Experts' Group on R&D
Priority Setting and Evaluation

Summary Report

From Roadmaps to Implementation

2-3 November 2009
International Energy Agency

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The International Energy Agency is the energy forum for 28 advanced economies. IEA member governments are committed to taking joint measures to meet oil supply emergencies. They also have agreed to share energy information, to co-ordinate their energy policies and to co-operate in the development of rational energy programmes that ensure energy security, encourage economic growth and protect the environment. These provisions are embodied in the Agreement on an International Energy Programme, the treaty pursuant to which the Agency was established in 1974.

The IEA carries out a comprehensive programme of energy cooperation among 28 Member countries[1]. The founding objectives of the IEA are to:

- Maintain and improve systems for coping with oil supply disruptions.
- Promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organisations.
- Operate a permanent information system on the international oil market.
- Improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use.
- Promote international collaboration on energy technology.
- Assist in the integration of environmental and energy policies.

Experts' Group on R&D Priority Setting and Evaluation

Research, development and deployment (RD&D) of innovative technologies is crucial to meeting future energy challenges. The capacity of countries to apply sound tools in developing effective national R&D strategies and programmes is becoming increasingly important. The Experts' Group on R&D Priority Setting and Evaluation (EGRD) was established by the IEA Committee on Energy Research and Technology (CERT) to promote development and refinement of analytical approaches to energy technology analysis; R&D priority setting; and assessment of benefits from R&D activities.

Senior experts engaged in national and international R&D efforts collaborate on topical issues through international workshops, information exchange, networking and outreach. Nineteen countries and the European Commission participate in the current programme of work. The results and recommendations support the CERT, feed into analysis of the IEA Secretariat, the G-8 and Major Economies Forum (MEF), and provide a global perspective on national R&D efforts.

For information on further activities of the EGRD, see www.iea.org/about/experts.asp.

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[1] IEA Member countries include Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, Germany, Hungary, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Netherland, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States. The European Commission also participates in the work of the IEA.

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Executive Summary

The 2008 *World Energy Outlook* projects that 97% of the projected increase in CO_2 emissions between today and 2030 will come from non-OECD countries, and three-quarters of that amount from China, India, and the Middle East. Under the IEA CO2-reduction scenarios, technological progress is important, but efficiency gains and deployment of existing low-carbon technologies account for most of the savings.

In the 2030 450 Policy Scenario (CO_2 at 450 parts per million), the power sector undergoes a dramatic change, with renewables, CCS, and nuclear each playing a crucial role. Renewables are expected to account for 40% of global electricity in 2030, with wind alone providing 9%.

Several IEA studies highlight the importance of wind energy and layout strategies for harnessing its potential. Among these are Deploying Renewables, Energy Technology Perspectives 2008, and the Wind Roadmap. Near-term key priorities for wind technology will be developing a better understanding of wind resources and forecasting, system integration, and the technical aspects of deep offshore wind power.

In the light of this declaration, the Experts' Group on R&D Priority Setting intends to accelerate deployment of energy technologies by focusing on best practice with existing roadmaps as well as the steps to roadmap implementation.

Energy technology roadmaps are important tools that enable industry, academic and research groups, civil society and governments identify strategic R&D and investments needed to achieve technology deployment. The current portfolio of IEA roadmaps has the potential to provide almost 90% of the reductions needed to halve global energy-related CO_2 emissions by 2050.

Though roadmaps are essential, they are not self-implementing. Cooperation between the public and private sector on low-carbon energy technologies will be vital to ensuring full implementation in major economies around the world. For example, at the Major Economies Forum (MEF) on Energy and Climate in L'Aquila, Italy, on 9 July 2009, world leaders agreed:

> *Climate change is one of the greatest challenges of our time a response should respect the priority of economic and social development of developing countries. Moving to a low-carbon economy is an opportunity to promote continued economic growth and sustainable development. The need for and deployment of transformational clean energy technologies at lowest possible cost are urgent. We recognize the scientific view that the increase in global average temperature above pre-industrial levels ought not to exceed 2 degrees C. We will take steps nationally and internationally, including under the Convention, to reduce emissions from deforestation and forest degradation and to enhance removals of greenhouse gas emissions by forests, including providing enhanced support to developing countries for such purposes.*

> *We will work together to develop, disseminate, and transfer, as appropriate, technologies that advance adaptation efforts. We are establishing a Global Partnership to drive transformational low-carbon, climate-friendly technologies. We will dramatically increase and coordinate public sector investments in research, development, and demonstration of these technologies, with a view to doubling such investments by 2015.*

This workshop examined the tools that roadmaps provide and explored the necessary steps to achieve implementation. It built upon previous analysis of roadmaps, and approaches and strategies for enhancing international technology collaboration carried out by the Experts' Group. It provided an opportunity for public or private sector R&D managers responsible for shaping strategy and planning, analysts, and modelers with knowledge of programmes, policies and measures to engage in robust discussion and analysis.

The IEA wind roadmap was chosen for in-depth analysis and to explore the remaining issues to be addressed for successful roadmap implementation. Participants reflected on their specific role in this process. Discussions focused on three themes:

Roadmaps: Status and Prospects

> Which roadmaps already exist? Are there gaps in technologies? What are the common problems and challenges? How do roadmaps fit into critical RDD&D strategies, activities and milestones?

Detailed Roadmap Exploration: the Wind Example

> What do roadmaps offer to R&D planners? What methodologies, experiences or approaches are the most effective? What role do roadmaps play in mapping R&D portfolios and capacities? What are the benefits for industrial and finance sectors? Is there a link between roadmaps and cost-reduction? Is there best practice that can be replicated? What lesson can be learned from roadmaps and how can they be incorporated into planning and policy?

Implementation: Issues, Challenges and Next Steps

> What will be required to translate a roadmap into implementation? How can they be incorporated into national strategic technology objectives, barriers, timelines/milestones and critical RDD&D activities? How does this foster international collaboration? What are the roles and responsibilities of stakeholders (government, private sector, others)? How will these roles be carried out? Can roadmaps play a role in establishing a common framework to advance particular technologies? What gaps remain and how can they be addressed?

Expected outcomes include recommendations on identifying opportunities for accelerating technology development and deployment. They are designed to serve as the basis for international efforts such as the Major Economies Forum, the Low-Carbon Technology Platform, the IEA *Energy Technology Perspectives* roadmap initiative, and as a tool for policymaking and implementation for all stakeholders.

Roadmaps: Status and Prospects

As requested by G8 leaders at July 2008 summit, the IEA has undertaken to devise energy roadmaps for selected innovative supply technologies or energy-efficiency technologies for specific sectors. The results of the roadmaps will be included in the 2010 edition of the IEA's technology flagship publication *Energy Technology Perspectives* (ETP). Roadmaps have already been completed for wind energy, CCS for power generation and industry, cement, and plug-in and electric vehicles. To ensure successful implementation of the roadmaps, the IEA will be working to identify industry, government, NGO partners to endorse the roadmaps and to follow progress. The IEA believes that technology roadmaps can support national emissions-reductions goals by identifying and addressing technology-specific barriers, highlighting necessary deployment policies and incentive, directing increased RD&D funding for new technologies, and supporting technology diffusion in all major economies.

The IEA's International Low-Carbon Energy Technology Platform aims to provide a forum where experts, policymakers and business from around the world can discuss how best to design policies to encourage the transition of their countries' energy systems to the most appropriate combination of emerging technologies. It is intended as a means of helping countries design and implement strategic energy technology development and deployment plans, drawing on existing experience, support and tools available such as the roadmaps.

The European Commission (EC) Strategic Energy Technology Plan (SET-Plan) includes eight technology roadmaps (wind, solar, electricity grids, bioenergy, carbon capture and storage, nuclear fission, energy efficiency-smart cities, and the European Energy Research Alliance) are a tool to help policy makers, researchers, and business leaders identify key challenges, recommend actions, determine investment levels needed, set priorities, and propose optimal levels of intervention. They describe the progress that can be made with respect to deployment and performance while specifying the policy and investment actions that must be taken to achieve those goals - including cost considerations.

Detailed Roadmap Exploration: the Wind Example

The **IEA Wind Roadmap** lays out a scenario for the technology's development and deployment levels out to 2050. The roadmap projects exponential growth in wind, and finds that the lower end of today's cost range for onshore wind technology is already competitive with many competing power-generation technologies. Multiple levels of government and industry sectors will need to work in a coordinated fashion to achieve the ambitious targets. International collaboration between developed and developing countries will also be a key part of this effort.

The mission of the **Implementing Agreement for Co-operation in the Research, Development and Deployment of Wind Energy Systems (Wind IA)** is "to stimulate co-operation on wind energy research and development and to provide high quality information and analysis to member governments and commercial sector leaders by addressing technology development and deployment and its benefits, markets, and policy instruments." The Wind IA is fully supportive of the Wind Roadmap as a tool to unify international efforts with respect to wind technology development and deployment.

According to the **Global Wind Energy Council (GWEC)** installed wind energy capacity has increased by nearly 30% annually in the last ten years, and similarly strong growth is expected to continue in the near term. Europe, the United States and China have a strong political commitment at the national level for wind deployment and as a result are the three largest wind energy markets in the world. Since 2000, there have been a number of key developments with respect to wind energy technology. Perhaps most importantly, offshore wind is rapidly moving from demonstration to commercial deployment thanks to technology transfer from offshore oil drilling rigs. GWEC analysis shows that wind energy can compete given an environment with fully functioning electricity markets, internalized external costs, sufficient infrastructure, and strong public support. In the long-term, firm commitment - including RD&D investment - will be necessary from both the public and private sector to overcome remaining technology and market integration challenges.

Launched in 2007, the **European Wind Energy Technology Platform (TPWind)** is a network of 150 members and six working groups who coordinate and work together on energy resources, power systems, integration, offshore development/operation; wind markets and economics, wind policy and the environment. TPWind, the European Wind Association and the EC SET-Plan are part of a broader coordinated effort that produced the SET-Plan wind energy technology roadmap. Completed in 2009, the roadmap's strategic objective is to improve the competitiveness of wind energy technologies, to enable the exploitation of the offshore resources and deep waters potential, and to facilitate grid integration of wind power. Key barriers to expanded wind deployment include grid planning, technical training, and necessary equipment and facilities to expand offshore capabilities. The roadmap concludes that a significant increase in the public share of energy research financing costs should be explored in the short term as a way to help overcome these barriers.

The **Danish government** has formalized a vision of total independence from fossil fuels by 2050. Realising this vision will require doubling renewable energy's share of Denmarks's total energy supply to 30% by 2025. The lead partnership for wind energy is known as Megavind, and includes a number of industrial, research, and government members. Its vision as that Denmark must continue to be a world-leading centre of competence within the field of wind power.

The Danish government has made plans for wind initiatives through 2011. Operation subsidies for new wind turbines will be increased but with a planned cap to balance expenditures. Consultations with municipalities have been held leading to a formal agreement regarding onshore site reservation procedures. Financial compensation for loss in property value due to nearby turbine installations will be made to land owners. Finally, the government will complete an action plan for offshore windfarm siting will prepare a tender for two 200-MWh offshore projects.

Roadmapping Activities in Energy Technologies in Russia: The Russian Federation's Federal Agency for Science and Innovation (FASI) supports practical implementation of state policies related to science, technology, and innovation. The Russian Federation currently forecasts energy technology development out to 2020. Roadmaps play an important role in developing these forecasts, and FASI held a workshop in Moscow in June 2009 to foster closer collaboration with IEA on this process.

Heading Offshore in Germany: Targets, Means, Status: Fraunhofer is a research community in Germany consisting of 60 other institutes, working groups, laboratories, and application centres. Fraunhofer's Institute for Wind Energy and Energy Systems Technology (IWES) is a technical research and testing center specializing in offshore wind components and systems (Bremerhaven branch), as well as grid integration and operation (Kassel branch).

As of September 2009, Germany had wind energy installations with total capacities of 25 GW onshore and roughly 0.1 GW offshore. While offshore wind currently plays a negligible role in Germany's power portfolio, it is viewed is one of the best opportunities for advancement toward national energy independence. To achieve its ambitious offshore wind development targets, the German government has implemented a supportive regulatory framework around its Renewable Energy Law and Infrastructure Planning Acceleration Act. The joint research, development, and testing at Alpha Ventus is an initiative of the Federal Ministry of the Environment. The primary objectives are to very offshore performance capabilities of 5 MW turbines and more generally further the development of offshore wind technology. Alpha Ventus and other wind-related activities undertaken by Germany and IWES are in recognition of the huge potential of offshore wind energy technology.

Facilitating Renewable Energy Technology Deployment in Developing Countries: The Intergovernmental Panel on Climate Change's (IPCC) Special Report on Technology Transfer (SRTT) defines technology transfer as "a broad set of processes covering the flows of know-how, experience and equipment." The SRTT concluded that successful, sustainable technology transfer requires a multi-faceted enabling environment, including favourable macroeconomic conditions, public involvement and acceptance, R&D, institutional capacity, adequate legal frameworks, and the means addressing equity issues.

There is often a funding gap in the development of new technologies that decreases as the technology moves further along its development continuum. The initial R&D stage of development is particularly challenging due to a frequent lack of funding from the private sector and an aversion to risky investments in the private sector. Existing flows to developing countries meet some, but not all, of their technology transfer needs, and in total are exceeded by an annual 300 billion USD in energy subsidies worldwide. The wind market in China provides an example of rapid and effective technology transfer. Total wind power capacity in China has increased from less than 1 000 MW in 2004 to more than 12 000 as of 2008, and continues to grow. During that same period, domestic and Chinese-foreign joint ventures have grown from 25% of manufacturing ownership in the wind power market to more than 75% today.

Accelerating Energy Technologies: The Carbon Trust's mission is to accelerate the move to a low-carbon economy. In September 2009 the Carbon Trust formalized a joint-venture with China's Energy Conservation Investment Corporation, with initial funding of 10 million GBP.

One primary innovation challenge is to reduce costs, and to hasten cost reductions as new technologies move along the development continuum. Beyond general cost reductions, the Carbon Trust believes low-carbon innovation needs progress on four parallel "journeys:" technology, company, market, and regulation.

To complement government R&D efforts, the Carbon Trust launched in October 2008 a collaborative consortium called the Offshore Wind Accelerator (OWA) with the goal of reduce deployment costs by 10%. The OWA has a provisional budget of 60 million GBP to which the Carbon Trust will contribute up to 20 million GBP. Technology accelerators like OWA are capable of opening future markets when they focus on the right market barriers and emphasize cost reductions.

Wind Energy Growth: Technology in Context: New energy technology growth requires a large domestic marketplace, a competitive supply chain, best technologies, intellectual property protection, and open trade policies. Today in the U.S., government energy R&D funding significantly lags most other developing nations. Japan currently spends more than three times as much as the U.S. as a percentage of GDP. Looking out to 2020, Europe is projected to the world's wind leader in terms of job years in the industry. Approximately 75% of the wind industry will be outside the U.S. at that point.

Two separate energy technology areas will play a big role in the proliferation of wind energy: smart grid technology and energy storage. Growth is in jeopardy of being slowed by protectionist leanings and R&D stagnation. Governments should move rapidly to roll back existing barriers and open markets, beginning with a WTO agreement on environmental goods and services.

Strategies for Wind Energy Deployment: We are in the middle of a significant stretch in the wind energy sector, particularly offshore. OEMs and project developers need to collaborate closely to continue driving innovation in wind technology. Continued cost reductions are needed in the areas of condition monitoring, meteorology technology, variable rotor geometry design, and permanent magnets. Oil and gas companies can add real value to the development of renewable energy with deep knowledge in technology and intellectual property.

There are a number of challenges to achieving widespread renewable energy deployment in most areas. Educating the public about costs and benefits will be critical success, as will agreeing who pays for transmission at which points along the grid. It has proven difficult to find the proper balance between protecting intellectual property and accelerating implementation. Many countries are struggling to link climate and energy policies with domestic industrial policies due to "leakage" concerns. Project financing remains an issue, particular in the aftermath of the global financial crises.There is also a need to more fully assess the impacts of specific technologies on water, land, biodiversity, and ecosystems.

Capital Investment for Renewables: Job creation is becoming a key driver to support the expansion of renewable. Wind power is the most commercial and fastest growing form of renewable power generation, and is therefore seen as least dependent on government support. Valuation for wind projects vary by country based on tariffs, local power prices, load factors, and other conditions. Barclays currently estimates a value of 1.4-1.6 million EUR per MW for operational assets, 0.7-0.8 million EUR per MW, and 0.1-0.2 million EUR per MW for assets under development. Building a wind farm can take as little as 18 months, after which operational life can extend to 25 years.

In the Americas, we forecast U.S. installations to reach 6.4 GW in 2009, a 23% demand contraction driven by the difficult financing environment and an extremely high level of activity in 2008. In Asia-Pacific, a compound annual growth rate of 16.5% will be driven by increased energy demand, energy security challenges and an expanding manufacturing base. We believe China will be the largest contributor to growth in the region with new installations growing from 6.3 GW in 2008 to 14.7 GW in 2013. While Chinese manufacturing of wind energy technology is growing rapidly, we do not expect Chinese turbine manufacturers to expand into the European and U.S. markets for several years. Innovative solutions and supportive policies will be necessary to overcome installation and transmission challenges, limited industry experience, project serviceability challenges, and uncertain energy costs.

Producing Synergies between Environmental Innovation and Markets: The market for environmentally-friendly energy technologies is expanding rapidly due to climate change and energy security issues. The wind industry must continue to focus efforts on reducing costs, which can be achieved with targeted R&D and mass production. Cost reductions are the primary objective for Vestas technology R&D, and we're exploring all areas of the development process. Vestas forecasts continued growth, and most industry leaders project future growth above and beyond what is shown in the IEA roadmap.

Implementation: Issues, Challenges and Next Steps

Roadmaps are a promising strategic tool to accelerate low-carbon technology development. There is a broad consensus about the IEA wind roadmap, with the BLUE scenario being one of several possible futures. Creating a great roadmap is just the beginning of what we are setting out to ultimately achieve. Implementation involves a combination of journeys where risks are to be shared and minimized. These journeys run in parallel through technologies, companies, markets, and regulations.

The IEA Experts' Group on Priority Setting and Evaluation, and the IEA convened this workshop to focus on the recently released IEA Technology Roadmaps and proposed ideas for an international low-carbon energy technology platform. This workshop served to confirm that roadmaps are a promising strategic tool to accelerate low-carbon technology development. While the IEA wind roadmap serves as an excellent example of a global roadmap effort, regional and national roadmaps will have to go into more detail, including identifying more specific actions, milestones, and designating task ownership. Gaps also remain in the road-mapping process, particularly with respect to R&D data. There is a need for more detailed information on investment levels in the public and private sector, returns-on-investment for specific technologies, knowledge-sharing, and international collaboration.

ROADMAPS: STATUS AND PROSPECTS

IEA's International Low-Carbon Energy Technology Platform

In response to the pressing need to develop and deploy innovative low-carbon technologies, the IEA laid out a global coordination strategy in its paper, "Toward an International Strategy for Accelerating the Spread of Clean Energy Technology." The paper was first presented to G8 Energy Ministers in May 2009 and, in effect, called for a roadmap for accelerating the implementation of roadmaps. G8 Leaders welcomed the idea and invited the IEA to further define its proposals. In October 2009, the IEA Ministerial Meeting formally requested the Secretariat to take forward the platform proposals.

The platform aims to provide a forum where experts, policymakers and business can discuss how best to design policies to encourage the transition of their countries' energy systems to the most appropriate combination of emerging technologies. It is intended as a tool to help countries design and implement strategic energy technology development and deployment plans appropriate for them, drawing on the experiences and support of others.

The platform will leverage synergies between existing activities (e.g. IEA, MEF, APP work) rather than creating new bureaucracies. In 2010, the IEA plans to gauge stakeholder interest and define the platform's goals and work programme. An expert-level meeting will be held in the second quarter of 2010, followed by a meeting of Director-Generals in the third quarter. Regional workshops will follow soon thereafter. The IEA will be working on the platform with other international organizations and key partners in these preparations.

Possible outcomes include country-level analyses of technologies; sharing of best policy practices to accelerate RD&D; new national roadmaps and technology strategies; capacity-building in developing countries; addressing barriers to technology development, transfer and deployment; matching technology with finance; and the establishment of advisory groups.

IEA Energy Technology Roadmaps and RD&D Mapping

Energy Technology Perspectives 2008 (ETP2008) detailed a number of different aspects of the current state of energy technology. It covered technologies that have potential to reduce emissions between now and 2050 and delineated the potential costs of those reductions as well as the RD&D policies that would be needed to implement them.

In developing Energy Technology Perspectives 2010 (ETP2010), the IEA intends to build on the success of ETP2008. One major undertaking for ETP2010 is the roadmaps for selected innovative technologies, as requested by the leaders at the G8 summit in July 2008. Each of these roadmaps will map pathways for the introduction of new energy technologies through a number of common elements, regardless of the technology. First, the future technology targets to be achieved and a timeline for achieving them will be established. Second, critical cost and performance milestones needed to meet these targets will be determined. Third, non-technical barriers (e.g., regulatory, financial, public acceptance) to development of the technology will be identified. Fourth, roles and responsibilities for various stakeholders, including potential international co-operation will be identified. And finally, near-term action items and evaluation criteria for assessing progress will be given.

Roadmaps have already been completed and released for the following technologies: CCS for power generation and industry, wind energy, cement, and plug-in and electric vehicles. The next wave of roadmap publications in 2010 will include solar photovoltaic, nuclear power, concentrating solar power, efficient heating and cooling, smart grids, biofuels, and efficient internal-combustion-engine vehicles.

To ensure successful implementation of the roadmaps, IEA will be working to identify industry, government, NGO partners to endorse roadmaps and help track progress. Partners will include the Major Economies Forum (MEF), collaborators in IEA's international technology platform, private sector stakeholders, and other key international organisations. A formal process for reporting on implementation progress will be established with partner consultation, and considering the needs and interests of developing countries. National-level roadmaps will also be developed for targeted countries.

IEA is also working closely with the MEF to map RD&D spending across eight technology areas for MEF members. With this process, RD&D priorities are being defined using IEA data, including the roadmaps, and other sources for non-IEA countries. The primary objective is to identify the "gap" between current levels of activity and BLUE Map 2050 technology targets.

A number of challenges exist for RD&D mapping. In some new such as smart grids, IEA data is deficient or not comparable across different countries. Private sector data is often unavailable, but critical to understand RD&D for some technology areas. It is also sometimes difficult to adequately incorporate new stimulus funding or accurately capture the impacts of unique national policies to foster technology innovation. MEF will publish a report on 15 November with results and recommended next steps. Meanwhile, IEA continues to seek opportunities to improve data quality and transparency, including possibly through cooperation with EGRD.

In conclusion, IEA believes that technology roadmaps can support national GHG goals by identifying and addressing technology-specific barriers; highlighting necessary deployment policies and incentives; directing increased RD&D funding for new technologies; and supporting technology diffusion in all major economies.

Costs of Implementation: SET-Plan Portfolio of Technology Roadmaps

EU energy policy is driven primarily by three objectives: reduce greenhouse gas emissions; ensure a secure energy supply, and promote economic competitiveness. The EC's Strategic Energy Technology Plan (SET-Plan) is a set of technology roadmaps that serves as the technology pillar of these policies. It is designed to help spur a reinvention of the EU's energy system with an eye toward 2050. The initial technologies selected for

2010-2020 roadmaps are wind, solar, sustainable bioenergy, smart grid, carbon capture & storage, sustainable fission, and smart-cities.

The SET-Plan brings together stakeholders from industry groups, research institutes, and cross-sector energy networks to identify the necessary increases in financial and human resources to meet EU energy policy objectives. The EU sees the next ten years as a critical period for investment in energy technologies given a carbon-constrained future. The technology roadmaps are a tool to help policy makers, researchers, and business leaders identify key challenges; recommend actions; determine investment levels needed; set priorities; and propose optimal levels of intervention.

The roadmaps are designed not only to inform stakeholders of a technology's potential, but also to mobilize targeted stakeholder actions. Each technology roadmap lays out what progress can be made with respect to deployment and performance, and then specifies what policy and investment actions – and at what cost – must be taken to achieve those goals.

In aggregate, the roadmaps call for additional investment of 50 billion euros (includes public and private funds) over the next ten years. The most effective investment strategy will involve public-private partnerships. The public domain must offer reasonable incentives and stable policy signals, while the private sector must fully leverage windows of opportunity as they open.

DETAILED ROADMAP EXPLORATION: THE WIND EXAMPLE

IEA Wind Roadmap as a Representative Example

The IEA Wind Roadmap lays out a scenario for the technology's development and deployment levels out to 2050. The roadmap focuses on large wind installations and growth in offshore capacity, and reflects ongoing industry efforts, as well as EU and national-level roadmaps.

The roadmap projects exponential growth in wind, and finds that the lower end of today's cost range for onshore wind technology is already competitive with many competing power-generation technologies. However, offshore costs are considerably further from being competitive. Future deployment levels will be determined by technical constraints with respect to not only wind turbines themselves, but also system integration, power transmission and energy storage technologies. To overcome these hurdles, the roadmap recommends supportive policies such as long-term targets, feed-in tariffs, tax credits, other financial incentives, and factoring in external costs such as pollution and evaluating competing technologies.

The roadmap evaluates wind as just one of a portfolio of energy sources that will all be necessary to realize targeted CO_2 reductions. Multiple levels of government and industry sectors will need to work in a coordinated fashion to achieve the ambitious targets. International collaboration between developed and developing countries will also be a key part of this effort.

Perspectives from IEA's Wind Energy Systems Implementing Agreement

The mission of IEA's Wind Implementation Agreement (Wind IA) is "to stimulate co-operation on wind energy research and development and to provide high quality information and analysis to member governments and commercial sector leaders by addressing technology development and deployment and its benefits, markets, and policy instruments." The Wind IA member countries make up 75% of global wind capacity, and include representatives from Europe, North America, and Asia/Pacific. Russia was recently invited to join and India has begun pre-membership discussions.

The Wind IA's strategic plan is, by design, well aligned with the Wind Roadmap. It's priorities for 2009-2013 are as follows:

Wind technology research to improve performance and reliability at competitive costs

Power system operation and grid integration of high amounts of wind generation including development of fully controllable, grid-friendly wind power plants

Planning and performance assessment methods for large wind integration

Offshore wind in shallow and deep waters

Social, educational, and environmental issues

National programs with information exchange and joint R&D are also an important part of IEA Wind's strategy. Focus areas include the planning and execution of large-scale wind energy deployment; policy incentives and regulatory mechanisms; grid integration; and lessons learned from national technology research projects. Country and Task reports are provided at biannual meetings of the Wind IA's Executive Committee, which is composed of 20 member countries, the European Commission, and the European Wind Energy Association. Topical expert meetings on wind sub-topics are held regularly throughout the year. The Wind IA's Annual Report provides a summary of key meetings and activities, and final reports are produced at the completion of each Task.

Wind IA oversees nine ongoing Tasks in all. Four Tasks have been launched recently to address key issues under the Wind IA. Task 26 brings together economists and engineers to more closely examine the underlying costs of wind power. Task 27 is focused on establishing a new labelling system for small wind systems. Task 28 is led by social scientists, planners, and project developers to investigate the influencing factors of social acceptance of wind energy projects. Finally, Task 29 is conducting an analysis of wind tunnel measurements to improve aerodynamic models.

The Wind IA is fully supportive of the Wind Roadmap as a tool to unify international efforts with respect to wind technology development and deployment. The Wind IA Executive Committee plans to discuss its specific role in roadmap implementation and further alignment of a synergistic long-term strategy. As a first step, the Wind IA recommends that IEA develop a "report card" for the roadmap to track annual progress toward specified targets.

Global View of Wind Technology RD&D: Status and Plans for Adoption

The rate of growth in wind energy over the past decade has been enormous (~ 30% annually), and similarly strong growth is expected to continue in the near term. Market projections may even prove conservative due to rapidly decreasing costs and stronger-than-expected growth in China and the U.S.

Europe, the U.S., and China are the three main markets for wind, each with a strong political commitment at the national level. China is now positioned as the largest national manufacturing industry for wind energy technology, and will soon be the number one wind market overall. European markets continue to broaden, and a new boom in offshore installments is just getting underway. Latin America, Africa, and the Pacific continue to hold potential as markets 'on the verge of take-off.'

The Global Wind Energy Council (GWEC) has built a set of three scenarios to drive future projections about growth and development in the wind energy industry. These 'Reference,' 'Moderate,' and 'Advanced' scenarios range from conservative to ambitious, and differ based on underlying energy and climate policy assumptions. Industry responses modeled under these scenarios are used to project capacity and production levels, investment and employment decisions, and development costs.

Since 2000, there have been a number of key developments with respect to wind energy technology. After 25 years of growth in turbine sizes, blade lengths are leveling off. Turbines are now being built to meet increasing requirements for reactive power, voltage, and frequency. A wide variety of turbine configurations have been introduced, and there is now an increased emphasis on the aerodynamic performance of turbine blades. Perhaps most importantly, offshore wind is quickly moving from demonstration to commercial deployment. These areas will continue to evolve during the next decade, with particularly rapid changes with respect to grid development and offshore technology.

However, despite ongoing progress, offshore wind will continue to present a number of challenges in the near future. The early stage of commercial technology has resulted in many technology variations that, in some cases, cannot be widely deployed. Unpredictable weather and regulatory delays diminish confidence in costs assessments. Transport, assembly, and installation issues continue to persist. Operation and maintenance costs are often higher than anticipated. Cost-effective transmission and grid integration continue to prove difficult. These challenges will need to be overcome if offshore wind is play a prominent role in electricity sector.

It has been observed that wind turbines are on par with large passenger aircraft in terms of dimensions, but very different in other aspects. In terms of cost, wind turbines must deliver “helicopter quality at farm tractor prices.” In other words, the prices for high quality turbines must be extremely low to make them cost-effective in today’s market. For example, the allowable price per kilogram for a large wind turbine is about 15 euros, compared with more than 1 000 euros per kilogram for an aircraft wine.

The GWEC believes wind can be competitive today in an environment with fully functioning electricity markets, internalized external costs, sufficient infrastructure, and strong public support. In the long term, firm RD&D investments will be necessary to from both the public and private sector. Public funding is critical for large and risky investments, reserving short-term applied investments primarily for the private sector. A minimum RD&D effort of 3% of annual investments is needed to sustain innovation. Assuming 2% comes from the private sector, and 1% from public funds, this translates to approximately 1 billion USD annually from the public sector – about ten times current levels.

European Wind Energy Technology Roadmap

The European Wind Energy Technology Platform (TPWind) was launched in 2007 as Europe’s official wind technology platform. The initiative consists of 150 organizational members and six working groups talked the following focus areas: wind energy resources; wind power systems; wind energy integration; offshore development & operation; wind market & economics; and wind policy & environment.

The European Wind Initiative (EWI) is a parallel effort focused on large turbines and larger wind energy systems. Its three objectives are:

To make wind energy the most competitive energy source on the market onshore in 2020, and offshore in 2030;

To enable the required large-scale deployment and grid integration of wind energy offshore and onshore with the aim of reaching wind penetration levels of 20% in 2020, 33% in 2030 and 50% in 2050; and

Ensuring the European technology leadership on- and offshore, and developing large offshore wind turbines.

TPWind, EWI, and the EC's SET-Plan are all part of a broader coordinated effort that helped produce a wind energy technology roadmap. Completed in 2009, the roadmap's strategic objective is to improve the competitiveness of wind energy technologies, to enable the exploitation of the offshore resources and deep waters potential, and to facilitate grid integration of wind power. Specifically within the industry sector, the roadmap aims to enable a 20% share of wind energy in final EU electricity consumption by 2020.

The wind technology roadmap covers four main sections. The first section is new turbines and components, which lays out specific targets and necessary actions for lowering investment, operation, and maintenance costs. The second section is offshore technology, which provides targets and actions specific to large-scale turbines and deep waters. Third is grid integration, which examines innovative techniques for penetration of variable electricity supply and windfarm management. The last section outlines key objectives and actions related resource assessment and spatial planning to support wind energy deployment.

The wind roadmap has helped identify key barriers to expanded wind deployment such as grid planning, technical training, and necessary equipment and facilities to expand offshore capabilities. The roadmap concludes that a significant rise in the public share of energy research financing costs should be explored in the short term as a way to help overcome these barriers. Under the roadmap's financing impact assessment, four policy options ranging from conservative to ambitious are compared, with specific programmes identified as possible resources to fill funding gaps.

Strategic Research Agenda and Roadmaps in Denmark: The Wind Example

The wind industry employs more than 28 000 people in Denmark and had revenues of 11 billion globally in 2008. The industry includes large turbine manufacturers such as Vestas and Siemens, as well as a number of suppliers serving Danish and non-Danish clients. The broader energy technology industry constituted approximately 10% of Danish exports in 2008.

The Danish government has formalized a vision of total independence from fossil fuels by 2050 at the latest. Realizing this vision will require a doubling renewable energy's share of Denmarks's total energy supply to 30% by 2025. This shift would be coupled with annualized savings in energy consumption of 1.25%. Specific technology targets have not been set, but constructive competition between energy technologies is being sparked by a diverse set of public funding mechanisms for academic institutions and private-sector firms.

The wide array of public funding programmes makes them at times difficult to coordinate, but this challenge is offset by the advantages provided by diversity. The government has recently taken a more "arms-length" approach to awarding R&D funding. Independent boards are now charged with the responsibility of funding decisions, working with a government-established framework. Funding strategies are formulated by industry-led public-private partnerships.

The lead partnership for wind energy is known as Megavind, and includes a number of industrial, research, and government members. Its vision as that Denmark must continue to be a world-leading centre of competence within the field of wind power. The partnership's primary ambition is for Denmark to provide wind power plants that ensure the best possible integration of wind power in large energy systems.

Megavind has established priorities for validation, testing, and demonstration in the areas of components, wind turbines, and energy system integration. Feeding into these priorities are five research objectives:
More efficient and reliable machines
Efficient utilization of wind
Optimal placement of wind turbines
Maximizing the utilization of wind power in energy systems
Advancement in offshore technology

Denmark has laid out next steps for its government wind initiatives through 2011. It will increase operation subsidies for new wind turbines, but with a planned cap to balance expenditures. A formal agreement will be reached with municipalities on onshore site reservation procedures. A financial mechanism will be finalized to compensate land owners for losses in property value due to nearby turbine installations. Finally, the government will complete an action plan for offshore windfarm siting will prepare a tender for two 200-MWh offshore projects.

Roadmapping Activities in Energy Technologies in Russia

The Russian Federation's Federal Agency for Science and Innovation (FASI) supports practical implementation of state policies related to science, technology, and innovation. This includes R&D programmes, roadmapping, and financing activities. FASI serves as the coordinator and contact point for governmental and international organizations collaborating with the Russian Federation on science and technology issues.

The Russian Federation currently forecasts energy technology development out to 2020. Roadmaps play an important role in developing these forecasts, and FASI held a workshop in Moscow in June 2009 to foster closer collaboration with IEA on this process. The workshop covered Russia's energy technology priorities, roadmapping methodologies, technology- and sector-specific approaches, and a case-study platform for energy efficiency in buildings. Several additional workshops are scheduled during the remainder of 2009 to more deeply explore specific related topics such as energy efficiency, biofuels, hydrogen storage, and cleaner coal technologies.

Heading Offshore in Germany: Targets, Means, Status

Fraunhofer is a research community in Germany consisting of 60 other institutes, working groups, laboratories, and application centres. These organisations combined represent approximately 17 000 staff and an annual budget of 1.5 billion euros. Fraunhofer's Institute for Wind Energy and Energy Systems Technology (IWES) is a technical research and testing center specializing in offshore wind components and systems (Bremerhaven branch), as well as grid integration and operation (Kassel branch).

As of September 2009, Germany had wind energy installations with total capacities of 25 GW onshore and roughly 0.1 GW offshore. Wind met approximately 8% of Germany's 40 TWh of electricity demand in 2008. While offshore wind currently plays a negligible role in Germany's power portfolio, it is viewed is one of the best opportunities for advancement toward national energy independence.

To achieve its ambitious offshore wind development targets, the German government has implemented a supportive regulatory framework around its Renewable Energy Law and Infrastructure Planning Acceleration Act. Key regulations include a 13 cent€/kWh feed-in tariff with an "early-bird" bonus and more generous terms for deeper and further-out offshore installations. Licensing procedures have been sped up and the government will also cover cost of offshore cable connections in some cases. This framework is complemented to government-funded research activities such as offshore research platforms; restructuring key port facilities to be "offshore-ready;" and enacting a maritime planning ordinance.

The continental shelf of the North Sea offers Germany's most attractive sites for offshore wind farms. The most suitable areas with respect to wind are otherwise limited by dense usage for other activities such as shipping, oil and gas rigs, military installations, and pipelines. These locations also present a technical challenge in that they are far from shore and in deep, rough waters. Such conditions are found at IWES's offshore test field, Alpha Ventus, located in the North Sea70 km from the nearest onshore connection and in waters 30 metres deep. The joint research, development, and testing at Alpha Ventus is an initiative of the Federal Ministry of the Environment. The primary objectives are to very offshore performance capabilities of 5 MW turbines and more generally further the development of offshore wind technology.

Alpha Ventus and other wind-related activities undertaken by Germany and IWES are in recognition of the huge potential of offshore wind energy technology. However, there are many challenges that must first be overcome, and which will require extensive international collaboration.

Facilitating Renewable Energy Technology Deployment in Developing Countries

The Intergovernmental Panel on Climate Change's (IPCC) Special Report on Technology Transfer (SRTT) defines technology transfer as "a broad set of processes covering the flows of know-how, experience and equipment." According to IPCC, the concept encompasses diffusion of technologies and technology cooperation across and within countries. It also includes the processes of learning to understand, utilize and replicate the technology, and the capacity to choose it and adapt it to local conditions.

The SRTT concluded that successful, sustainable technology transfer requires a multi-faceted enabling environment, including favourable macroeconomic conditions, public involvement and acceptance, R&D, institutional capacity, adequate legal frameworks, and the means addressing equity issues. Different technologies require different levels of strength in these areas. Some low-cost technologies are more likely to face police or acceptance barriers, while high-cost alternatives may require particularly robust R&D contributions.

There is often a funding gap in the development of new technologies that decreases as the technology moves further along its development continuum. The initial R&D stage of development is particularly challenging due to a frequent lack of funding from the private sector and an aversion to risky investments in the private sector. It is often not until the demonstration phase of technology development that public and private sector funding levels converge to fill the investment gap. Role of government can evolve to fill early-stage funding gaps by focusing on policies that create demand and public funding, put a price on carbon, or overcome market barriers through regulation.
Funding needs for technology transfer in developing countries are significant. Existing flows meet some, but not all, of these needs, and in total are exceeded by an annual 300 billion USD in energy subsidies worldwide. The funding emphasis to date has been on ensuring access to finance, but more is required. In particular, there is a need to create and balance the demand for and supply of financing. This can best done by first building capacities and mobilizing early investments, and then moving to full-scale investment. It is critical to not separate capacity-building from investment mobilization during this process.

The wind market in China provides an example of rapid and effective technology transfer. Total wind power capacity in China has increased from less than 1 000 MW in 2004 to more than 12 000 as of 2008, and continues to grow. During that same period, domestic and Chinese-foreign joint ventures have grown from 25% of manufacturing ownership in the wind power market to more than 75% today. This transformation of the industry was enabled by firm commitments and concrete actions by key stakeholder groups, including the private sector, the Chinese government, and foreign governments.

Accelerating Energy Technologies

The Carbon Trust's mission is to accelerate the move to a low-carbon economy. This mission is supported by providing business and the public support in the way of expert advice, finance, accreditation, funding, and knowledge-sharing. The Carbon Trust plays a key role in supporting innovative technologies by screening proposals, incubating early-stage companies, investing in new ventures, collaborating with technology partners, and publishing related reports.

In September 2009 the Carbon Trust formalized a joint-venture with China's Energy Conservation Investment Corporation, with initial funding of 10 million GBP. The project aims to make its first set of investments to support company incubation by June 2010.

One primary innovation challenge is to reduce costs, and to hasten cost reductions as new technologies move along the development continuum. Low-carbon technologies are no exception to this rule, as not only the technologies themselves are new, but also the markets and regulatory frameworks in which they operate. Beyond general cost reductions, the Carbon Trust believes low-carbon innovation needs progress on four parallel "journeys:" technology, company, market, and regulation.

The Carbon Trust's experience in the United Kingdom suggests a significant challenge to meet its EU renewable energy targets for 2020. Approximately 29 GW of offshore wind power will be necessary based on a reasonable set of assumptions, and on- and offshore wind are likely to make up more than 70% of UK renewable generation. Given this massive scale-up, we estimate that the UK could reduce the total cost of deploying offshore wind by 14 billion GBP by increasing public R&D by just 600 million GBP. R&D investments in this range will be necessary to overcome the market barriers to offshore wind deployment.

To complement government R&D efforts, the Carbon Trust launched in October 2008 a collaborative consortium called the Offshore Wind Accelerator (OWA) with the goal of reduce deployment costs by 10%. The OWA has a provisional budget of 60 million GBP to which the Carbon Trust will contribute up to 20 million GBP. The OWA is focusing on four RD&D workstreams: offshore foundation, wake effects, electrical systems, and operational & management access. First phase of OWA's work was to set up a funding delivery structure, which is now led by an independent steering committee and the Carbon Trust management team. The second phase is conduction demonstration feasibility studies, and was begun in 2009. OWA's collaborative structure allows intellectual property sharing across the work programme and benefits the entire industry.

Technology accelerators like OWA are capable of opening future markets when they focus on the right market barriers and emphasize cost reductions. Close collaboration with industry partners is important for sharing knowledge and investment cost burdens. Direct research accelerators can also help overcome technical barriers to specific technologies. The Carbon Trust is currently leading direct research accelerators in the areas of advanced photovoltaics, algae biofuels, and pyrolysis oil.

Wind Energy Growth: Technology in Context

New energy technology growth requires a large domestic marketplace, a competitive supply chain, best technologies, intellectual property protection, and open trade policies. The promise of large markets creates the technology leadership necessary to overcome early-stage market barriers.

Many examples of such growth can be throughout the history of energy technology development. Today's global nuclear industry was born from U.S. government R&D, launched in the 1940s and expanded worldwide beginning in the 1970s. Heavy-duty gas turbines are a by-product of U.S. government defense spending, and today generate 20% of all U.S. electrical power. Europe's strong wind industry became so largely because of supportive and consistent policies throughout the E.U.

Today in the U.S., government energy R&D funding significantly lags most other developing nations. Japan currently spends more than three times as much as the U.S. as a percentage of GDP. U.S. wind installations are expected to drop in 2010 after several years of rapid growth. Proposed renewable energy standard targets will require no new renewable once energy efficiency gains are accounted for. In Europe, GE has participated actively in TP Wind, and supports the EWEA Wind Technology Roadmap. As the roadmap lays out, strong EU government support for both turbine technology and related infrastructure is crucial to achieving its long-term vision. Looking out to 2020, Europe is projected to the world's wind leader in terms of job years in the industry. Approximately 75% of the wind industry will be outside the U.S. at that point.
Two separate energy technology areas will play a big role in the proliferation of wind energy. The first is smart grid technology, which will facilitate implementation with more reliable distribution systems. The second is energy storage, which will mitigate

intermittency challenges normally associated with wind. GE is leading R&D initiatives in both fields.

Further growth in wind energy technologies is in jeopardy of being slowed by protectionist leanings and R&D stagnation. Governments should move rapidly to roll back existing barriers and open markets, beginning with a WTO agreement on environmental goods and services. Innovation will need to be promoted more actively to lower costs drive competition. More financing programmes will need to be rolled out, ideally within the UNFCC framework.

Strategies for Wind Energy Deployment

BP Alternative Energy (BPAE) leads BP's global efforts on biofuels, wind, solar, and CCS. BPAE takes a project approach to energy technology roadmaps, the first step of which is to develop a view of market deployment. Next, we review the history of learning rates and technology development, and then examine future technology developments and potential market. We combine future developments into learning rates to complete the first cycle of an iterative loop between roadmaps and implementation.

We are in the middle of a significant stretch in the wind energy sector, particularly offshore. OEMs and project developers need to collaborate closely to continue driving innovation in wind technology. Continued cost reductions are needed in the areas of condition monitoring, meteorology technology, variable rotor geometry design, and permanent magnets. In addition, large-scale energy storage will be critical for load balancing.

Oil and gas companies can add real value to the development of renewable energy with deep knowledge in technology and intellectual property. BP and other companies in its industry have extensive experience with project development and cost management for large-scale and complex offshore projects. They also have a demonstrated ability to manage and diversify risks, navigate complex regulatory hurdles, and operate safely in a hostile offshore environment.

BP has learned many valuable lessons from its experience on the frontline. Every project is different, and learning rates can vary significantly (high capital requirements lead to slow learning rates). It is also important to consider innovation in other technologies that may impact your target technology. Supply chain buy-in is essential to turn roadmaps into reality, and constructive engagement from regulators can accelerate a project's pace.
Lastly, it is important to have quality R&D metrics, and to understand interactions with other primary energy sources.

There are a number of challenges to achieving widespread renewable energy deployment in most areas. Educating the public about costs and benefits will be critical success, as will agreeing who pays for transmission at which points along the grid. It has proven difficult to find the proper balance between protecting intellectual property and accelerating implementation. Many countries are struggling to link climate and energy policies with domestic industrial policies due to "leakage" concerns. Project financing remains an issue, particular in the aftermath of the global financial crises.There is also a need to more fully assess the impacts of specific technologies on water, land, biodiversity, and ecosystems.

Capital Investment for Renewables

Barclays Renewables and Wind Farm Investment Group is active in project financing for individual projects, lending to renewable firms, providing access to capital markets, facilitating equity stakes in renewable markets, and providing investment advisory services.

Job creation is becoming a key driver to support the expansion of renewable. Wind power is the most commercial and fastest growing form of renewable power generation, and is therefore seen as least dependent on government support. Solar PV demand remains primarily underpinned by government incentives in a few countries that are aimed at generating economies of scale. Barclays continues to believe that cost reductions will be the most critical driver for the solar industry. Concentrated solar technologies offer a competitive, utility-scale option with the advantage of storage capabilities, and will continue to attract investment in the coming years.

Wind farm operators face a complex set of investment, operational, and financial considerations when exploring and managing projects. These factors are further complicated by fluctuations in the market-wide costs for more conventional sources of energy. Valuation for wind projects also vary by country based on tariffs, local power prices, load factors, and other conditions. Barclays currently estimates a value of 1.4-1.6 million EUR per MW for operational assets, 0.7-0.8 million EUR per MW, and 0.1-0.2 million EUR per MW for assets under development. Building a wind farm can take as little as 18 months, after which operational life can extend to 25 years.

With regard to wind project financing, increased due diligence from lending institutions has lengthened the financing approval process. Activity levels in the second and third quarters of 2009 suggest that wind as an asset class is remaining an attractive destination for capital. However, wind projects remain a less liquid asset which lacks a secondary market for the normalized flow of capital.

Barclays has developed a wind demand forecast for 2009-2013. In the Americas, we forecast U.S. installations to reach 6.4 GW in 2009, a 23% demand contraction driven by the difficult financing environment and an extremely high level of activity in 2008. In Asia-Pacific, a compound annual growth rate of 16.5% will be driven by increased energy demand, energy security challenges and an expanding manufacturing base. We believe China will be the largest contributor to growth in the region with new installations growing from 6.3 GW in 2008 to 14.7 GW in 2013. In Europe, the Middle East, and Africa, we forecast wind installations to remain stable in 2009 driven by the relative resilience of Germany, Italy and France, and growth in the UK, Denmark, Turkey, Poland and Greece.

In looking at the 2008 turbine manufacturers' market, industry leader Vestas' market share declined as new entrants gained through the supply of smaller, lower technology turbines. We believe the rate of growth and attractive financial returns should restrict price competition with the focus more likely to be on the cost of energy, turbine size, reliability and warranty returns. The emergence of new entrants from China does not present a near-term threat, in our view, given existing turbine manufacturers' lead in product quality, turbine availability and global scale.

While Chinese manufacturing of wind energy technology is growing rapidly, we do not expect Chinese turbine manufacturers to expand into the European and U.S. markets for several years. Given the unproven track record and reported quality issues, we believe wind farm developers and financial institutions in mature markets are unlikely to partner with Chinese turbine manufacturers in the near term. In addition, the lower price per MW often quoted is not comparable to European peers with more advanced standards.

Various approaches with respect to size and configuration are being taken in the still risky onshore wind market, with the largest turbines generating 4.5 MW. Offshore markets are less mature and therefore present even greater risks. Innovative solutions and supportive policies will be necessary to overcome installation and transmission challenges, limited industry experience, project serviceability challenges, and uncertain energy costs.

Producing Synergies between Environmental Innovation and Markets

The market for environmentally-friendly energy technologies is expanding rapidly due to climate change and energy security issues. Stability and early coordination is key for developing new technologies into mature, competitive sources of energy. Government policies need to be coordinated and stable even as governments change. Denmark is one example where this was achieved, and is an important reason why it is succeeding with wind energy.

The wind industry must continue to focus efforts on reducing costs, which can be achieved with targeted R&D and mass production. Cost reductions are the primary objective for Vestas technology R&D, and we're exploring all areas of the development process. Vestas also believes it is important to maintain a global outlook while pursuing a local presence with clean technologies. This entails exploring all global markets and developing a presence, including local manufacturing, in those with significant potential. International cooperation, with a government focus on education and grid modernization and integration, will also enable substantial gains for wind energy in the future.

Global wind energy capacity has risen dramatically over the past 15 years. Vestas forecasts continued growth, and most industry leaders project future growth above and beyond what is shown in the IEA roadmap.

IMPLEMENTATION: ISSUES, CHALLENGES AND NEXT STEPS

Session wrap-up and summary

Roadmaps are a promising strategic tool to accelerate low-carbon technology development. The development and implementation process for roadmaps is as important as the result, and there will eventually be an iterative loop between roadmaps and implementation.

There is a broad consensus about the IEA wind roadmap, with the BLUE scenario being one of several possible futures. More abstract global roadmaps must lead to more specific regional roadmaps taking into account local circumstances and costs. This will require finding the proper balance between top-down priorities and bottom-up processes led by industry. International collaboration and gaining public acceptance will also be important in fine-tuning roadmaps for smaller markets.

Creating a great roadmap is just the beginning of what we are setting out to ultimately achieve. The real test will be implementation, which is by no means a trivial task. Financing will be a huge part of making implementation a success, and the keys will be to both wise the money and, just as importantly, to spend it wisely. Roadmaps cannot be implemented without the industry and institutional capacities to do so. Capacities go beyond financing, and include quality assurance, applying lessons from more mature industries, and adopting technologies for local needs.

Implementation involves a combination of journeys where risks are to be shared and minimized. These journeys run in parallel through technologies, companies, markets, and regulations. They are each led by different stakeholder groups, but must be coordinated to work in harmony toward the same objective. Smart R&D and finance metrics will also be critical for measuring implementation effectiveness, not just expenditures.

Workshop Conclusion

The IEA Experts' Group on Priority Setting and Evaluation, and the IEA convened this workshop to focus on the recently released IEA Technology Roadmaps and proposed ideas for an international low-carbon energy technology platform. We wanted to identify opportunities to accelerate technology development and deployment. The workshop built upon the Group's previous workshops on roadmapping, and approaches and strategies for enhancing International technology collaboration. The results and recommendations will support CERT, and IEA analysis in support of the G-8, MEF and Framework Convention. Insights gained during this workshop also feed into the work of other IEA Implementing Agreements.

This workshop served to confirm that roadmaps are a promising strategic tool to accelerate low-carbon technology development. The group identified several keys for a successful roadmap development and implementation. First it is necessary to communicate challenges, targets, actions, and milestones. Second, there must be coordination of view points from diverse stakeholders. Third, cooperation across private and public sector is absolutely essential. Fourth, a consensus should be reached, but robust roadmaps are flexible, living documents that will evolve along with the consensus. Finally, there must be a commitment to take action rather than just talk about what needs to happen.

In reflecting on the workshop, it is clear that the IEA wind roadmap serves as an excellent example of a global roadmap effort. However, regional and national roadmaps will have to go into more detail, including identifying more specific actions, milestones, and designating task ownership. Public support will be essential for a successful roadmap implementation, so it will be important to emphasize the benefits and not just the costs of doing so.

Gaps remain in the roadmapping process, particularly with respect to R&D data. There is a need for more detailed information on investment levels in the public and private sector, returns-on-investment for specific technologies, knowledge-sharing, and international collaboration. A toolbox for combing roadmaps and translating them to the regional and national level would accelerate implementation efforts. More work is also needed to integrate emerging economies and other organisations into the roadmapping process.

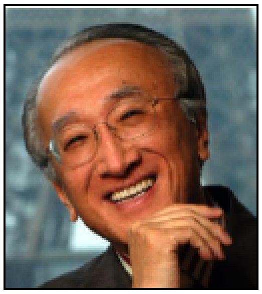
Appendix A - Agenda

9:00		**Opening Remarks**	*Nobuo Tanaka, Executive Director International Energy Agency*
		I. ROADMAPS: STATUS AND PROSPECTS	
		Session Chair: Rob Kool, SenterNovem	
9:15	**1**	**IEA International Low-carbon Energy Technology Platform**	*Ambassador Jones, Deputy Executive Director International Energy Agency*
9:45	**2**	**IEA Energy Technology Roadmaps and**	*Peter Taylor, Head, Energy Technology Policy International Energy Agency*
10:15	**3**	**Costs of Implementation: SET-Plan Portfolio of Technology Roadmaps**	*Estathios Peteves, Head of Unit, DG JRC European Commission*
10:45		Break	
		II. DETAILED ROADMAP EXPLORATION: THE WIND EXAMPLE	
		Session Chair: Paolo Frankl, International Energy Agency	
11:00	**4**	**IEA Wind Roadmap as a Representative Example**	*Hugo Chandler, Analyst, Renewable Energies and Technologies Division, IEA*
11:30	**5**	**Perspective from Wind Energy Systems Implementing Agreement**	*Hugo Chandler, Analyst, Renewable Energies and Technologies Division, IEA*
12:00	**6**	**Global View of Wind Technology RD&D: Status and Plans for**	*Steve Sawyer, Secretary General Global Wind Energy Council*
12:30	**7**	**Wind Technology RD&D and Roadmap Implementation**	*Filippo Gagliardi, TPWind Project Manager European Wind Energy Association*
13:00		Lunch	
		Experiences with Wind Roadmaps	
		Session Chair: Birte Holst Jorgensen, Riso National Laboratory for Sustainable Energy	
14:15	**8**	**Strategic Research Agenda and Roadmaps in Denmark: the Wind**	*Mr. Per Dannemand Andersen and Lykke Margot Ricard, Technical University of Denmark*
14:45	**9**	**Roadmapping activities in energy technologies in Russia**	*Ms. Ludmila Orletskaya, International Programmes & Projects Director, Federal Agency for Science and Innovation of the Russian*
15:15	**10**	**Heading Offshore in Germany: Targets, Means, Status**	*Michael Durstewitz, R&D Coordination Alpha Ventus*
15:45		Break	
16:15	**11**	**Facilitating Renewable Energy Technology Deployment in**	*Mark Radka, Chief, Energy Branch United Nations Environmental Program*
16:45	**12**	**Issues Raised Day 1**	*Session Chair*
17:30		Close day 1	

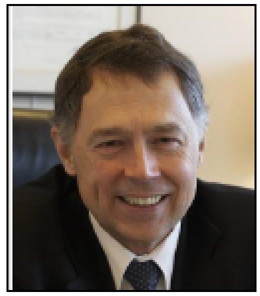
Experiences with Wind Roadmaps, cont'd			
9:00	**12**	**Accelerating Energy Technologies**	*Cath Bremner, Head of Corporate Development Carbon Trust*
9:30	**13**	**Technology Roadmaps for Wind**	*Andreas Lippert, Manager Alternative Energy Technologies, GE Global*
10:00	**14**	**Strategies for Wind Energy Deployment**	*Atul Arya, Head, Policy and Long-term Strategy, BP Alternative Energy*
10:30		Break	
10:45	**15**	**Capital Investment for Renewables**	*Rupesh Madlani, Head Global Renewables Equity Research, Barclays*
11:15	**16**	**Producing Synergies between Environmental Innovation and Markets**	*Lise Backer, Project Manager R&D Vestas Global Research*
11:45	**17**	**Session wrap-up and summary**	*Session Chair*
12:30		Lunch	
I.		**IMPLEMENTATION: ISSUES, CHALLENGES AND NEXT STEPS**	
Moderator: Roberto Vigotti, Chair, Renewable Energy Working Party			
14:00	**18**	**Reflection, Discussion and Next Steps**	*Robert Marlay, Director , Climate Change Policy and Technology, Department of Energy*
14:30	**19**	**Open Discussion**	*Moderator: Paolo Frankl, Head, Renewable Energies and Technology Division, International Energy Agency* *Questions may include:* *What will be required to translate a roadmap into implementation? How can they be incorporated into national strategic technology objectives, barriers, timelines/milestones and critical RDD&D activities? How does this foster international collaboration? What are the roles and responsibilities of stakeholders (government, private*
16:30	**20**	**Session wrap-up and summary**	*Moderator*
17:00	**21**	**Workshop Conclusion**	*Rob Kool, Manager, International Sustainable Development, Senternovem*
17:30		Close	

Appendix B - Speakers

IEA Committee on Energy Research and Technology
EXPERTS' GROUP ON R&D PRIORITY SETTING AND EVALUATION



Nobuo Tanaka, Executive Director of the IEA, has over 35 years of strategic energy policy and energy security experience. Mr. Tanaka also has extensive national government and international experience within the Japanese Ministry of Economy, Trade and Industry (METI), the Embassy of Japan in Washington D.C. and the OECD, where his most recent post was as Director of the Directorate for Science and Technology and Industry. While at METI, Mr. Tanaka served in a number of high-ranking positions, including as Director-General, Multilateral Trade System Department, Trade Policy Bureau, where he led many trade negotiations for the World Trade Organisation. Mr. Tanaka holds a degree in Economics from the University of Tokyo and an MBA from Case Western Reserve University, Cleveland, Ohio.



Ambassador Richard Jones, Deputy Executive Director of the IEA, brings over thirty years of diplomatic and policy experience with high-level issues such as Middle East politics, trade negotiations and energy security. He served as the American Ambassador to four countries: Israel, Kuwait, Kazakhstan, and Lebanon and has acted as the U.S. Secretary of State's Senior Advisor and Co-ordinator for Iraq Policy from February-August, 2005. During his diplomatic career Ambassador Jones was instrumental in facilitating negotiations on oil security issues in areas of political or financial sensitivity. Ambassador Jones also is well-versed in the work of international organisations, most notably as Economic Policy Advisor at the U.S. Mission to the OECD. Ambassador Jones holds a BA in mathematics from Harvey Mudd College and an MS and PhD in Business/Statistics from the University of Wisconsin.

Rob Kool, Chair of the IEA Experts' Group on R&D Priority Setting and Evaluation, is Manager of the Energy and Climate Cooperation Europe for SenterNovem, the Dutch agency on Innovation and Sustainability. Rob has over 30 years of experience with a broad range of topics in the energy field such as municipal energy policy, design of new efficient suburbs, district heating, build environment, JI, CDM and leading international co-operation projects. Rob is active and holds leadership roles in many international fora, including the association of European Energy Agencies EnR, vice-president of European Council for Energy Efficiency, and vice-chair for the Demand Side Management Implementing Agreement. Rob holds a business degree from the Netherlands Business School and a doctorate in biology from the University of Utrecht.

Peter Taylor, Head of the Energy Technology Policy Division at the IEA, leads the analytical activities concerning energy technologies. Prior to working at the IEA, Peter was Technical Director of Future Energy Solutions (a business of AEA Technology plc), a major UK energy and environmental consultancy. At FES he was part of the senior management team and had responsibility for maintaining and enhancing the technical expertise of the business. Previously Peter spent 15 years working in both research and consultancy on a range of national and international energy and climate change policy issues. Peter holds a BSc in Applied Physics from the University of Nottingham, and both an MSc in Environmental Technology and PhD in Energy Economics from Imperial College, London.

Stathis Peteves is Head of the Energy Systems Evaluation Unit in the Institute for Energy of the European Commission's Joint Research Centre. Mr. Peteves has over 20 years of experience at the EC addressing issues all broad range of energy technology, modelling and policy issues. The key activities of his Unit include techno-economic assessments of energy technologies, energy technologies/systems modelling and impact analyses. His current focus is the energy technology pillar of EU's energy & climate change policy, the Strategic Energy Technologies Plan (SET-Plan) and specifically the Information System (SETIS), the scientific and technical support tool to the decision making of the SET-Plan governance. Stathis holds degrees from the National Technical University of Athens, George Washington University and the University of Florida. He has authored more than 100 publications.

Paolo Frankl, Head of the Renewable Energy Division at the IEA, oversees renewable energy policy and market analysis for the Agency and serves as Secretary to the CERT Working Party on Renewable Energy Technologies. From 2000 to 2002 Paolo served as Advisor to the Director-General of the Italian Ministry for the Environment. Previous positions held were in academia and in private Italian consultancy firms researching renewable energy, life cycle assessment and eco-labeling. A physicist by training, Paolo holds a Ph.D in energy and environmental technologies from the University of Rome.

Hugo Chandler, energy analyst in the Renewable Energy Division of the IEA, is the lead author for the IEA wind roadmap. Hugo provides expertise in the field of wind energy and is the project leader for the Grid Integration of Variable Renewables. Previously Hugo carried out policy research for the European Wind Energy Association, where he led the establishment of the European Technology Platform for Wind Energy. Previously, Hugo worked at the Wales Centre for Alternative Technology, in the House of Commons in London, and at the Parliamentary Assembly of the Organisation for Security and Co-operation in Europe. Hugo holds an MSc from Imperial College, London, in environmental technology and energy policy.

Steve Sawyer joined the Global Wind Energy Council as its first Secretary General in April 2007. The Global Wind Energy Council represents the major companies in the wind industry and the major wind energy associations in China, India, Japan, Australia, Canada, USA, Europe, Germany, Spain and Italy). Steve has worked in the energy/environment field since 1978, focussing on climate change and renewable energy. He spent many years with Greenpeace International, is a founding member of the REN21 Renewable Energy Policy Network, an expert reviewer for the IPCC's Working Group III and was an advisor to China on the formulation of its renewable energy support law.

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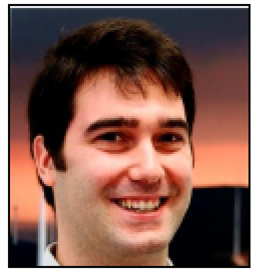
Filippo Gagliardi, Project Manager at the EWEA, is in charge of the European Wind Energy Technology Platform (TPWind) Secretariat, supported by the European Commission through the FP6 Windsec project. Prior to that, Filippo held several posts as project manager for several organisations dealing with EU programmes and funds. Filippo holds a degree in Business Administration.



Birte Holst Jørgensen has returned to her research at Risø DTU after four years as Director of Nordic Energy Research. She is an acknowledged expert and reviewer at the EU Commission and several Nordic research councils and research funding institutions. Birte was a Senior Scientist at Risø DTU where she specialised in science, technology and innovation policies, in particular in new energy technologies. Previous work experiences also included positions in private and public consultancy companies as well as a 3-year assignment at the Technical University of Ecuador. Birte holds a M.Sc. in Business Economics from Copenhagen Business School and a Ph.D. in Political Science from the University of Copenhagen.

Lykke Margot Ricard is PhD scholar in Innovation Systems and Foresight at Department of Management Engineering, Technical University of Denmark (DTU). Lykke Margot has previously worked as a special advisor in Science, Climate and Energy to the DTU Public Sector Consultancy and was part of the project management and development team of the Climate Change Technologies Programme. Lykke Margot is currently working on the European RDD&D Strategies in Energy Technologies project, including case studies in the European Technology Platforms in Wind and CCS. She specializes in the field of technology foresight, strategy processes and R&D prioritizing focusing on the entire value chain in energy technologies. She has a M.Sc. in Business Economics and Philosophy from Copenhagen Business School and has studied at the School of Management at Erasmus University of Rotterdam.

Michael Durstewitz is a research scientist at Fraunhofer Institute for Wind Energy and Energy System Technology (Fraunhofer IWES). Michael has over 20 years experience in wind energy research focusing on measurement and monitoring programmes, grid integration, reliability analysis, technical and economical studies, turbine operation in harsh environments and teaching. Presently Michael is responsible for Germany's offshore joint research initiative "RAVE" for the coordination of research activities in Germany's first offshore wind farm alpha ventus, and as a task leader, in the project "RAVE – grid integration of offshore wind farms". Michael olds degrees in electrical engineering with a focus on control engineering and power engineering.

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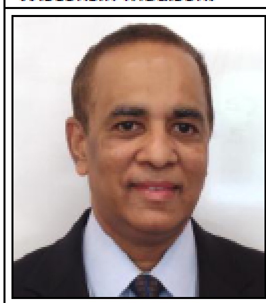
Mark Radka heads the UN Environment Programme's Energy Branch, where he is responsible for managing the Programme's efforts to link the global energy and environment agendas. This includes reducing GHG emissions through renewables and energy efficiency, with a special focus on promoting private sector engagement in the sustainable energy sector. Mark has a special interest in the technology needs of developing countries, and was a coordinating lead author of the IPCC's Special Report on Methodological and Technological Issues in Technology Transfer. Mark holds a Masters of Public Policy in Environmental Policy from Harvard University, where he was a Kennedy Fellow. He also received a M.S. degree in Environmental Engineering from the University of California at Berkeley, and a S.B. in Civil Engineering from the Massachusetts Institute of Technology.

Catherine Bremner is Head of International Development at the Carbon Trust where she is responsible for building a portfolio of strategic international engagements with key world economies and multilateral organisations to accelerate the move to a low carbon global economy. Previously Catherine provided energy efficiency advice to UK business and public sector organisations and led a programme that doubled implementation rates of energy efficiency measures. For McKinsey & Company and then for Ecos Corporation, a sustainability consultancy, Catherine provided advice to a broad range of multinational industrial companies. Catherine has a 1st Class Honours Degree in Chemical Engineering and an MSc in Environmental Management from Oxford University.

Andreas Lippert is currently Manager, Alternative Energy Technologies, in GE's Global Research Center (Germany). Prior to his joining GE, Andreas was the Director for Global Energy Systems at General Motors R&D and Strategic Planning (United States), where he led the strategic analysis and outlook on global energy developments and energy supply chains, and co-authored GM's foundational outlook on energy diversity for transportation. Previously, Andreas held Group Manager positions for Diesel Engine Systems and Thermofluid Simulations. In addition to having authored more than 25 research papers, conference publications and reports, Andreas holds several patents. Andreas holds a BA and MA from the University of Pretoria, South Africa and a PhD in mechanical engineering from the University of Wisconsin-Madison.



Atul Arya is the Chief Advisor for Energy and Climate Policy for BP where he is responsible for analysing the impact of energy and climate policies on BP's long range participation choices and for developing BP's strategic and policy response. Atul has held various commercial, technical, planning and strategy leadership roles in BP's the Exploration & Production business, BP Solar and the Corporate Headquarters. He spent early part of his career as an oil industry consultant. Atul is a member of the World Economic Forum's Global Agenda Council on Climate Change and is on the advisory boards of the National Council for Atmospheric Research (USA) and the University of Kent (UK) and has previously served on the boards of Tata BP Solar, Green Mountain Energy Company and the US Solar Energy Industry Association. Atul holds a PhD in Engineering from the University of Texas at Austin.

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Rupesh Madlani is a senior analyst at Barclays Capital where he leads the Renewables team within the Equity Research branch. Prior to that, Rupesh was part of the equity research team for the European Renewables division covering wind, solar and energy efficiency companies for Lehman Brothers. Previously Rupesh worked in the corporate finance practice at PricewaterhouseCoopers. Rupesh graduated with a degree in Economics from the London School of Economics and is a chartered accountant. He is a member of the International Institute of Strategic Studies and is a Freeman of the City of London.

Lise Backer is project manager at Vestas Technology R&D where she is responsible for R&D relations with external stakeholders. Lise also serves as chairman of the Danish Wind Power Association's R&D committee. Previously, Lise held several positions within the Ministry of Energy in the area of climate change negotiations in the UN. Lise holds a M.Sc. in renewables engineering and a PhD in renewable energy business development Copenhagen Business School.

Roberto Vigotti, Chair of the IEA Renewable Energy Working Party, is Senior Advisor for Renewable Energies and the Mediterranean Solar Plan for the Mediterranean Energy Observatory, an association of leading energy companies in the Mediterranean region. Roberto has more than 30 years of strategic, advisory and business development roles in the energy sector at Enel. He was also involved in the field of ultra high voltage transmission and coordination of research and demonstration programs in the field of new renewable energies for the Research and Development Division of the Italian National Power Board. Roberto holds an M.Sc. in Electrical Engineering from the University of Pisa.

Robert Marlay is the Director of the Office of Climate Change Policy and Technology in the Office of Policy and International Affairs at the U.S. Department of Energy. He has more than 30 years experience in the areas of national security, energy policy, science policy, and management of research and development programs. Earlier, Bob served as Director of the DOE's Office of Science and Technology Policy. He has also held leadership positions in the Offices of Science, Energy Efficiency and Renewable Energy, and in the Federal Energy Administration. Bob holds a B.S.E. from Duke University, as well as two Masters degrees and a Ph.D. from the Massachusetts Institute of Technology.

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