Technology Action Plan

EXECUTIVE SUMMARY

MAJOR ECONOMIES FORUM
ON ENERGY AND CLIMATE

DECEMBER 2009

EXECUTIVE SUMMARY OF MEF TECHNOLOGY ACTION PLANS

In July of 2009, the Leaders of the Major Economies Forum on Energy and Climate (MEF), representing the 17 largest economies of the world, launched the Global Partnership for low-carbon and climate-friendly technologies. As an initial step, they requested a suite of plans, which now span ten climate-related technologies that together address more than 80% of the energy sector carbon dioxide (CO_2) emissions reduction potential identified by the IEA. This document summarizes the resulting menu of potential actions for all countries to consider in pursuit of the common goal of a global low-carbon economy.

The Leaders of the Major Economies Forum on Energy and Climate (MEF) consider climate change to be one of the greatest challenges of our time and have recognized "the scientific view that the increase in global average temperature above pre-industrial levels ought not to exceed 2 degrees C." Ambitious globally coordinated clean technology action is essential to achieve the emissions reductions required to hold expected warming below this threshold.

Accordingly, in July, the MEF Leaders announced a Global Partnership to spur development and deployment of low-carbon and climate-friendly technologies and asked their respective ministers to develop an initial set of deliverables prior to the Copenhagen climate negotiations in December 2009. These included an analysis entitled *Global Gaps in Clean Energy Research, Development, and Demonstration* (GCERD), prepared by the International Energy Agency (IEA) for the MEF Global Partnership, and a suite of ten Technology Action Plans (TAPs), prepared by MEF countries, focused on advanced vehicles; bioenergy; carbon capture, use, and storage; buildings sector energy efficiency, industrial sector energy efficiency; high-efficiency, low emissions coal; marine energy; smart grids; solar energy; and wind energy. In all, these TAPs address roughly 80% of the energy-related global CO_2 abatement potential identified by the IEA, though other energy technologies such as nuclear energy, mass transit, and geothermal energy and non-energy opportunities (e.g., reducing deforestation) can also play a key role in mitigating climate change.

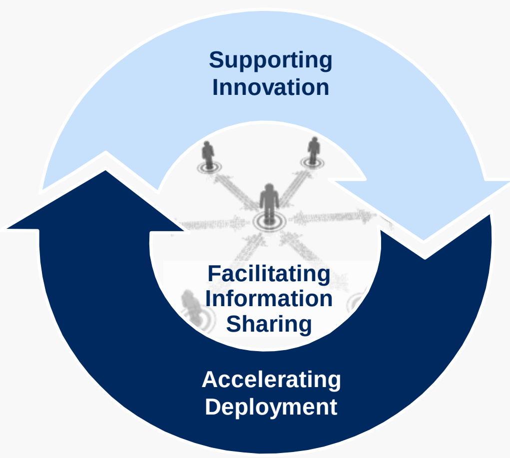
The GCERD establishes a new global baseline for current funding for research, development and demonstration (RD&D) for each of the technology categories covered by the TAPs. It also specifies research priorities and assesses gaps in funding between today's level of support and the substantially higher levels of sustained support that will be needed to achieve shared climate goals to 2050. This information will inform MEF countries as they scale up clean energy innovation investment consistent with their stated intention to at least double clean energy innovation funding by 2015.

Each of the TAPs contains a wealth of detail for national leaders to consider, including the (1) mitigation potential of the technology, (2) barriers and best practice strategies to overcome them, and (3) a menu of potential government actions to move towards best practice policies as appropriate to their respective national circumstances and priorities.

During the October 2009 MEF meeting in London, the Leaders' representatives called for an Executive Summary to communicate the main findings and implications of this work. Accordingly, this document describes the common framework MEF members have used to draft TAPs and the potential ongoing role for the Global Partnership in developing and deploying clean technologies.

All sectors of society have an important role to play in achieving sustainable economic growth, but government leadership is essential. In particular, stable and transparent policy can encourage market participants to confidently invest in clean energy technologies. From the TAPs, three major opportunities emerge for individual and collective leadership by governments, as illustrated in Exhibit 1.

EXHIBIT 1: THREE KINDS OF GOVERNMENT ACTION NEEDED TO ENABLE CLEAN TECHNOLOGIES



Public innovation support yields advances otherwise blocked by investor uncertainty

Public facilitation of information-sharing accelerates both innovation (e.g., research partnerships) and deployment (e.g., best practices to overcome market barriers)

Clear deployment policies encourage private investment in direct scale-up and related innovation

A cross review of the TAPs suggests government policy that simultaneously supports innovation and deployment can create a positive "feedback loop" involving both the public and private sector, with proactive information sharing serving as an accelerant. Multilateral and global coordination of national level policies can further increase the scale, scope and speed of progress.

Across these three policy areas, the TAPs identify a menu of actions for all countries to consider. Key strategies to encourage innovation include public investment in RD&D as well as stable deployment policies that enable private RD&D investment. Possible policies to enable deployment include establishing a price on carbon emissions, clear rules for connecting distributed renewable energy and cogenerated electricity to the electricity grid, efficiency labels for appliances, and production-based incentives for emerging clean energy technologies, among many other options. Information sharing includes sharing insights about best practice national policies that successfully enable development and deployment of clean energy technologies.

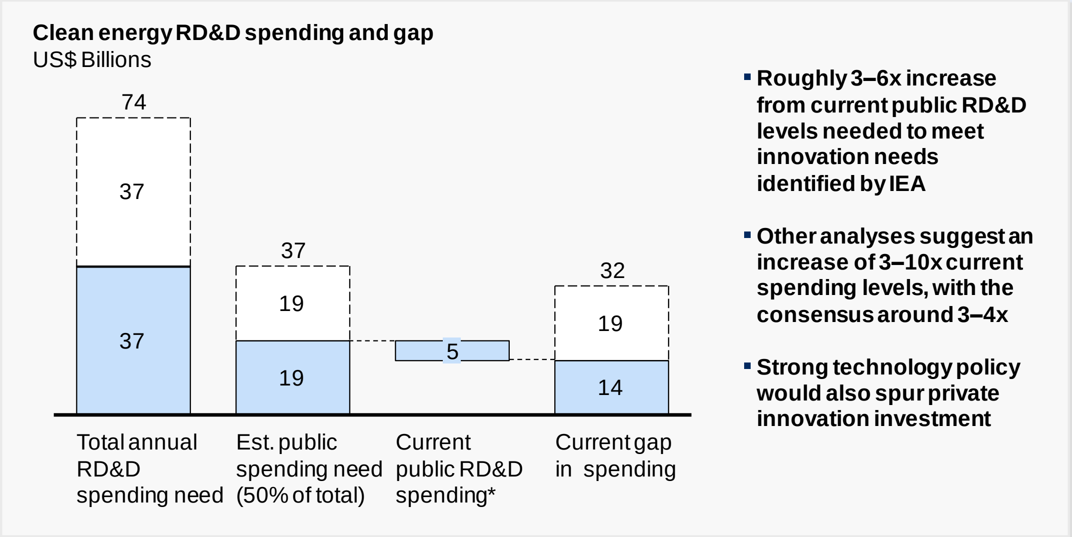
The relative priorities for each country will vary by technology, geography, and context (e.g., the presence of a price on carbon emissions may reduce the need for other economic incentives), but all governments can develop a portfolio of nationally appropriate policies.

Supporting Innovation

While many clean energy technologies are already available, new options will need to be developed and commercialized to achieve long-term global ambitions for emissions reductions and economic progress.

The GCERD summarizes current RD&D levels in the MEF countries, confirming that public and private investment to develop new clean energy technologies has grown substantially over the last 10 years, as clean energy innovation has risen to the top of many national policy agendas. These efforts have been augmented by state and national government policies that support deployment, most recently via national economic stimulus initiatives. Nonetheless, as Exhibit 2[1] shows, in the GCERD the IEA estimates an annual clean energy research innovation investment gap (relative to requirements to realize the IEA BLUE Map Scenario that would be broadly consistent with maintaining warming below 2°C) approaching US$20 billion across the categories covered by the TAPs. This would represent at least a threefold increase over the investment levels prevailing prior to the large increases associated with one-time stimulus spending—though other studies cited by IEA include recommendations ranging from a doubling to a full order of magnitude increase in RD&D investment.

Exhibit 2: Range of IEA Estimates for Required Increases in Annual Global RD&D Investment



* Excludes one-time recovery spending
Source: Global Clean Energy RD&D Gap Analysis (2009), prepared by the IEA for the MEF Global Partnership

[1] The bars in Exhibit 2 show ranges, with the shaded part representing the lower end of the range, and the open part the upper end of the range. The estimated total annual RD&D funding need, for both public and private sectors, is US$37–74 billion. Of this, approximately half may be said to rely on pubic sources, that is, between US$19–37 billion. The current public funding level (excluding one-time stimulus spending) is approximately US$5 billion, leaving a public RD&D funding gap estimated to between US$14–32 billion, which translates to a 3–6 times multiple from current levels.

Example Actions to Support RD&D-Driven Innovation from the TAPs

- **Advanced Vehicles:** Expand research efforts and set standards for recycling of materials from electric vehicles and batteries, motors, etc. with the objective of maximum re-use of valuable or scarce materials and protection of the environment.
- **Bioenergy:** Undertake joint demonstration projects in lignocellulosic biofuels, integrated food and energy systems, and other innovative bioenergy technologies or practices.
- **Solar:** Provide for appropriate, permanently available test facilities and demonstration projects, particularly for the specific needs of new and emerging technologies.

International coordination through the Global Partnership can accelerate RD&D-driven clean energy innovation. First, a coordinated increase in public and private R&D investment by major economies could help to ensure that the most critical global investment gaps are covered within a robust global portfolio that maximizes risk-adjusted returns on innovation investment. Second, international coordination can help to ensure key emerging clean energy technologies cross the "valley of death" between pilot projects and commercial success. Finally, joint public-private international research efforts can further accelerate global clean energy innovation.

Although future cost reductions for any given technology category are uncertain, globally-coordinated investment in a broad portfolio of emerging clean energy technologies could accelerate major reductions in the long-term cost of clean energy, with the benefits shared globally as low-cost clean energy solutions spread worldwide.

As a part of their commitments to the Global Partnership, MEF member countries will work together with a view to dramatically increase and better coordinate public investment in clean energy innovation, while simultaneously supporting strong enabling environments to encourage private sector R&D. As part of this effort, MEF countries may consider extending any notably successful clean energy innovation investments currently expected to sunset as part of short-term stimulus programs.

Finally, enhanced deployment policy and information sharing efforts—as described below—would also help to promote clean energy innovation. For example, emerging technologies benefit from cost reductions through learning-by-doing and increased economies of scale under strong deployment policies. Countries can further enhance innovation through information sharing, including joint development of technology innovation roadmaps and alliances and networks of research institutes.

Accelerating Deployment

The TAPs indicate that there are common barriers to deploying clean energy technology as well as common policy solutions needed to overcome these obstacles. Within the context of their unique national circumstances, all MEF countries aspire to draw on global best practice policies to remove barriers, establish incentives or a price on externalities, enhance their capacity building, and otherwise accelerate clean energy technology deployment in their own borders as well as internationally. A review of the TAPs suggests some important themes for each country to consider in their efforts.

EXAMPLE ACTIONS TO ACCELERATE DEPLOYMENT FROM THE TAPS

- **Carbon Capture, Use and Storage:** Government should lay the foundations for investment in integrated infrastructure for CO_2 transport and storage networks including identifying and planning potential pipeline networks as necessary.
- **Buildings Sector Energy Efficiency:** Expand international collaboration on minimum energy performance standards for end-use equipment (e.g., Asia Pacific Partnership building and appliance taskforce, IEA implementing agreement on end-use equipment, International Partnership for Energy Efficiency Cooperation, and Collaborative Labeling and Appliance Standards Program).
- **Smart Grids:** Establish a platform to enable cross-country and cross-regional Smart Grids standards development and coordination.
- **Wind Energy and Solar Energy:** Establish ambitious renewable targets and reliable support policies in order to send clear investment signals to the market.

First, transparent predictable and long-term policy commitments by governments facilitate private investment in clean energy. Without a stable enabling environment, investors may hesitate to put capital at risk in long-term clean energy technology and infrastructure projects. The introduction of a carbon price can be a key driver for all low-carbon technology investments. Similarly, mandatory emissions regulations or technology deployment commitments, such as renewable energy targets complemented with adequate support schemes, can give investors the confidence to scale up clean energy solutions, and the latter may be particularly helpful for emerging technologies that are still relatively costly. Stretch performance goals may help to impel further policy reforms and additional private investment to meet anticipated clean energy demand.

Second, collaborative action across the major economies can speed progress, particularly when developed and emerging economies collaborate given the rapid pace of energy infrastructure deployment in many developing countries.

Third, government policy may usefully address barriers specific to each technology category. For example, building-integrated renewable energy will struggle to compete without clear standards for connection to the power grid and appropriate compensation exported to the power grid. Similarly, enabling infrastructure is often essential, such as outlets for plug-in vehicles or grid technologies that enable fluctuating renewable electricity to connect to the power grid without affecting network reliability and security.

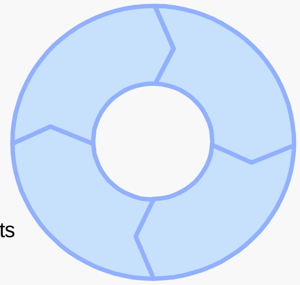
Finally, policies targeting deployment will also encourage innovation and information sharing. In particular, clean energy technologies will become cheaper the more widely they are deployed. Historically, costs for a particular emerging technology have declined approximately 20% each time cumulative production volume has doubled. Moreover, deployment efforts in each country will add to the knowledge base in all countries, particularly with concerted international efforts to increase knowledge sharing. Exhibit 3 describes an example of globally coordinated effort to encourage appliance efficiency, highlighting the resulting innovation and information benefits.

EXHIBIT 3: APPLIANCE EFFICIENCY POLICIES ILLUSTRATE THE BENEFITS OF COORDINATED INTERNATIONAL STANDARDS, LABELING, AND INCENTIVES

Appliance abatement can be accelerated through global coordinated action

Efficiency labeling influences consumer decisions
Broad coordination enhances recognition and improves the impact of marketing

Incentives drive adoption of the most efficient technologies
Coordination across markets drives consistent demand for efficient products



Increase minimum standards to drive improvement
Coordinated standard-setting efforts facilitate manufacturer compliance

Products increasingly exceed standards
Broad, multi-market demand makes efficiency attractive to manufacturers

Refrigerators exemplify the past success and future potential of appliance efficiency	**Compared to 1970,** a typical refrigerator today uses less than 1/3 the energy, is less than half the price has more features	**Today,** commercially available technology could reduce energy use 60%, lowering total cost of ownership and maintaining quality	**Over five years,** a global, accelerated deployment program could reduce product lifetime energy use by well over 1 Gt of CO_2

Facilitating Information Sharing

Proactive information sharing can accelerate both development and deployment of clean energy technologies. To accomplish this, governments can pursue four kinds of information collaboration.

First, governments can **share best practice policies and successful implementation strategies** with each other. This will require active collaboration to adapt successes to the unique circumstances of each country. For example, strategies to promote energy efficiency will vary with the market and regulatory context in each country.

Second, governments can provide **market enabling information** to the private sector. For example, public agencies can provide renewable energy resource maps and tools to identify energy efficiency and renewable energy technology options. They can also enable sharing of best practices in project development, including effective financing strategies.

Third, governments can **provide tools and use their convening power** to enable information sharing within the private sector itself. For example, governments can support professional associations and industry forums for sharing best practices for financing project development.

Fourth, and cutting across all aspects of innovation and deployment, governments can **play an active role in education, workforce development and training** to ensure that firms are able to hire the skilled labor needed to develop and deploy clean energy solutions at scale.

In sum, a major constraint to developing and deploying clean energy technologies is the fragmented nature of information available on what has been done, what is being done, and how effective these efforts have been. Recognizing the role of the private sector in reaching public clean energy goals, routine consultations with industry will help government to succeed in all four of the above activities. A review of the TAPs' findings further suggests that MEF members could productively collaborate to create global information technology solutions to accelerate both innovation and implementation of clean energy technologies. Exhibit 4 illustrates some of the potential functionality of the Clean Energy Gateway tool currently under development for the Global Partnership.

EXHIBIT 4: PROPOSED GLOBAL CLEAN ENERGY GATEWAY TO FACILITATE INFORMATION SHARING

EXAMPLE ACTIONS TO FACILITATE INFORMATION SHARING:

- **High-efficiency, Low-emissions Coal:** Identify and share information on Best Available Technology (BAT) Options and Best Practices (BP).
- **Solar Energy:** Jointly develop a global solar atlas with all relevant information to attract cross border investments (i.e., a comprehensive database on country specific economic, legal and administrative investment conditions combined with a global inventory of the potential of solar energy with a high spatial and temporal resolution to allow appropriate global, regional, and national renewable energy modeling.).
- **Wind Energy:** Establish an international technology platform (ITP) to address limited consultation among policy, investors, and stakeholders and to promote an intensive dialogue between governments and industry.

Next Steps for the Global Partnership

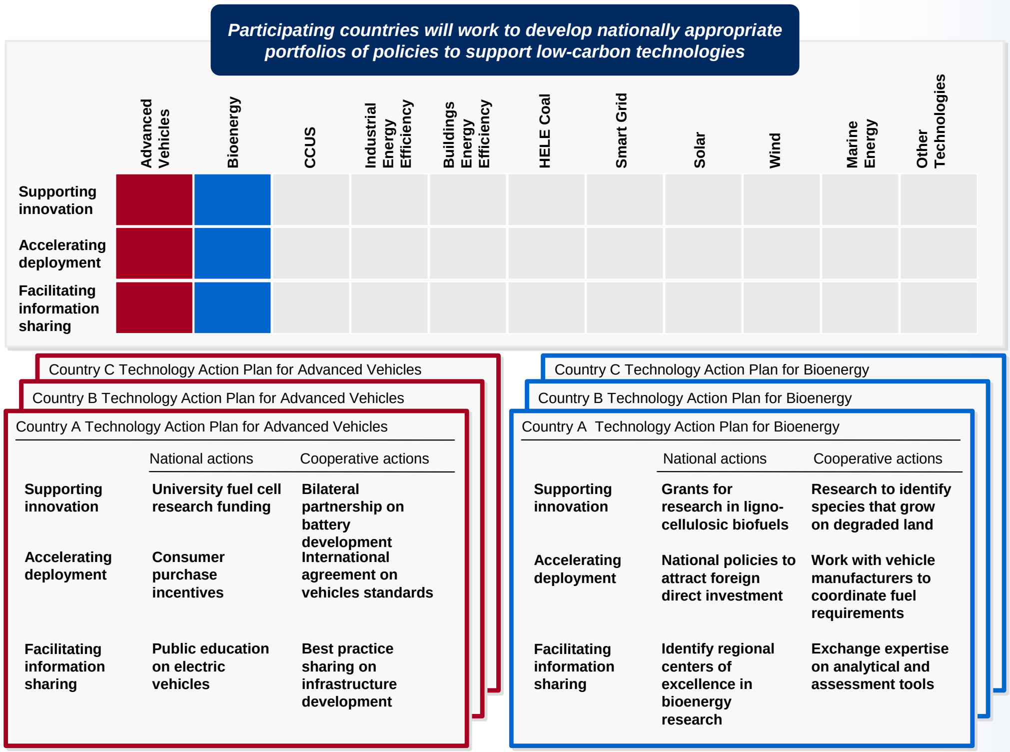
The Global Partnership is expected to catalyze action across all three areas of opportunity discussed previously. The illustrative examples in this executive summary are merely a potential starting point to an active and flexible Global Partnership. These examples also could be expanded well beyond these initial ideas to meet the scale of the climate change challenge and associated clean energy opportunities, taking into account other existing initiatives, institutions and forums to avoid duplication and realize potential synergies.

The Global Partnership holds tremendous potential to accelerate the development and deployment of these transformational technologies. It is anticipated that the MEF partners will consider undertaking a wide range of specific activities at the national level and through various multilateral efforts and forums in support of the menus of actions included in the technology action plans. Additional actions could be included for recognition upon the request of a partner, encouraging continuously enhanced ambition and impact. Countries outside the MEF will also be welcome to join these efforts and implement national or collective actions in support of the Global Partnership.

As an initial step, all MEF countries and other interested countries are urged to review their innovation investment portfolios and enabling policies in light of the gaps identified by the GCERD. Similarly, they should consider the full menu of actions presented in each of the ten TAPs and challenge themselves to develop a full portfolio of nationally appropriate policies to support clean energy technologies. Exhibit 5 shows a hypothetical example for an individual country, including a set of both domestic and collaborative initiatives across all technologies of interest to that country.

To facilitate the Global Partnership's efforts to advance these transformational clean energy technologies, MEF countries and other countries actively participating in the Global Partnership could consider having periodic meetings at which energy and other relevant ministers could review progress, receive updates on the status of individual and collective efforts, explore options for further cooperation and coordination, and provide guidance as appropriate. These meetings might take place in conjunction with other relevant multilateral efforts, or as MEF-focused meetings.

EXHIBIT 5: NATIONALLY APPROPRIATE PORTFOLIOS OF CLEAN ENERGY TECHNOLOGY POLICIES



Technology Action Plan Summaries

The Leaders of the 17 partners of the Major Economies Forum on Energy and Climate (MEF) (Australia, Brazil, Canada, China, the European Union, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, Russia, South Africa, the United Kingdom, and the United States) agreed on 9 July 2009 that moving to a clean energy economy provides an opportunity to promote continued economic growth and sustainable development as part of a vigorous response to the danger posed by climate change. They identified an urgent need for deployment of clean energy technologies at the lowest possible cost, and established the Global Partnership to drive transformational progress.

Action plans were created with actions that may be undertaken voluntarily by interested partners on:

ADVANCED VEHICLES (led by Canada)

BIOENERGY (led by Brazil and Italy)

CARBON CAPTURE, USE, & STORAGE (led by Australia and United Kingdom)

BUILDINGS SECTOR ENERGY EFFICIENCY (led by the United States)

INDUSTRIAL SECTOR ENERGY EFFICIENCY: (led by the United States)

HIGH-EFFICIENCY, LOW-EMISSIONS COAL (led by India and Japan)

MARINE ENERGY (led by France)

SMART GRIDS (led by Italy and Korea)

SOLAR ENERGY (led by Germany and Spain)

WIND ENERGY (led by Germany, Spain and Denmark)

ADVANCED VEHICLES (led by Canada)

Technology description

Advanced vehicles incorporate a number of technologies that reduce the amount of fossil fuel consumed and carbon emitted by road vehicles. Advanced vehicles achieve these goals through improved, more-efficient gasoline and diesel engines and transmissions (including gasoline hybrids), reduced vehicle weight and aerodynamic drag, and substitution of energy from the electric grid, fuel cells, or lower-carbon fuels (e.g., natural gas).

Mitigation potential

Transport sector energy demand accounts for nearly 25% of total global energy-related CO_2 emissions. Transport energy demand and resultant carbon emissions are expected to rise 50% by 2030, and by more than 80% in 2050. This plan focuses on technologies relevant to light duty vehicles (passenger cars and trucks, including two- and three-wheel vehicles), which account of over half of transport energy use. Several recent studies on technology to improve light duty vehicle fuel efficiency assert that, at constant vehicle performance and size, a 30–50% reduction in new light-duty vehicle fuel consumption is feasible.

Barriers & best practice solutions

EXAMPLE BARRIERS	EXAMPLE BEST PRACTICE SOLUTION
High incremental costs of improved technologies (e.g., advanced batteries)	Consumer tax incentives to offset costs
Differing standards and testing protocols internationally	Participation in standards harmonization efforts, such as UNECE Working Party 29
Insufficient manufacturer incentives to implement and market efficient but more costly advanced vehicle technologies	Accelerated efforts to implement increasingly strict fuel economy and GHG standards

Potential actions

Example actions to accelerate the development and deployment of advanced vehicles:

- **Supporting innovation:** Expand research efforts to ensure recycling of materials from transportation technologies with the objective of maximum re-use of valuable or scarce materials and protection of the environment.
- **Accelerating deployment:** Endorse the “50 by 50” Global Fuel Economy Initiative (GFEI) proposed jointly by UNEP, the IEA, the ITF, and the FIA Foundation.
- **Facilitating information sharing:** Enhance international liaison between vehicle and fuels regulators through existing organizations and forums, as well as through bilateral exchanges.

BIOENERGY (led by Brazil and Italy)

Technology description

Bioenergy is chemical energy produced by recent photosynthetic processes and used for heat, power and transport. Today, biomass supplies some 50 exajoules globally, which represents 10% of global annual primary energy consumption. This primarily consists of traditional biomass used for cooking and heating, although use of modern biomass, which relies on efficient technologies for applications, has recently been increasing. Forestry, agricultural, and municipal residues and wastes are the main feedstocks for the generation of electricity and heat from biomass. In addition, a small share of sugar, grain and vegetable oil crops are used as feedstocks for the production of liquid biofuels.

Mitigation potential

If implemented effectively, bioenergy can play a significant role in mitigating climate change. The impact of bioenergy on CO_2 mitigation depends on the feedstock, the agricultural practices and inputs employed, and the conversion technology. Bioethanol made from sugarcane and the production of heat and power from the incineration of biomass or from biogas have some of the highest potential to save energy and avoid CO_2 emissions. The potential for CO_2 reduction is higher in all cases if useful by-products are created (e.g., animal feed, chemicals) and renewable energy from biomass is used to provide process electricity and heat. However, negative land use changes (e.g., cutting of rainforest for new plantations) or burning of the residues (e.g., cane straw) will adversely affect the CO_2 balance.

Barriers & best practice solutions

Example Barriers	Example Best Practice Solution
Limited capacity, skills, and access to advanced technology	Promoting technology partnerships, business alliances, networking, and knowledge sharing
Limited access to financial mechanisms for bioenergy projects	International cooperation to develop mechanisms tailored to local conditions and user needs
Institutional (e.g., no coordination of international market in biofuels)	Participation in the Global Bioenergy Partnership (GBEP) and its Task Forces

Potential actions

Example actions to accelerate the development and deployment of bio-energy:

- **Supporting innovation:** Identify or foster the establishment of international regional centers of excellence in bioenergy R&D and innovation networks that connect researchers and industry along the whole bioenergy value chain.
- **Accelerating deployment:** Identify the principles, conditions, and institutional frameworks that will best facilitate the deployment of technologies for sustainable bioenergy. Establish or enhance frameworks for widespread cooperative action to help shift from traditional to modern bioenergy.
- **Facilitating information sharing:** Facilitate the establishment or identification and strengthening of regional hubs and the sharing of information from developed and developing countries and international initiatives.

CARBON CAPTURE, USE, & STORAGE (led by Australia and United Kingdom)

Technology description

Carbon capture, use, and storage (CCUS), which includes geological sequestration, is a process consisting of separating CO_2 from industrial and energy related sources, transporting that CO_2 to a storage location and then isolating it from the atmosphere for the long term. Various technologies with different degrees of maturity are competing to be the low-cost solution for each stage of the CCUS value chain but each stage of the CCUS process is technically available and has been practiced commercially for many years (although almost exclusively for the oil and gas sector). The Global Carbon Capture and Storage Institute (GCCSI) has recently identified 213 active or planned carbon capture and storage projects globally, of which 101 are at commercial scale.

Mitigation potential

The IEA has estimated climate benefits of CCUS under the ETP BLUE Map scenario (2008). Global deployment of CCUS is projected to capture 10.1 gigatonnes (Gt) in 2050, with 55% of captured CO_2 coming from the power sector, and 45% from industrial and upstream sources. The cumulative storage of CCUS from 2010-2050 is estimated at 145 Gt CO_2.

Barriers & best practice solutions

Example Barriers	Example Best Practice Solution
Absent or insufficient policy and regulatory frameworks, creating uncertainty and risks for CCS project proponents	Legislation establishing clear regulatory frameworks, including clarification of long-term liability
Insufficient skills, knowledge, and motivation to facilitate the deployment of CCS projects	International partnerships and forums that build CCS awareness, understanding, and expertise
Limited experience with scale-up of technologies and integration of CCS components	Public-private partnerships to fund integrated, large-scale demonstrations in developed and developing countries
Suitable storage sites still need to be identified globally	Pre-exploration mapping of prospective storage sites, including cooperative international efforts

Potential actions

Example actions to accelerate the development and deployment of CCUS:

- **Supporting innovation:** Take steps to ensure the fulfillment of the G8 commitment to support the launch of 20 commercial-scale CCS projects by 2010 and recognize that by 2020, many more could be required in both developed and developing countries, which may need assistance from developed countries.
- **Accelerating deployment:** Develop comprehensive legislative and regulatory frameworks that address, among other things, long-term storage and financial liability.
- **Facilitating information sharing:** Develop principles to facilitate knowledge sharing from publicly funded projects.

BUILDINGS SECTOR ENERGY EFFICIENCY (led by the United States)

Technology description

Energy efficiency in buildings often tops the list of carbon mitigation options, largely because of the opportunities that can be achieved at low or negative net cost—saving both energy and money. Moreover, many of the technologies and practices to achieve these reductions are available today. Successful strategies to improve buildings sector energy efficiency target whole buildings, appliances and building products (e.g., windows) and more cross-cutting areas such as capital mobilization to improve existing buildings.

Mitigation potential

In 2004, buildings accounted for 8.6 Gt, or about 25%, of global CO_2 emissions. These numbers are expected to increase in the next decades as appliance and total buildings floor space is increasing quickly in some high-growth countries. However, according to one estimate, available technologies could reduce energy consumption in buildings below the baseline by 41% in 2050, corresponding to 11.5 Gt (or roughly 40%) of total global fossil CO_2 emissions (IEA).

Barriers & best practice solutions

Example Barriers	Example Best Practice Solution
Insufficient or incorrect information	Energy performance labels and certification; energy efficiency targets
Misaligned economics	Financing programs that help accumulate funds for energy efficiency investments
Ingrained behaviors	Voluntary and/or mandatory energy efficiency standards
Insufficient access to capital	Financing programs that use the building as collateral

Potential actions

Example actions to accelerate the development and deployment of buildings energy efficiency:

- **Supporting innovation:** Establish domestic (or international) centers of excellence focused on key efficiency drivers (e.g., lighting, insulation, roofing, windows, HVAC).
- **Accelerating deployment:** Expand international collaboration on minimum energy performance standards for appliances (e.g., APP building and appliance taskforce, IEA implementing agreement on end-use equipment, IPEEC, and CLASP). This work could encourage uniform national and international standards where feasible to encourage manufacturing scale economies.
- **Facilitating information sharing:** Support development of nationally (or internationally) consistent and consumer-friendly certification and labeling of high-performance buildings and appliances (e.g., according to their energy consumption and carbon emissions).

INDUSTRIAL SECTOR ENERGY EFFICIENCY (led by the United States)

Technology description

Improving the energy efficiency of the industrial sector's manufacturing, mining, and construction activities is a key strategy for achieving significant carbon emissions reductions. Energy intensity and efficiency vary significantly across manufacturing sectors and within sectors the current level of energy efficiency can vary quite substantially across different countries, even for relatively mature industries such as iron, steel, and cement. The reasons for these variations include the processes employed, the size and age of individual facilities, the cost of energy, and the policies that affect energy efficiency.

Mitigation potential

The industrial sector consumes over one-third of the world's energy and accounts for 36% of global CO_2 emissions from fossil fuels (IEA 2007 and 2009), excluding an estimated 16–18 EJ of biomass feedstock used by industry. This translates to an estimated 9.9 Gt CO_2 emissions from energy-related sources in 2004 (IPCC 2007), with significant growth expected in the future. The Intergovernmental Panel on Climate Change (IPCC) indicates that global industrial emissions could be cut by 53%, or 4 Gt CO_2 equivalent (Gt CO_2e), by 2030 (IPCC 2007).

Barriers & best practice solutions

EXAMPLE BARRIERS	EXAMPLE BEST PRACTICE SOLUTION
Performance risks and high costs associated with new industrial technology	Financial incentives; loan guarantees or insurance to reduce performance risk
Lack of expertise and inadequate workforce capability	Information exchange among governments, industries; partnerships with colleges and universities on training programs
Limited capital availability	Enabling financial institutions to address local legal, regulatory, and market enabling conditions; enlist the partners needed to market the programs and deliver the technology; and prepare their own staffs for the special technical issues associated with financing energy efficiency projects

Potential actions

Example actions to accelerate the development and deployment of industrial energy efficiency:

- **Supporting innovation:** Fund energy efficiency research that benefits multiple industries (e.g., steam systems, motors design and usage, water, industrial buildings, etc).
- **Accelerating deployment:** Establish industry benchmarks and create consistent methodologies for performance auditing.
- **Facilitating information sharing:** Launch an international industry recognition campaign to offer participating organizations a means to promote their positive actions to their stakeholders, their competitors, and the general public.

HIGH EFFICIENCY, LOW-EMISSIONS COAL (led by India and Japan)

Technology description

Coal is a fossil fuel that will continue to be a vital energy source in the coming decades for the power sector of many countries. At the same time, coal-based power generation is one of the largest sources of CO_2 emissions in the world. High-efficiency, low-emissions (HELE) coal technologies can help reduce the carbon emissions produced by coal-fired power generation while enabling this energy source to continue to meet growing power demand.

Mitigation potential

Current levels of fossil fuel power generation account for over 40% of global energy-related CO_2 emissions (44% for MEF countries). According to the United Nations Framework on Climate Change (UNFCCC), clean fossil fuel power generation has the potential to reduce emissions by 1.6 Gt CO_2e by 2030.

Barriers & best practice solutions

EXAMPLE BARRIERS	EXAMPLE BEST PRACTICE SOLUTION
Insufficient RD&D	Prioritized and accelerated government and private R&D funding
Lack of information on available technologies	Utilization of ongoing initiatives that cooperate on HELE coal technologies to share information on best available technologies (BAT) and best practices (BP)
Inadequate operations and maintenance skills	Development of effective capacity building measures and training programs
Lack of appropriate price, financial, legal, and regulatory frameworks	Establishment of policies incentivizing efficiency; identification of sub-sectoral energy efficiency benchmarks

Potential actions

Example actions to accelerate the development and deployment of high-efficiency lower-emissions coal technologies:

- **Supporting innovation:** Formulate roadmaps for HELE coal technologies including, where appropriate, setting nationally appropriate RD&D goals; enhance RD&D domestic and international efforts for HELE coal technologies through public/private partnerships.
- **Accelerating deployment:** Identify best available technology (BAT) options and best practice (BP) relevant to HELE coal technologies and practices; consider development of a Nationally Appropriate Technology Deployment Roadmap for coal-fired power plants.
- **Facilitating information sharing:** Develop an international initiative for creating "international technology hubs" in key sectors (e.g., power sector) utilizing expertise of existing international forums (e.g., IEA).

MARINE ENERGY (led by France)

Technology description

The world's oceans absorb and produce vast amounts of energy that are virtually untapped by current technology—including offshore wind, tidal streams, wave energy, biomass, thermal conversion, and more. Marine power is a clean, renewable energy source that holds great promise for helping to reduce the greenhouse gases emitted during power generation. Nevertheless, the maturity of marine energy technologies varies greatly. Several technologies—such as offshore wind, tidal turbines, etc.—have reached the deployment or development stage, while others are still in test stands or pilots.

Mitigation potential

The physical annual global marine energy potential is estimated to be many times greater than global energy demand, but remains theoretical due to technical, economic, administrative, and environmental constraints. The part of this physical potential that could indeed be exploited is difficult to evaluate, because of the infancy state of several marine technologies.

Many countries all around the world have an access to the ocean, so that marine technologies could provide a widespread source of renewable energy, exploited on every continent.

Barriers & best practice solutions

EXAMPLE BARRIERS	EXAMPLE BEST PRACTICE SOLUTION
Technology immaturity and costs	Prioritization of government R&D funding
Lack of incentive for investment	Government support for first generation facilities; feed-in tariffs and renewable electricity standards
Complexity of integrating large amounts of marine energy into the electric grid	Upgraded transmission networks using best available cable technologies
Space use and environmental conflicts	Designation of areas for marine energy deployment, and consultation and dialogue with the coastal populations

Potential actions

Example actions to accelerate the development and deployment of marine energy:

- **Supporting innovation:** Provide R&D funding for all marine energy technologies based on strategic research agendas, and identify potential areas for joint cooperation between countries.
- **Accelerating deployment:** Identify maritime zones for large power generation to allow operators to encourage industry to develop technologies; set ambitious concerted targets to provide long-term investment security for marine energy.
- **Facilitating information sharing:** Strengthen cooperation networks of marine energy research centers and further important players; raise public awareness of marine energy technologies using a variety of instruments.

SMART GRIDS (led by Italy and Korea**)**

Technology description

The term “smart grids” has many definitions but in very basic terms represents the move from analog, one-way and manual-based electricity transmission and information sharing to a digital, two-way, more automated process through the use of computer, sensor, and other technologies. The technologies are intended to enable better performance of the electrical grid (e.g., efficiency, equipment utilization, power quality, reliability). Smart grids technologies are expected to enable improved power reliability, safety and security, energy efficiency, environmental impact, and financial performance. They also can improve grid integration for renewable power generation by facilitating load management and storage technologies integration.

Mitigation potential

The electricity network is of central importance to a carbon-constrained energy system. Wide and effective deployment of most advanced energy technologies that reduce CO_2 emissions will be limited without a suitable electrical network. For example, integrating large amounts of wind power into the energy system requires specific preparation of the electricity grid, including sufficient current carrying capacity, power flow control, and, possibly, energy storage capabilities. Additionally, typical smart grid concept features (i.e., smart meters) must be suitably developed and deployed before load leveling and active demand response can be used to conserve energy in buildings. Thus, smart grids are a key enabler for other CO_2-reduction technologies and solutions.

Barriers & best practice solutions

EXAMPLE BARRIERS	EXAMPLE BEST PRACTICE SOLUTION
Market uncertainty related to grid needs, technology development, and regulatory frameworks	Definition of a clear roadmap or strategy for smart grids development, together with supporting legislation
Cyber-security and interoperability concerns	Coordinated standards and protocols development among standards development organizations, alliances, and user group
Perception of unproven performance of new technologies	Demonstration of technology performance and business case through pilot programs

Potential actions

Example actions to accelerate the development and deployment of smart grid technology:

- **Supporting innovation:** Develop a global smart grids technology strategy to work with current research initiatives to integrate and align current development efforts across the globe.
- **Accelerating deployment:** Establish a platform to enable cross-country and cross-regional Smart Grids standards development and coordination.
- **Facilitating information sharing:** Develop and manage a central global repository with past and ongoing smart grids R&D, pilot, and full-scale deployment efforts by different entities.

SOLAR ENERGY (led by Germany and Spain**)**

Technology description

Solar energy is clean, inexhaustible, sustainable and secure. The three main technologies discussed in this action plan are photovoltaic (PV), concentrating solar power (CSP) and solar heating. PV can be applied in roof-top applications that allow consumer self-supply. CSP can support system integration of other renewables because it can deliver dispatchable electricity. Solar heating and cooling is an often underestimated technology that can cover increasing demands for these services. The solar market is very dynamic and multiple novel technologies are emerging.

Mitigation potential

The technical solar potential is estimated at up to 40 times today's total energy consumption. Moreover, solar energy remains largely untapped in most areas. For example, only the three leading PV markets (Germany, Spain and Japan) account for 75% of today's global installed PV capacity. The IEA estimates that, in 2050, *solar electricity* (PV, CSP) could contribute about 16% of total electricity generation while *solar heating* could contribute about 17% of the total heat production. In sum, the IEA estimates solar energy could contribute nearly 4.5 Gt of CO_2 emission reductions in 2050. Several industry estimates are considerably higher.

Barriers & best practice solutions

EXAMPLE BARRIERS	EXAMPLE BEST PRACTICE SOLUTION
Challenge of integrating large shares of solar electricity into the grid	Investments in utility-scale storage technologies; investments in Smart Grid to facilitate two-way electricity flows and renewables integration
Lack of expertise, particularly on installation and advanced operations & maintenance (O&M)	Green jobs programs to train PV installation personnel
Inadequate market pull	Reliable, long-term incentives, e.g., well adapted feed-in tariffs or premium, renewable electricity standards
Investment risks	Attractive loans or loan guarantees to reduce cost of capital for utility-scale generation facilities; tax incentives

Potential actions

Example actions to accelerate the development and deployment of solar energy:

- **Supporting innovation:** Provide, as appropriate, for sufficient test facilities and demonstration projects, particularly to address specific needs of new and emerging technologies.
- **Accelerating deployment:** Set ambitious and stable targets to provide long-term investment security energy without "stop and go" cycles; develop a global CSP plan for large scale demonstration and deployment projects.
- **Facilitating information sharing:** Develop a global solar database including country specific economic, legal and administrative investment conditions and a global inventory of the potential of solar energy with high spatial and temporal resolution.

WIND ENERGY (led by Germany, Spain, and Denmark)

Technology description

Wind energy is clean, inexhaustible, sustainable and secure. Wind energy has already achieved substantial market penetration on land with typical installations using three-bladed turbines with rated powers between 1–3 MW. New concepts under development include 7–10 MW turbines, advanced real-time online monitoring of turbines and remote intervention capabilities or self-diagnostic systems, improvements in wind assessment, energy yield prediction and wind forecasting, improved network-support technology for small wind turbines, and new turbine design concepts (e.g., floating turbines for deep offshore applications).

Mitigation potential

The IEA estimates in its BLUE Map (2008) scenario that wind could contribute 12% of global electricity generation and about 3.3 Gt of CO_2 emission reductions, while some wind industry estimates significantly higher. Five leading markets (United States, Germany, Spain, China and India) account for approximately 75% of the total installed wind capacity of 121 GW in 2008, but very good wind resources remain and are spread all over the world. Onshore wind energy can be competitive today, where the wind resource is good and where the price for carbon is reflected to some extent. The IEA projects onshore wind costs of US$0.05–0.06 per kWh in 2015 and offshore wind to be competitive between 2025 and 2035.

Barriers & best practice solutions

EXAMPLE BARRIERS	EXAMPLE BEST PRACTICE SOLUTION
Challenge of integrating large shares of solar electricity into the grid	Investments in utility-scale storage technologies, investments in wind capture efficiency technology at less windy sites and in new turbine concepts for offshore markets, investments in grid integration technologies and the efficient expansion of transmission capacity
Lack of expertise, particularly on operations and maintenance	Green jobs programs to train necessary personnel
Inadequate market pull	Reliable, long-term incentives, e.g., well adapted feed-in tariffs or premiums, renewable electricity standards
Investment risks	Attractive loans or loan guarantees to reduce cost of capital for utility-scale generation facilities; tax incentives

Potential actions

Example actions to accelerate the development and deployment of solar energy:

- **Supporting innovation:** Follow a combined approach of RD&D and consequent deployment policy benefiting from economies of scale and spillover effects between research and mass-scale testing.
- **Accelerating deployment:** Set ambitious and stable targets to provide long-term investment security without disruptive "stop and go" cycles. Follow a holistic approach in planning activities to integrate renewable energy into the overall system and balance rival interests.
- **Facilitating information sharing:** Support transparent consumer information on the effect that their green power purchase agreements have on the deployment of additional renewables installations.