
ENERGY TECHNOLOGY ROADMAPS

Status report



INTERNATIONAL ENERGY AGENCY



Introduction

Current trends in energy supply and use are clearly unsustainable – economically, environmentally and socially. Without decisive action, energy-related CO₂ emissions will more than double by 2050 and increased oil demand will heighten concerns over the security of supplies. We can and must change the path that we are now on, but this will take an energy revolution and low-carbon energy technologies will be at its heart. In June 2008, the International Energy Agency (IEA) published its *Energy Technology Perspectives (ETP)* study, which evaluated scenarios and strategies to achieve a halving of CO₂ emissions from current levels by 2050. The ETP identified those technologies that could play the most important role in achieving this outcome and presented the outlines of roadmaps for these technologies. The IEA is now working with governments and industry in all major economies to further develop and implement these roadmaps to bring about the global energy technology revolution that is needed to achieve a more secure and sustainable energy future.

The G8 request on roadmaps

In response to the pressing need to accelerate the development of advanced energy technologies, at the Japan G8 Summit, Ministers from G8 countries, China, India and South Korea requested the IEA to prepare energy technology roadmaps:

“We will establish an international initiative with the support of the IEA to develop roadmaps for innovative technologies and cooperate upon existing and new partnerships, including carbon capture and storage (CCS) and advanced energy technologies. Reaffirming our Heiligendamm commitment to urgently develop, deploy and foster clean energy technologies, we recognize and encourage a wide range of policy instruments such as transparent regulatory frameworks, economic and fiscal incentives, and public/private partnerships to foster private sector investments in new technologies...”

The IEA response

The IEA has begun to implement this request, designing a multi-year effort to develop a series of roadmaps for a portfolio of promising, low-carbon technologies. The figure below identifies the priority technology areas.





Current Status

■ Supply side

- CCS power generation
- Coal – IGCC
- Coal – USCSC
- Nuclear III + IV
- Solar – Photovoltaic
- Solar – Concentrating Solar Power
- Wind
- Biomass – IGCC & co-combustion
- Advanced electricity networks
- Second-generation biofuels

■ Demand side

- Energy efficiency in buildings
- Energy efficient motor systems
- Efficient Internal Combustion Engines
- Heat pumps
- Plug-ins and electric vehicles
- Fuel cell vehicles
- CCS in Industry
- Solar heating
- Efficient industry processes (starting with Cement)

Work has already begun on technologies shown in green, and these roadmaps will be launched later in 2009.

The roadmaps will be designed to advance global development and uptake of the low-carbon technologies needed to achieve a 50% reduction in CO₂ emissions by 2050. For each roadmap, the IEA is convening a group of experts from government, industry and other organisations to identify the current technology baseline and current context. The groups will map the necessary expansion of the different technologies from today to 2050, providing key performance, regulatory, public acceptance and financing milestones for each step. The roadmaps will include a list of action-oriented recommendations for all relevant stakeholders, to answer their questions about the next steps that will be needed for implementation. In addition, the roadmaps will not simply be static documents; instead, they will provide an ongoing international forum where the IEA works with its partners to monitor and update the progress of roadmap implementation.

A critical focus for the roadmaps will be the emerging economies, where much of the new energy technology investment will take place. The IEA will host roundtables in key countries and regions with large anticipated market shares for particular technologies to better understand their current market and policy contexts, and to engage stakeholders. This information will then inform the roadmaps and will form an important basis for enhanced technology collaboration with these important countries. To aid in this task, the IEA is seeking strategic partnerships with multilateral and bilateral organisations with a special focus on capacity building, technology diffusion and outreach. Recent outreach activities undertaken by the IEA include: co-sponsoring with the Russian Federal Agency for Science and Innovation (FASI) a workshop on “Energy Technology Roadmaps as an Instrument for Developing Long-term Foresights and Advancement of Energy Technologies”, and discussions with the Chinese National Energy Administration and its Energy Research Institute, and the Indian Ministry of Power to cooperate on developing national technology roadmaps.

Progress to date

The IEA has initiated roadmaps for the following technologies:

- CCS for power generation and industry
- Solar photovoltaic
- Wind energy
- Plug-in and electric vehicles
- Efficient industry processes (starting with cement)
- Nuclear power (in conjunction with the Nuclear Energy Agency)

Work to date has included hosting technology and policy expert stakeholder meetings, conducting analysis and research to develop technology expansion scenarios, and developing technical, policy and financing milestones from 2010-50. Some preliminary findings emerging from the roadmaps include:

CCS for power generation and industry

- Governments are making significant new funding commitments to large-scale CCS demonstration projects; the critical next step will be to ensure further funding and to develop suitable policy frameworks and public consultation mechanisms for these early projects.
- CCS retrofits at coal-fired power plants and CO₂ capture in the industrial sector (*e.g.*, cement, chemicals, iron and steel, pulp and paper, refining) are critical research and demonstration needs that have not received sufficient attention to date.
- Some emerging economies, notably China and Brazil, have impressive plans to move forward with CCS pilot projects, but require policy support and enhanced international cooperation to ensure optimal project design and effective implementation.
- There is a need to expand international efforts to harmonise CO₂ storage monitoring and verification schemes with international greenhouse gas policy mechanisms, either through the Clean Development Mechanism or another mechanism under the United Nations Framework Convention on Climate Change.

Solar photovoltaic

- Photovoltaic (PV) power has the potential to be a significant and affordable contributor to global electricity generation in the future. The PV industry has the capability to sustain a double-digit annual growth for the next several decades. As a consequence, the total world PV capacity deployed by 2050 could be much higher than previously projected.
- Strong growth for PV in major emerging economies is expected, driven by increased demand for electricity. Distributed generation from PV can play a major role both in buildings in urban areas as well as in rural areas that currently lack access to electricity.
- Today, PV has achieved grid parity in areas where electricity prices are high and solar irradiation is very good, but remains more costly than grid-supplied electricity in most regions. Due to technology improvements and economies of scale, PV is expected to reach grid parity in at least 10% of the world by 2020; this may grow up to 80% by 2030, depending on concurrent developments in the energy mix.

- Transitional policy measures are needed to support accelerated PV development and market uptake. Support schemes should be long-term, predictable, and declining at an acceptable rate in order to foster innovation and the deployment of most cost-efficient PV technologies.
- Increased research and development efforts toward continued cost reductions are an important priority.

Wind energy

- Wind power has the potential to be a major, affordable contributor to global electricity generation portfolios with 5.200 TWh or 12% of global power production in 2050 according to the ETP BLUE scenario. Other scenarios suggest up to 7.200 TWh in 2050.
- Incremental technology improvements will drive cost reduction in the near term, but governments need to significantly increase R&D funding up to 2050 to advance technology with the potential to reduce cost of energy more significantly.
- Regional level planning of electricity networks development, and collaboration among system operators, are essential, both to gather up dispersed wind resources and to smoothen the aggregated electricity output from those resources.
- High penetrations of wind energy require power systems to be flexible – able to effectively manage the variable nature of wind output. Regulatory frameworks should be designed in such a way that flexibility is increased cost-effectively.
- Regulations to support wind deployment must ensure effective price support for producers; access to the grid; and simple and transparent permitting procedures.

Plug-in and electric vehicles

- Electric vehicles (EVs) and plug-in hybrid vehicles (PHEVs) are nearing wide-spread market introduction by major vehicle manufacturers around OECD countries and in some parts of the developing world (especially China).
- Key technologies (*e.g.*, batteries, motors) are technically proven but need to be optimised through production-scale learning.
- There is a need for a common regional and global roadmap for the introduction and scale up of EVs and PHEVs due to the complex nature of market development. This includes coordinating vehicle introduction dates and production targets, battery production targets, recharging infrastructure planning and creating a policy and market environment that provides consumers with sufficient incentives to purchase vehicles.
- Common standards and regulatory systems are also needed to allow EVs and PHEVs to enter the market and be scaled up at a sufficient pace to meet targets around the world.

Cement sector

- Cement is a key construction material used worldwide. Reducing cement demand or introducing substitution materials do not appear to be viable options in most applications.
- Lower-emitting technology options that exist today—including best available technologies (BAT), alternative fuels and clinker substitutes – are insufficient to meet cement sector GHG reduction goals, due to expected increasing demand. Therefore, new technology advances will be needed,

primarily CO₂ capture and storage and new cement types. In the very long term new CO₂ free production processes are needed.

- Deep emission cuts in the cement sector will be costly and capital-intensive. The majority of the savings are expected to cost USD 50 – 100/t CO₂, but options of up to USD 200 will also be needed.
- Policies should address economic implications as cement as cost is forecast to become twice as expensive during the timeframe of the roadmap. This poses both a challenge and an opportunity which could accelerate innovation in the industry.

Nuclear power

- More ambitious nuclear energy deployment does not require significant technological breakthroughs; however, human and industrial capacity investments are required.
- Policy support and public acceptance are the main requirements for the growth of nuclear power; addressing long-term nuclear waste stewardship and addressing the risks of nuclear weapon proliferation are essential elements for enhancing public support.
- A clear and stable definition of the role of nuclear power in national energy policy is a prerequisite for investors to make funding decisions and to maintain competitiveness.

These findings are preliminary; first review drafts of the roadmaps are currently under development. The roadmaps will be published as stand-alone documents in time for the IEA Ministerial in October 2009.¹

Next steps

The IEA will publish the initial set of roadmaps on its webpage as they become available and promote them through various international fora, including the United Nations Framework Convention on Climate Change meetings in Bangkok and Copenhagen in 2009 and as input to the 2010 G8 meetings in Canada. The Major Economies Forum and other multilateral climate/energy efforts have also asked for more detailed, expanded energy technology roadmaps. Additionally, the roadmaps will form a chapter in the IEA's *Energy Technology Perspectives* publication in 2010.

The initial set of roadmaps is a start; there is a need to begin analysis and roadmap efforts for the other technologies included in the figure. Additional roadmaps that are currently under consideration for development in 2009 include:

- Concentrating solar power
- Advanced electricity networks (including energy storage)
- Second-generation biofuels
- Efficient internal combustion engines
- Energy efficiency in buildings

Work on these roadmaps, as well as the other technology roadmaps identified in the ETP study, will continue as funding becomes available. More information on the Terms of Reference for roadmap design and selection is included in the Annex.

¹ The nuclear energy roadmap will be published separately at the end of 2009.

Annex – Building the Foundation – IEA Roadmap Terms of Reference

Page | 8

The initial phase of the roadmaps process focused on developing terms of reference to be used by the IEA and stakeholders during roadmap development. These terms of reference addressed: (1) developing an IEA working definition for “technology roadmap”; (2) defining the scope and boundaries to be used for each roadmap; and (3) creating selection criteria by which to choose the technologies to be further developed. The IEA developed the following terms of reference for guiding the design and development of its technology roadmaps.

Definition

The term “technology roadmap” has multiple meanings to various audiences and establishing a common working definition of a technology roadmap was critical to our effort. In 2008, the IEA held a workshop with experts to improve our understanding of the utility of using energy roadmaps as a tool to advance international technology collaboration. Important findings from this workshop include the following:

1. There is a need for a common roadmap definition.
2. Roadmaps should include all phases of research, development, demonstration and deployment (RDD&D).
3. Stakeholders that should be engaged in the development of the roadmap include: governments, private-public partnerships, industry and the financial community.
4. The process and forum for development of roadmaps may be more important than the document itself.
5. Roadmap implementation is critical.

Additionally, there was general agreement that roadmaps are useful to accelerating technologies as they set out milestones, identify challenges and facilitate communication between the participants to align a vision. Drawing from these findings, the following definition was developed:

A technology roadmap shall be defined as a dynamic set of technical, policy, legal, financial, and market and organizational requirements identified and agreed to by all stakeholders involved in its development. The effort shall lead to improved and enhanced sharing and collaboration of technology-specific RDD&D information among participants. The goal is to accelerate overall RDD&D in order to deliver an earlier uptake of the specific technology into the marketplace.

Roadmap scope

Roadmaps can be developed to fulfill several objectives. The IEA roadmaps are broad in scope, and must include technology, policy, financing, and public acceptance aspects of energy technology development. Specifically, each technology roadmap should include:

1. A vision of the specific technology targets to be achieved by 2050;
2. Strategic technology objectives to be met e.g. in terms of cost and performance;



3. Barriers (technology, legal, financial, policy, market and organizational) to overcome;
4. Timelines and milestones for meeting these objectives;
5. Critical RDD&D activities and milestones needed to meet objectives;
6. Identification of roles and responsibilities among partners for meeting targets *i.e.*, policies by governments, investments by private partner, and technology areas by both;
7. Evaluation criteria for assessing progress and timelines; and
8. Agreed to next steps for implementation.

Roadmap boundaries

In order to allow for maximum flexibility and recognising that technologies are in various stages of development, a roadmap should:

1. Use the *Energy Technology Perspectives 2008* roadmaps and analysis of CO₂ mitigation potential as a starting point;
2. Include timelines and milestones out to 2050;
3. Cover all phases of the RDD&D cycle;
4. Consider technical, legal, regulatory, policy, market and organizational issues;
5. Assess current international RDD&D and technology mapping efforts to determine a baseline; and
6. Identify the activities that are needed to meet the ETP targets.

Selection criteria

Although the technology roadmaps developed in the *ETP* will serve as the starting point, the IEA recognises that other technologies may require expanded cooperation. Accordingly the following criteria shall be considered in identifying future selection of IEA roadmaps:

1. Significant and robust CO₂ reduction potential under the ETP Blue Map scenario
2. Contribute to improved energy security
3. High international interest and potential for international collaboration
4. Of interest to emerging economies
5. Political acceptability
6. Represents a technology sector (industry, building, power generation, transport)
7. Recommendation from member countries and industry

Stakeholders interested in energy technology roadmap efforts should contact the IEA Secretariat to discuss possible input and collaboration.