels provide 2.7% of global road transport fuel on an energy basis, but higher shares are achieved in some countries and regions. In Brazil, as much as 21% of all transport fuel is from biofuels; in the United States its share is 4% and in the European Union it is around 3%.

The development of advanced biofuel technologies will be essential to achieving the BLUE Map scenario over the next few decades. These technologies—including cellulosic-ethanol, biomass-to-liquids diesel, biosynthetic gas and other innovative conversion routes—will need to rapidly move from current demonstration plants to commercial-scale production units over the next 10 years (Figure 29).

Figure 28. Global biofuels production by type of fuel, 2000-10

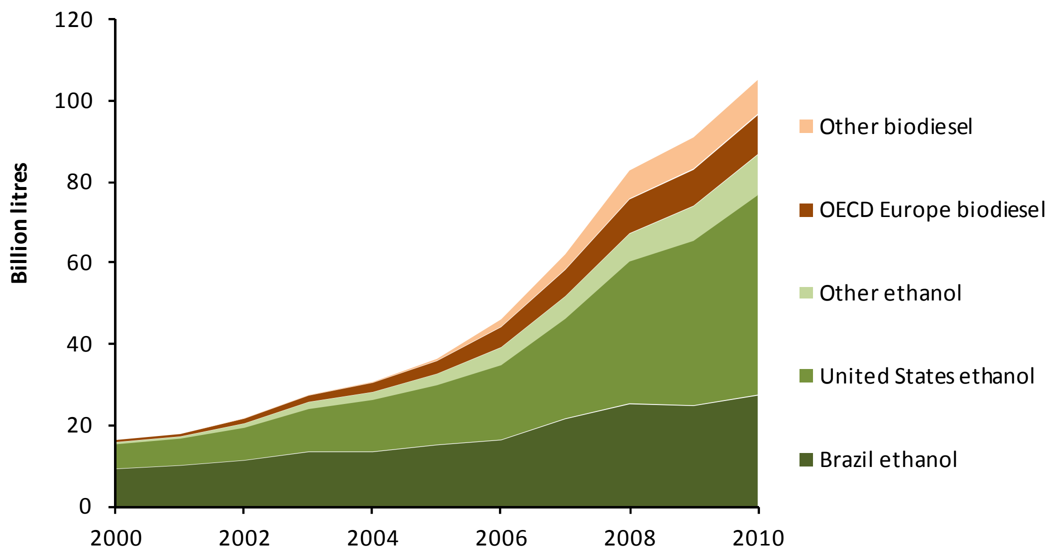
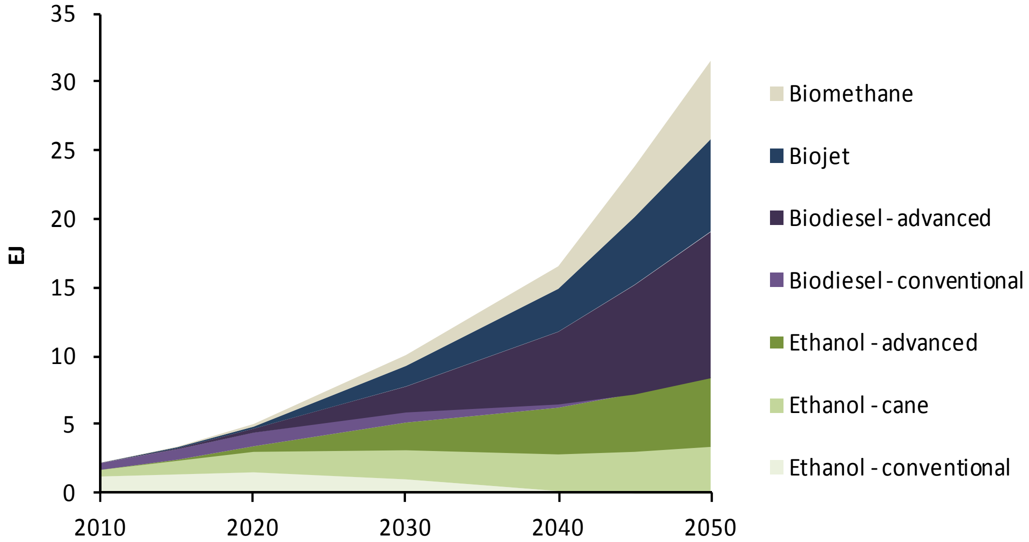
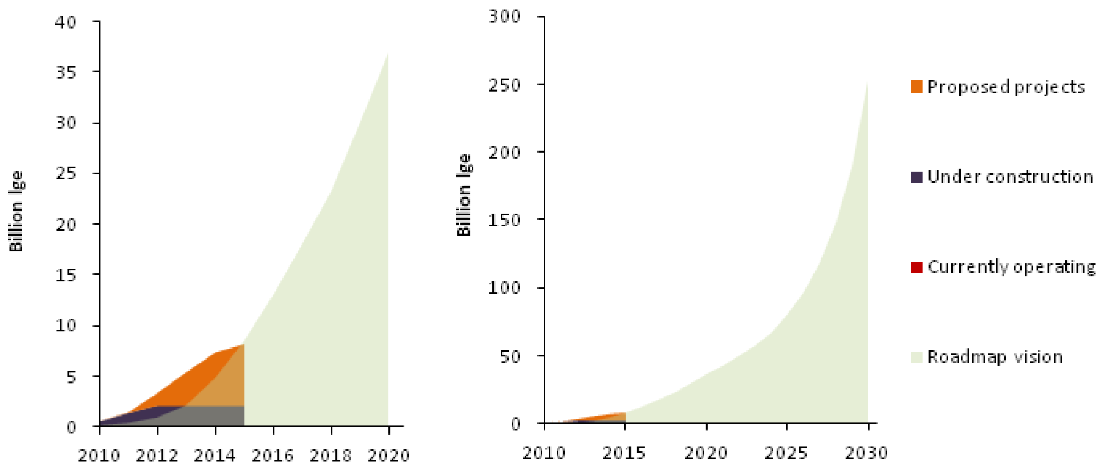


Figure 29. IEA biofuel roadmap's vision[18] for biofuel supply, 2010–50



Installed advanced biofuel capacity (*e.g.* ligno-cellulosic ethanol, biomass-to-liquids and other types) today is roughly 175 million litres gasoline equivalent (lge)/year, but most plants are currently operating below nameplate capacity. Another 1.9 billion lge/year production capacity are currently under construction and would, if operating with full load, be sufficient to meet the IEA BLUE Map targets for advanced biofuel production until 2013. In addition, project proposals for an additional 6 billion lge annual capacity by 2015 have been announced. Advanced biofuels have not yet been produced at a commercial scale; several pilot and demonstration plants have been announced during the past decade and a considerable number of projects are expected to become operational in the next five years (Figure 30).

Figure 30. Advanced biofuel production capacity: current status with planned capacity to 2015 and IEA Biofuel roadmap vision for growth to 2020 (left) and 2030 (right)



Notes: A load factor of 70% is assumed for fully operational plants. Actual production volumes may be well below nameplate capacity during the first years of production.

[18] The IEA Biofuels Roadmap will be published in May 2011.

The challenge of reaching this vision becomes clear when looking at the required development of advanced biofuel capacity out to 2030 in the graph above, and even more so when looking at the long term vision in the IEA BLUE Map scenario. A 40-fold increase in currently announced advanced biofuel capacity will be required to reach 320 billion lge in 2030. Between 2030 and 2050, a further doubling of advanced biofuel capacity will be required. Policies will be critical to achieve this pathway.

Policy developments

The most important policies to encourage biofuels include mandatory sustainability requirements, blending targets or mandates for biofuels with traditional fuels and loan guarantees and other financing mechanism that address the investment risk of developing commercial-scale advanced biofuel production units.

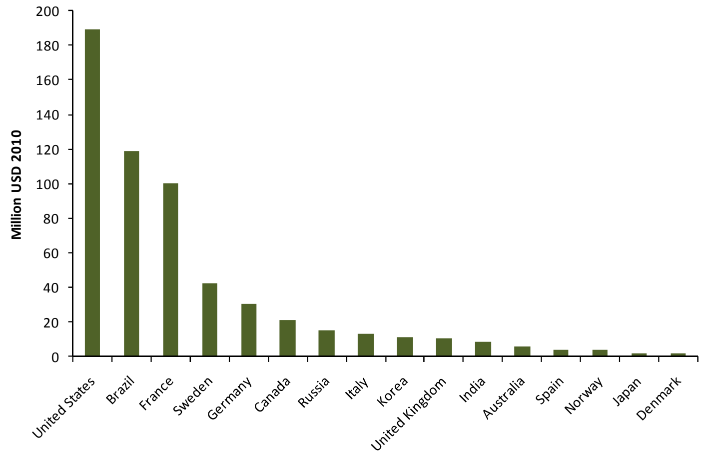
- Sustainability criteria ensure that biofuels develop with a positive social impact and without competing with food or causing negative impacts for biodiversity. There are a number of sustainability requirements underway; the Global Bioenergy Partnership is currently working to develop an internationally agreed standard.
- Over 50 countries have introduced blending targets or mandates for biofuels in gasoline and/or biodiesel, often coupled to reduced excise duties. When backed by effective enforcement, these have been effective in increasing biofuel use.
- In February 2010, the US Environmental Protection Agency (EPA) finalised regulations under the Energy Independence and Security Act of 2007 that make significant changes to the renewable fuel standard in the Energy Policy Act of 2005. The changes aim to boost domestic biofuels production by, among other things, expanding the volume of renewable fuel that transportation fuel sold in the United States must contain. This rulemaking also represents the first time that GHG emission performance standards are being applied in a regulatory context for a nationwide programme. The United States also has a cellulosic-ethanol quota, which creates a market for this advanced biofuel. The United States provides loan guarantees and funding mechanisms for advanced biofuel production plants through the United States Biomass Program.
- The EU's Renewable Energy Directive requires that biofuels generate GHG savings of at least 35% compared to fossil fuels starting at the end of 2010; these requirements rise to 50% savings in 2017 and 60% in 2018. The European Union will also maintain a target of 5.75% renewable fuels (by energy content) in transport by 2010 and a 10% renewable energy mandate for 2010. Further, advanced biofuels from lignocellulosic biomass counts twice against the EU targets. Funding is provided under the EU's Research Framework Programme; some Member States, *e.g.* Denmark and Germany provide specific financial support for advanced biofuels plants.

Public spending on research, development and demonstration

For biofuel technologies, there have been important historical data gaps for key countries, particularly regarding the division between liquid biofuels and other biomass in terms of RD&D spending. This was also the case in the United States and Brazil. For the purposes of this Progress Report, CEM countries reported increasingly detailed data on certain technologies, including for biofuels RD&D that consists of thermo-chemical, biochemical production of biofuels, algal and other liquid biofuels. Thanks to this additional data, a better assessment can be made of the investments in different types of bioenergy.

The United States is the leading country at USD 189 million (Figure 31), with major interest in biochemical and thermochemical sources of fuels. France has invested increasingly in biofuels since 2004, reaching USD 100 million in 2009 accounting for 10% of total national energy RD&D in that year and comparable with Brazil who spent an estimated average of USD 90 million on biofuels between 2009 and 2010.

Figure 31. Public spending on biofuels in CEM countries in 2010



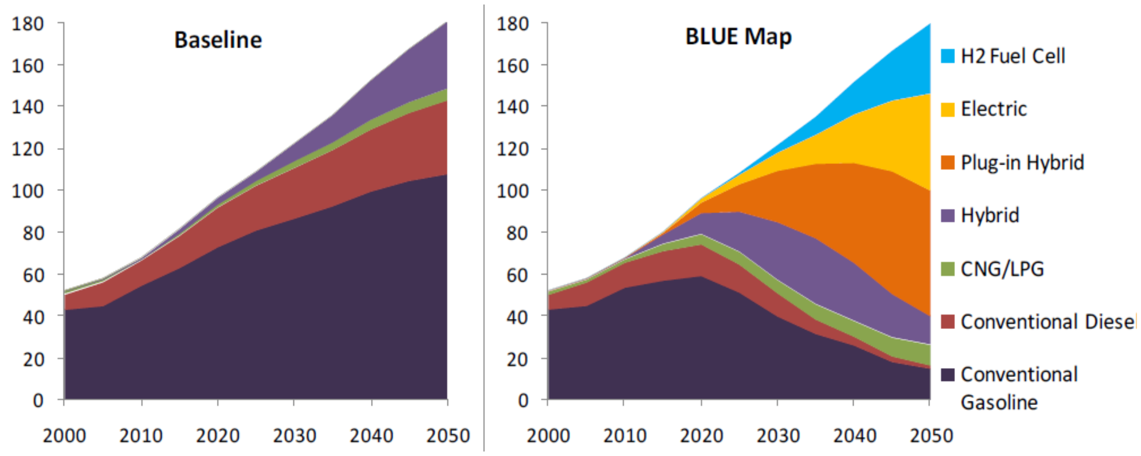
Source: Country submissions, Kempener *et al.*, 2010

Notes: France and Russia is 2009 data. Data for India are *R&D budgets* and are from the Office of the Principal Scientific Adviser to the Government of India ; amounts were estimated on a yearly basis as one fifth of total budgets. Data for non-IEA countries, Germany and Korea might include amounts spent on solid biomass and biogas.

Electric vehicles and vehicle efficiency

In the *ETP 2010* Baseline scenario, light-duty vehicle sales are mainly conventional internal-combustion-engine (ICE) vehicles through 2050; hybrids reach about 20% of sales. The BLUE Map scenario shows strong penetration of hybrids by 2015; plug-in hybrid electric vehicles (PHEVs) and EVs reach substantial sales (over 5 million) by 2020; and FCVs begin selling in earnest around 2025. By 2050, plug-in and fuel cell vehicles account for more than two-thirds of all sales (Figure 32). Though EVs and PHEVs represent only 2% of the world vehicle fleet by 2020, it is essential to reach those intermediate (yet fast-growing) steps in order to achieve substantial EV penetration later (*e.g.* 10% of stocks by 2030 and around half by 2050).

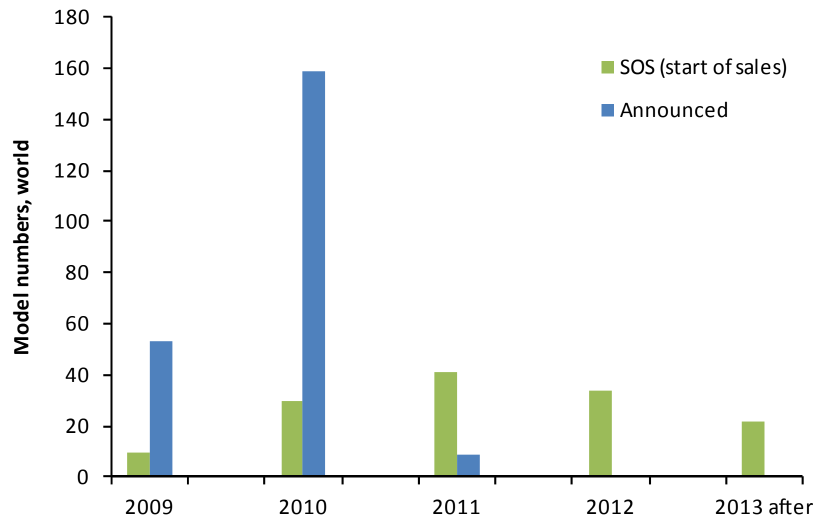
Figure 32. Passenger LDV sales by technology type and scenario (million sales per year)



Technology deployment

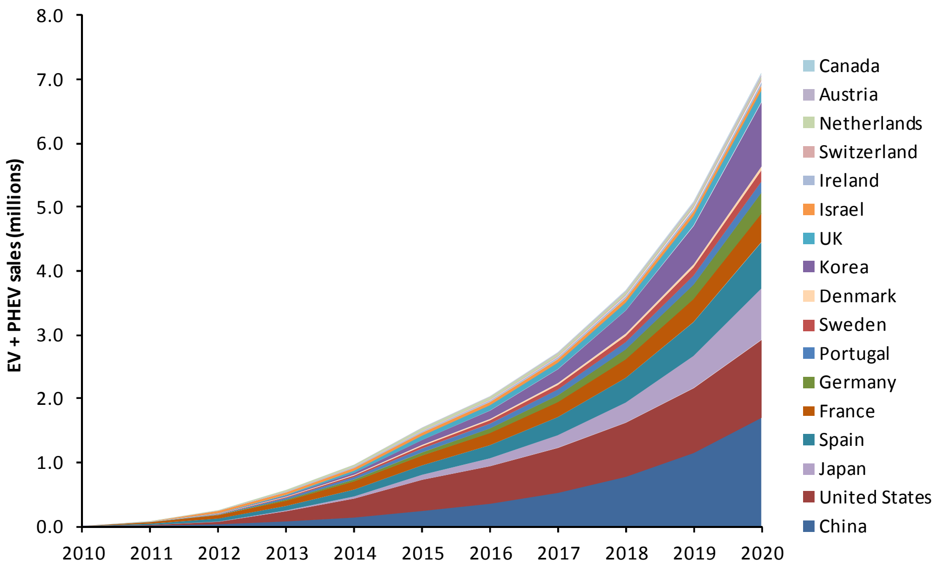
An early indicator for EVs and PHEVs is the availability of vehicles. The numbers and types of models available to consumers to purchase must be large enough to attract a wide range of buyers, and thus enable rapid growth in market share and sales. Figure 33 shows some good news in this regard – the number of EV and PHEV models that have been announced, and planned to be introduced in the future, was over 200 at the end of 2010. About half of these models are from Chinese companies, and most of the rest are from manufacturers in OECD countries.

Figure 33. PHEV/EV model introductions



However, plans must become reality; and as of the end of 2010 only about 30 models were actually available on markets around the world (and far fewer on the market for any one country). This appears likely to change soon, with the expectation of about 40 more models to be introduced in 2011 and close to 40 more in 2012.

Figure 34. Aggregated national targets for EV/PHEVs



An increase in the availability of different models will give consumers greater choice and make it easier for governments to fully implement EV programmes. The final step will be to see if consumers respond by buying these vehicles in the numbers hoped: based on national targets, this amounts to hundreds of thousands worldwide within the next 2-3 years, over one million per year by 2015 and 7 million by 2020 (Figure 34).

Policy developments

Other key indicators are the budgets countries are allocating for deployment, through grants and purchase incentives, and the per-vehicle level of incentives. During 2010, a number of important EV/PHEV policy developments were announced:

- Japan announced that by 2020, PHEV/EV sales would represent 15-20% of total LDV sales. The country has announced a per-vehicle subsidy of half of the price difference between EVs/PHEVs and a base, comparable ICE vehicle.
- China has tentatively announced a stock target of five million EV/PHEVs by 2020. The country has announced subsidies of Yuan 60,000 (USD 9 100) per vehicle for EVs in pilot cities, with funds allocated through 2012.
- Denmark exempts the vehicle purchase tax for EVs (equivalent to an exemption of 105% of the car value below DKK 76 500 (USD 14 400), and 180 % of the car value above this, plus an exemption from annual registration fee of between DKK 500 and 10,000 (USD 95 and 1900). Additional funding of DKK 35 million (USD 6.6 million) is provided for a test programme with business and municipal fleet operators.
- France announced a stock target of 2 million PHEVs/EVs by 2020. The country has announced up to a EUR 5 000 (USD 7 000) tax credit per vehicle through 2012 for the first 100 000 vehicles, with a total budget of EUR 400 million (USD 560 million).
- Spain announced stock targets of 250 000 by 2014 and 2.5 million by 2020. Incentives outlined are up 25% of EV cost, with an upper limit of EUR 6 000 (USD 8 200) per vehicle. EUR 72 million (USD 100 million) are allocated in 2011 and EUR 160 million (USD 225 million) in 2012.
- Sweden announced a stock target of 600 000 for 2020 and EUR 20 million (USD 28 million) worth of purchase incentives through 2014.
- The United States announced a stock target of 1 million by 2015 with up to a USD 7 500 incentive per vehicle, for the first 200 000 vehicles sold by a manufacturer. The US Department of Energy is providing relevant funding and grants of over USD 2 billion for battery and electric-drive component manufacturing.
- The United Kingdom has not announced a firm sales or stock target (though 800 000 on road by 2020 has been mentioned in reports). An EV/PHEV purchase incentive of GBP 5 000 (about USD 8 000) is set through 2012.

Taking into account caps, current programmes could result in total expenditures of around USD 20 billion. Total worldwide spending through 2020 could be far higher if incentive programmes continue, even if incentive levels decline over time. For example, if the average incentive were USD 5 000 per vehicle for the next 10 years, total incentive spending for those vehicles would be USD 100 billion if 20 million vehicles are sold.

Deployment of light-duty vehicle fuel economy technologies

Improving the fuel economy of internal combustion engine vehicles over the next 10 years is also a priority for cutting fuel use and CO_2 emissions. Figure 35 demonstrates that there is a wide range of current average new LDV fuel economy, with countries like France and India selling cars with the lowest fuel consumption per kilometre, while the United States and Australia are among the highest. The global average in 2005 was estimated to be about 8.1 litres per 100 km (about 29MPG), improving to 7.7 litres by 2008 (31 MPG). However, most of the improvements were in OECD countries; non-OECD countries overall experienced a slight worsening of fuel economy.

Figure 35. Light-duty vehicle fuel economy

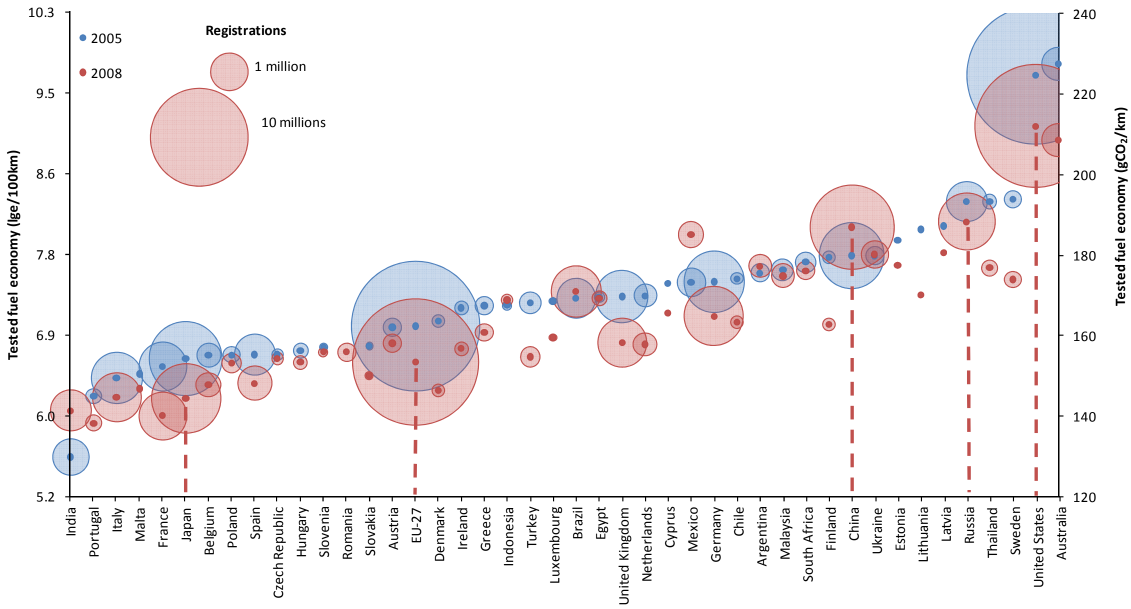
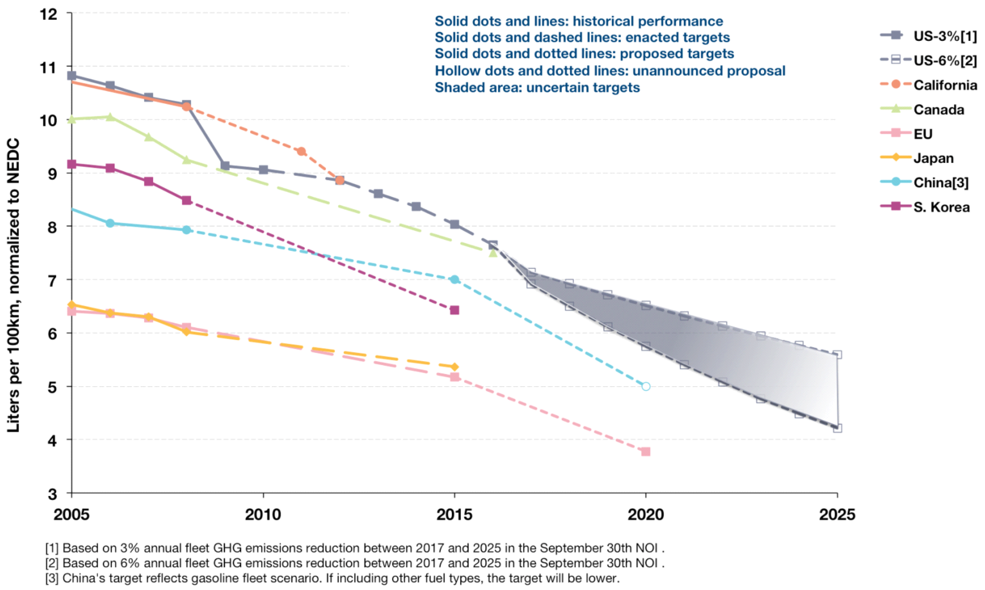


Figure 36. Average fuel economy trends through 2008 by region, with enacted or proposed targets through 2020



Source: ICCT, 2011.

The Global Fuel Economy Initiative has called for a global target of half the 2005 level of 8.1 L/100km – or about 4 L/100km – by 2030. As shown in Figure 36, good progress in this direction appears likely to occur in OECD countries over the next five years, thanks to relatively strong fuel economy standards now in force in most countries. But it will be important to continue strong improvements after 2015, and the best way to do this will be for countries to set targets – and standards – through 2020 and beyond, sooner rather than later. It will also be important for more countries in the developing world to set strong policies, whether these are standards or market-based policies (like CO_2-differentiated vehicle registration fees).

Policy developments

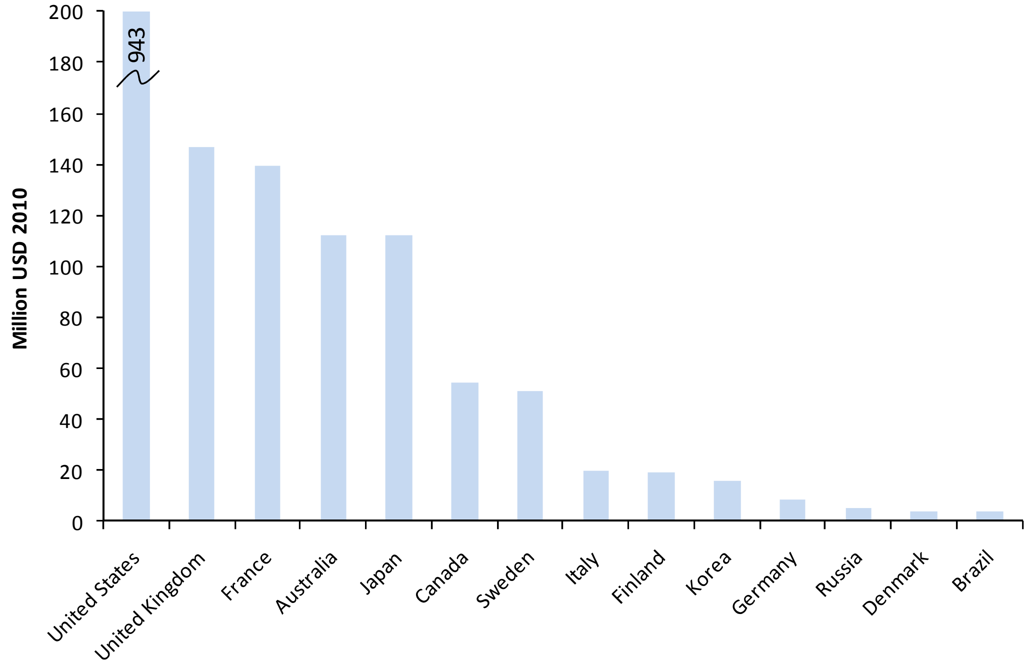
Fuel economy policy developments during 2010 included:

- **United States** set revised CAFÉ standards for LDVs with target 35.5 mpg by 2016 (about a 25% improvement compared to today). The United States also proposed fuel economy/greenhouse gas standards for heavy-duty vehicles, in development.
- **EU** – New CO_2 regulation for passenger LDVs was adopted, requiring 120 G/km maximum CO_2 levels by 2015 and 95 G/km was adopted in 2009); CO_2 standards for commercial vans was proposed and is under consideration (proposal: 175 gCO_2/km by 2014, 135 gCO_2/km by 2020).
- **China** has proposed tightening its fuel economy standards (only non-OECD country with standards) through 2020, but
- **Many countries**, especially in the EU, have implemented fuel economy or CO_2-based vehicle taxation schemes, or "bonus-malus" schemes (with higher taxes for high fuel consumption/CO_2 vehicles and rebates for the most efficient models). There are a wide range of such schemes now in place, sometimes sending mixed signals to manufacturers.

Public spending on research, development and demonstration

The RD&D data on vehicle efficiency include on and off-road transport vehicles as well as agricultural transport systems and waste heat recovery. Electric vehicles include infrastructure and storage systems and hydrogen and fuel cells for mobile applications. Figure 37 shows RD&D spending in electric/ PHEV and vehicle efficiency. Spending dramatically increased since 2003 in all countries, from USD 265 million to USD 1.6 billion in 2010. The countries with large vehicle markets (and manufacturing) dominate the spending: the United States, France, Japan and Sweden made up more than 80% of total RD&D between 2005 and 2010. Germany shows surprisingly low amounts of spending in these technology areas while Australia spent impressive amounts between 2009 and 2011 (USD 270 million) against previous decadal average of less than USD 4 million in the period 1999-09. No data is available for China and other emerging economies. Few countries recently submitted detailed RD&D data which permit to make a split on different research categories. For example, the United States spent over USD 100 million on electric vehicles, vehicle batteries and EV infrastructure, at least USD 280 million on fuel and on-road vehicle efficiency and further USD 44 million on other transport efficiency in 2010. In Japan, only about 10% of total budgets for transport efficiency were spent on on-road vehicles the same year. Still, both countries were not able to allocate more than 50% of the amounts spent on transport RD&D in 2010.

Figure 37. Public RD&D spending on EV/PHEVs and vehicle efficiency in CEM countries, 2010

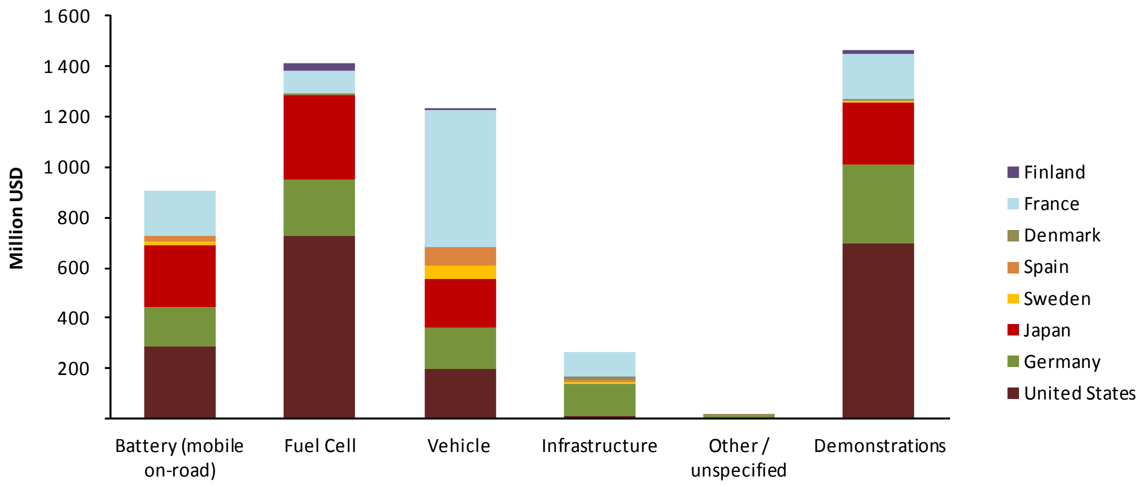


Notes: France and Russia is 2009 data, other non-IEA countries are 2008 data

Source: Country submissions.

Figure 38 breaks out EV/PHEV spending by various categories for selected countries. The totals for 2008-11 show that fuel cell research still ranks high in spending, slightly ahead of battery research. Other vehicle R&D (such as motors and advanced drive trains) is also significant. Spending on demonstration projects – a form of deployment – also received more than USD 1.4 billion over this period. This is likely to grow in coming years, particularly in the form of incentive programmes for purchases of EVs, PHEVs and other advanced vehicles.

Figure 38. Public spending on electric vehicle RD&D category for selected countries 2008-11



Source: Country submissions.

Acronyms, abbreviations and units

This annex provides information on acronyms, abbreviations and units used throughout this paper.

Acronyms

BAT	best available technology
CCS	CO_2 capture and storage
CEM	Clean Energy Ministerial
CERT	carbon emissions reduction target
CFL	compact fluorescent light bulb
CHP	combined heat and power
CSP	concentrated solar power
DOE	Department of Energy (United States)
EE	energy efficiency
EMDS	electric motor-driven systems
ENARSA	Energia Argentina SA
EPA	Environmental Protection Agency (United States)
EU	European Union
EV	electric vehicle
FCV	fuel-cell vehicles
FIT	feed-in tariffs
FYP	five-year plan
GCCSI	Global Carbon Capture and Storage Institute
GFEI	Global Fuel Economy Initiative
GHG	greenhouse-gas
GPS	global positioning systems
GSHP	ground source heat pumps
GWEC	Global Wind Energy Council
ICE	internal combustion engine
ICT	information and communications technology
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IGCC	integrated gasification combined cycle
LDV	light-duty vehicle
LEDs	light-emitting diodes
LLCC	least life-cycle cost
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
PHEV	plug-in hybrid electric vehicles
PV	photovoltaic
R&D	research and development
RDD&D	research, development, demonstration and deployment
RENGEN	Renewable Energy Generation
RHI	Renewable Heat Incentive

S&L	standards and labelling
SSL	solid state lighting
USC	ultra-supercritical
USD	United States dollar

Abbreviations

CO_2	carbon dioxide

Units of measure

EJ	exajoule
Gt	gigatonne
Gtoe	gigatonnes of oil equivalent
GW	gigawatt
GW_{th}	gigawatt thermal capacity
km	kilometre
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
mpg	miles per gallon
Mt	megatonne
Mtoe	million tonne of oil equivalent
MW	megawatt
MWh	megawatt-hour
TWh	terawatt-hour

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