Energy Technology Roadmaps

a guide to development and implementation

International Energy Agency

2014 Edition

INTERNATIONAL ENERGY AGENCY

The International Energy Agency (IEA), an autonomous agency, was established in November 1974. Its primary mandate was – and is – two-fold: to promote energy security amongst its member countries through collective response to physical disruptions in oil supply, and provide authoritative research and analysis on ways to ensure reliable, affordable and clean energy for its 28 member countries and beyond. The IEA carries out a comprehensive programme of energy co-operation among its member countries, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The Agency's aims include the following objectives:

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

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Foreword

Many countries are facing serious challenges as a result of the lingering global economic crisis. At the same time, all nations share a responsibility to ensure that their energy sectors become more sustainable and more secure to manage the risks and impacts of climate change. Over the coming decades, energy efficiency, many forms of renewable energy, carbon capture and storage (CCS), nuclear power, new transport technologies, and more efficient use of fossil fuels will all require widespread deployment. The need for action is urgent, but drastically changing energy infrastructure and end-use equipment on a national scale is a complex and expensive undertaking. Careful planning is required to ensure that limited resources are devoted to the highest-priority, highest-impact actions in the near term while laying the groundwork for longer-term improvements. Every major country and sector of the economy must be involved.

Awareness is growing of the need to turn political statements and analytical work into concrete action. To spark this movement, at the request of the G8, since 2008 the International Energy Agency (IEA) has been leading the development of a series of roadmaps for some of the most important technologies. To date the IEA has completed 20 global energy technology roadmaps covering both supply and demand technologies, as well as supporting the development of two national technology roadmaps.

By identifying the steps needed to accelerate the implementation of radical technology changes, these roadmaps will enable governments, industry and financial partners to make the right choices. This will in turn help societies make the right decisions in seeking to transition to a low-carbon future. The IEA roadmaps, which provide a global perspective, can inform more detailed roadmaps with a regional, national or sectoral focus.

Drawing upon the extensive IEA experience, this guide is aimed at providing countries and companies with the context, information and tools needed to design, manage and implement an effective energy technology roadmap process relevant to their own local circumstances and objectives. This edition of the *Energy Technology Roadmaps: a guide to development and implementation* includes more detailed guidance on how to identify key stakeholders, develop a technology baseline and development of indicators to help track progress against roadmap milestones. The IEA hopes that this guide and the examples and references it offers, together with the new IEA *How2Guides*, which provide technology-specific guidance, will help national and local policy makers and industry to develop strategies that accelerate the deployment of low-carbon energy technologies worldwide.

This publication is produced under my authority as Executive Director of the IEA.

Maria van der Hoeven
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Understanding roadmaps

A roadmap is a strategic plan that describes the steps an organisation needs to take to achieve stated outcomes and goals. It clearly outlines links among tasks and priorities for action in the near, medium and long term. An effective roadmap also includes metrics and milestones to allow regular tracking of progress towards the roadmap's ultimate goals.

There are many kinds of roadmaps. Technology-specific roadmaps, which are the focus of this guide, are intended to support the development of a specific type of technology, such as an advanced solar photovoltaic cell or a highly fuel-efficient passenger vehicle. Individuals involved typically include technical experts, policy makers, energy analysts and university researchers, who come together to outline performance targets, pathways, priorities and time frames for the research, development, demonstration and deployment (RDD&D) of a technology.

The IEA definition of a technology roadmap "is a dynamic set of technical, policy, legal, financial, market and organisational requirements identified by all stakeholders involved in its development. The effort shall lead to improved and enhanced sharing of and collaboration on all related technology-specific RDD&D information among participants. The goal is to accelerate the overall RDD&D process in order to deliver an earlier update of the specific energy technology into the marketplace."

Before proceeding to develop a national roadmap for a given technology or sector, it is crucial to determine whether such a roadmap would in fact be valuable or necessary for a country. This should be done by carrying out an evaluation of the country's current situation with regard to that particular technology or sector in relation to the energy system as a whole.

Roadmapping: A living process

Roadmapping is the evolving process of creating and implementing a roadmap and monitoring and updating it as necessary. The process is often as important as the resulting document, because it engages and aligns diverse stakeholders in a common course of action, sometimes for the first time. By getting interested parties to work together towards shared goals and results, the process can build relationships that have a significant, long lasting effect and will help support roadmap implementation.

An effective roadmapping process maximises participants' engagement in creating the plan, thereby building consensus and increasing the likelihood that those involved will implement the roadmap priorities. A roadmap also evolves in the sense that the process does not stop when the document is published. Rather, the roadmap evolves as progress is made, external factors change and more information becomes available. The frequency with which a roadmap is updated depends largely on the time frame under consideration. Typically, roadmaps are updated periodically (e.g. every two to five years). In some cases roadmaps are updated more frequently to reflect progress, changes in available resources or scheduling considerations. More information on roadmap updating is provided later in this document.

Definition of terms

Roadmap: a specialised type of strategic plan that outlines activities an organisation can undertake over specified time frames to achieve stated goals and outcomes.

Roadmapping: the evolving process by which a roadmap is created, implemented, monitored and updated as necessary.

Setting a vision: the process of analysing future scenarios and identifying objectives.

Stakeholders: relevant individuals who have an interest in seeing the roadmap developed and implemented, such as representatives from industry, government, academia and non-governmental organisations (NGOs).

Implementation: the process of putting a roadmap into action, by carrying out projects and initiatives that address roadmap tasks and priorities, and by monitoring progress using a tracking system.

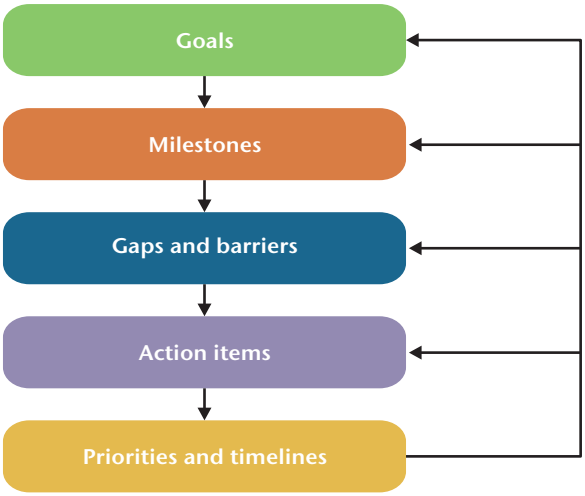
Typical roadmap audiences

Roadmap audiences vary depending on the type of document being developed. For national-level energy technology roadmaps, audiences may include:

- national government decision makers in ministries of energy, environment, industry, natural resources and infrastructure
- national government decision makers in ministries of finance or economics
- state/provincial and local policy makers and national regulators
- energy sector decision makers, particularly from industries that produce or consume large amounts of energy (e.g. electricity, natural resources, agriculture and energy-intensive industry)
- leading scientific, engineering, policy, social science and business experts involved in researching specific energy technologies and the supporting policies and financing mechanisms needed to accelerate commercialisation
- NGOs engaged in research and advocacy in low-carbon energy.

Key elements of a successful roadmap

Figure 1: The logic of a roadmap



Note: unless otherwise indicated, all material in tables and figures derives from IEA data and analysis.

A successful roadmap contains a clear statement of the desired outcome followed by a specific pathway for reaching it. This pathway should include the following components:

Goals: a clear and concise set of targets that, if achieved, will result in the desired outcome; quantified goals (e.g. "improve energy efficiency in commercial buildings by 25% in ten years") provide the most specific guidance.

Milestones: the interim performance targets for achieving the goals, pegged to specific dates (e.g. "improve the energy efficiency of commercial buildings by 2% per year during the next five years without slowing economic growth").

Gaps and barriers: a list of any potential gaps in knowledge, technology limitations, market structural barriers, regulatory limitations, public acceptance or other barriers to achieving the goals and milestones.

Action items: actions that can be taken to overcome any gaps or barriers that stand in the way of achieving the goals; typical solution actions include technology development and deployment, development of regulations and standards, policy formulation, creation of financing mechanisms, and public engagement.

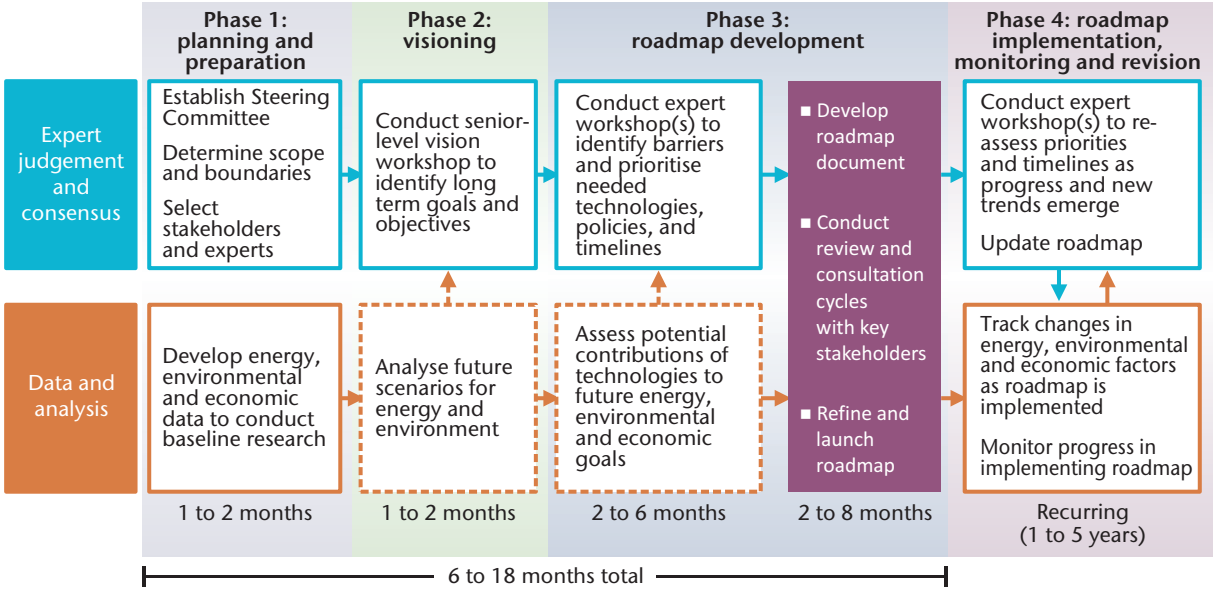
Priorities and timelines: a list of the most important actions that need to be taken in order to achieve the goals and the time frames, taking into account interconnections among those actions and stakeholder roles and relationships.

If designed correctly, a successful roadmap should provide the ability to link any project or activity back through this logical structure to understand how the project or activity ultimately contributes to the achievement of the roadmap goals. Simply writing a roadmap is not enough — the true measure of success is whether or not the roadmap is implemented and achieves the organisation's desired outcome. Such progress can be tracked with proper monitoring indicators as presented later in this document.

The roadmap development process

The development process ensures that a roadmap identifies mutual goals and determines specific and achievable actions towards realising a common vision (Figure 2). On average, it takes 6 to 18 months to develop a roadmap. The process includes two types of activities (expert judgement and consensus, and data and analysis) and four phases (planning and preparation, visioning, roadmap development, and roadmap implementation and revision). After a roadmap is completed, implementation and updating ensure the complete realisation of the vision and goals.

Figure 2: Roadmap process outline



Note: dotted lines indicate optional steps, based on analysis capabilities and resources.

Expert judgement and consensus activities

Expert judgement and consensus-building activities form the core of an effective technology roadmapping process and are conducted through roadmap workshops (Table 1). Workshops gather a cross-section of experts in technology, policy, economics, finance, social sciences and other disciplines to formulate roadmap goals and milestones, identify gaps, determine priorities and assign tasks. Expert judgement is also often needed to make choices among possible scenarios or options revealed by data and analysis activities. Structured vision and technology strategy workshops:

- build consensus on goals and targets
- evaluate and verify assumptions (such as technology costs or performance metrics)
- identify key technical and institutional barriers
- define alternative technology pathways to overcome barriers
- develop implementation strategies with priorities for action.

Building consensus across a broad cross-section of experts helps to generate strong suppor for the roadmap and reduces the chance that a major technology or policy issue is missed. This approach can also provide cost and time savings during implementation because key stakeholders are already familiar with the roadmap. The greater involvement of people with diverse views, however, can create a process that is more complex, takes longer and requires more resources.

Table 1: Expert workshop and consensus activities: Points to consider

• Diverse technical expertise ensures fewer potential roadmap gaps. • Critical market, policy, social and institutional factors should be considered. • Broad consensus facilitates roadmap implementation. • The roadmap should not rely solely on existing data and analysis.	• Greater stakeholder involvement increases roadmap development time and requires more resources. • Longer, more detailed stakeholder processes may make it more difficult to achieve consensus.

Data and analysis activities

Expert judgement should be supported by sound data and analysis to establish current baseline conditions, so that milestones and performance targets can be set and technology pathways defined to achieve the roadmap goals. These tasks can be accomplished by a team of analysts and technology experts with access to reliable data sources, analytical and modelling tools, and technology performance characteristics. The extent of data and analysis activities will vary depending on the amount and quality of available data, and the time, resources and analytical capabilities available to the roadmapping team.

Effective starting points for analysis include sound national baseline data on current energy supply by fuel type, consumption by end-use sector, energy costs and conversion efficiency. For more detailed analyses, national economic and demographic models can be used to help forecast population and market growth that provide the basis for estimating future energy requirements (Table 2). Technology performance data and energy system modelling enable analysts to examine alternative future energy supply portfolios that use different levels of energy sources such as fossil fuels, renewable energy and energy efficiency. Similar performance information on end-use technologies can help define energy end-use consumption profiles.

While these additional analytical tasks add value to a roadmapping process and should be completed when possible, they require additional resources and time to complete and hence are considered optional. An effective roadmap can still be developed using expert judgement and consensus and by drawing from other sources, such as the IEA global technology roadmaps or roadmaps from other regions with similar characteristics.

Analysts and technologists should aim to effectively link and integrate various data, models, forecasts and technology portfolios into a comprehensive framework to examine whether technology choices meet future energy needs. However, technology development and implementation does not take place in a vacuum. Its success relies on supportive economic, technology and environmental policies and the actions of a variety of key stakeholders including scientists, technology developers, entrepreneurs, financiers and community leaders. Accordingly, data and analysis should be a supporting part of a larger process to ensure that influential and informed leaders are included in roadmap development.

The most effective roadmapping initiatives rely upon sound data and analysis in combination with expert workshops to build consensus, thereby gathering the information needed for the roadmap while also building awareness and support throughout the process.

Table 2: Data and analysis activities: Points to consider

• Roadmaps based on strong analysis will obtain consensus more easily. • Government-sponsored analysis requires fewer resources and can be developed more quickly but may ignore critical technology or market issues.	• Conducting analysis in partnership with stakeholders maximises support from business, government and community leaders but takes more time. • The data, models and analytical skills available may not be sufficient.

Phase 1: Planning and preparation

In the planning and preparation phase, the organisation undertaking the roadmapping initiative needs to answer several questions:

- What are the boundaries of the roadmapping effort?
- Which technology areas or classes will the roadmap consider? Which energy sources or end-use sectors will be considered?
- What is the time frame for the roadmapping effort? Is the roadmap a 5-year plan, a 20-year plan or a 50-year plan?
- What is the current state of the technology under consideration (current installed base, potential energy savings, cost, efficiency, etc.)?
- How will the organisation conducting the roadmapping effort implement and use the resulting roadmap?
- Will the roadmap be used primarily to guide national government decision making?
- Will the roadmap need to engage the private sector to achieve the stated goals?
- What existing tools or analysis, such as other roadmaps, can be used to influence scoping decisions?

The actions that follow can help organisations to answer these questions.

Ensure leadership commitment

Even if a roadmap is well designed and has clear goals and committed participants, it still needs an audience committed to implementing it. Senior industry executives and/or policy officials must be engaged in the process, as they can authorise resources for the roadmap's completion and commit to implementing its findings. Ensuring such commitment is a top priority of the roadmap preparation and planning process, and forms the foundation for a successful public-private partnership to carry out implementation. In some cases, a political decision maker is the champion of the roadmap process and leadership commitment is secured. In others, the roadmap team must seek such leadership support.

To inform senior executives and policy makers about the roadmap and to gain input and commitment, a draft statement of purpose and scope should be prepared, accompanied by a short, clear presentation of materials for briefing senior managers — in person, if possible. Roadmap planners should consider asking senior stakeholder representatives to approve the project and to participate in the process, for example by providing opening remarks at the first roadmap workshop. Doing so gives decision makers an immediate role and stake in the outcome of the roadmap process. Industry leaders can also provide staff-level experts to participate in the roadmap process.

Appoint a steering committee

Most successful roadmapping efforts are led by a small steering committee whose members possess the knowledge and authority to make decisions regarding goals, scope and boundaries. They should have the ability to direct analytical efforts regarding baseline data requirements and the responsibility to define the body responsible for implementing the roadmap. The ideal size and composition of the steering committee should be determined by considering how the roadmap will be implemented and who must be involved. In roadmapping efforts that have been championed by a senior government decision maker, a committee of three to six key

decision makers is appropriate. For roadmapping efforts that lack such support, a larger steering committee of 6 to 12 people may be needed to ensure that a range of interests is represented.

Develop a statement of purpose and scope

To maintain focus throughout the roadmap development process, it is good practice to begin by developing a brief document of two to three pages that clearly and succinctly answers four questions:

- Purpose: why is the roadmap being developed?
- Scope and objectives: what is the roadmap expected to do?
- Process: how will the roadmap be developed and implemented?
- Participants: who will be involved?

This document serves as a valuable tool to help the organiser ensure that the roadmap remains committed to achieving the desired goals and to educate colleagues, managers, stakeholders and prospective participants.

The purpose section explains why the roadmap is being developed and the specific issues and problems it is meant to address. For example, a roadmap can be intended to address a market sector (such as residential and commercial buildings); to accelerate adoption of certain technologies (such as efficient lighting or heating and cooling equipment); or to achieve certain aims (such as reducing greenhouse-gas emissions).

The scope and objectives section explains what kinds of project the roadmap is expected to guide and over what time frame. For example, a roadmap can focus on technology development to lower the cost and improve the performance of certain equipment in specific applications by a chosen time.

The process section explains how the roadmap will be developed and includes the schedule for completion. For example, a roadmap process can include: a vision workshop of leaders from government and industry; a scenario analysis of future conditions and possibilities; a roadmap workshop of practitioners from government and industry; and periodic update workshops during implementation for monitoring, evaluation and mid-course corrections.

The participant section explains the types of organisations and individuals expected to be involved in the roadmap process. For example, a roadmap could involve representatives from national and local government agencies, private companies (both local and multinational), trade associations, universities, and environmental and consumer groups. The section should also include the types of experts that might be required in science and engineering, technology transfer and commercialisation, business analysis and finance, public administration and policy analysis, and education and outreach. The involvement of different stakeholders can be informed from the RACI (responsible, authorised, consulted, informed) chart (Table 4).

Conduct baseline research

An energy roadmapping effort should begin by developing a baseline for energy supply and consumption. Baseline data development includes a current situation analysis of the key factors affecting the roadmap, such as energy supply and demand, economic growth, technology commercialisation and readiness, infrastructure development and needs, institutional capacities, and energy and environmental policies and regulations. Figure 3 summarises some of the data and analysis that most roadmapping activities will require to establish the technology baseline.

Some countries may have detailed energy statistics from which to develop the baseline, while others may need to rely on less accurate or comprehensive data sets. For countries that lack detailed energy statistics, often one of the first activities proposed is to develop more robust data collection and assessment systems.

What if data for the situation analysis are not available?

Sometimes critical information on the variables that affect the current status and future conditions may not exist or may be difficult to obtain. The lack of this information poses a challenge to developing an effective roadmap.

In most roadmapping projects, it is essential for the participants to have an equal and effective understanding of the current status as a baseline for structuring activities and setting priorities. If such information is not available at the outset of the roadmap process, data collection and analysis should be developed as one of the initial roadmap activities and top roadmap priorities.

See the appendix of this guide for resources on international technology development status and collaboration.

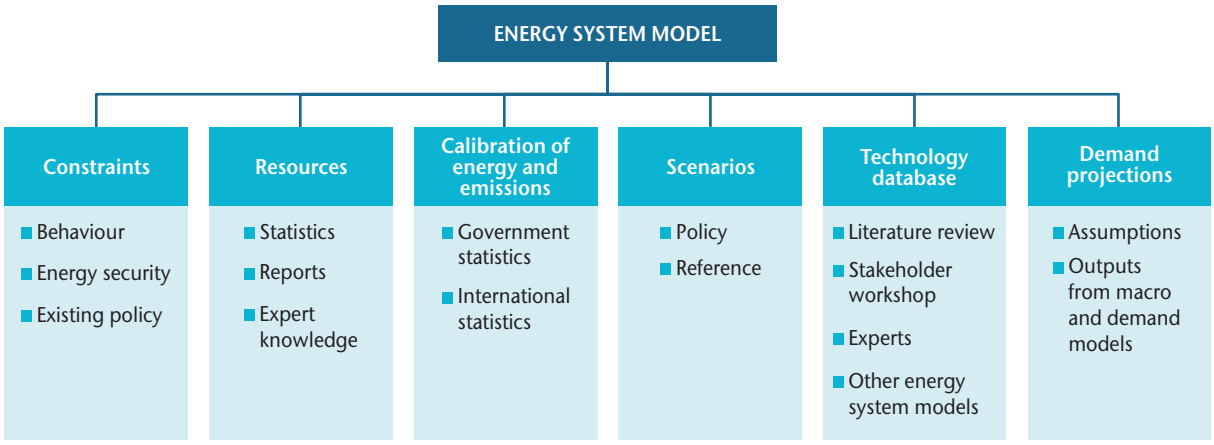
The first step in developing a baseline is to create a list of the types of data needed to address the purpose, scope and objectives of the roadmap. At the highest level there are normally three broad topic areas for situation analysis: technologies, markets and policies.[1] However, additional detail is typically needed to understand the state of low-carbon energy development today. Answering the following questions will result in the appropriate level of detail:

- Which technologies will be addressed?
- In which market sectors or segments will the technologies be applied?
- What public policies can help or hinder application of the technologies in the relevant market sectors or segments?

Organisations should be able to combine the answers to these additional questions with the broader topic areas to form a coherent structure that can guide data collection and analysis.

1. The IEA *How2Guides* provide additional technology-specific guidance for undertaking this baseline research.

Figure 3: Inputs for energy system model



Source: "Use of energy systems modelling for policy analysis: Experience from the United Kingdom", presented at the IEA Energy Training Week 2011, Paris, 6 April.

The aim of the **situation analysis for technologies** is to develop accurate information on the current status of costs, performance, technology readiness, manufacturers, vendors, market penetration and limitations (Table 3). The situation analysis for technologies should also include a summary of forecasts or projections with information on the trends that are expected to affect the technologies. Other important sources include prior roadmaps on relevant topics, including IEA roadmaps, and the work of other technology expert groups. For example, for a roadmap on co-generation[2] it is important to have information on the capital and operating costs of prime movers such as reciprocating engines and gas turbines, efficiency ratings for these devices, costs and performance

2. Co-generation refers to the combined production of heat and power.

of heat recovery equipment and thermal management systems, and communications and controls equipment for grid integration, operations and maintenance.

The aim of the **situation analysis for markets** is to develop accurate information on the current status of the supply chain (suppliers, distributors and customers); number of companies; size of the market and number of participants; energy system characteristics (production, delivery, storage and consumption); and environmental impact (air emissions, water and land impacts, and resource issues and constraints). For example, for a roadmap involving the buildings sector, it is important to have information on the stock of housing and commercial buildings, numbers of appliances and other types of equipment, demographic information on the age and income structure of the population, and factors that influence energy consumption in buildings, such as climate. The situation analysis for markets should also include information on the factors that are likely to affect the structure of the market and its participants, as well as a summary of forecasts, projections and expectations for the market sectors or segments.

Table 3: Situation analysis

	Description
Technology	Development status Technology performance (e.g. conversion efficiency) Technology costs Environmental impacts (air, water and land impacts) Technology potential (saturation levels/other limitations) Links to other technology areas
Markets	Suppliers Distributors Customers (including outlook for demand by end-use sector) Financing aspects Market penetration Existing studies/forecasts for the market/energy sector
Public policy	Current status and requirements Existing laws and regulations

Information-gathering for situation analysis literature reviews

Expert consultations with:
- industry experts
- university professors
- independent consultants
- other experts.

Additional consultations with:
- industry associations (for technologies and markets)
- government officials (for public policies).

Web searches of:
- vendor sites (for technologies)
- trade association sites (for markets)
- ministry sites (for public policies).

The aim of the **situation analysis for public policies** is to develop accurate information on the current status and requirements of existing laws, regulations, policy directives and other rules that affect the technologies and markets in the roadmap. The situation analysis for public policies should also include information on trends that are likely to lead to new policies or to prevent policies from being enacted. For example, for a low-carbon energy roadmap addressing transportation, information on urban air pollution levels and policies, regulations for the electric power sector for plug-in electric vehicles, and incentives for biofuels and hydrogen energy development are important factors to consider.

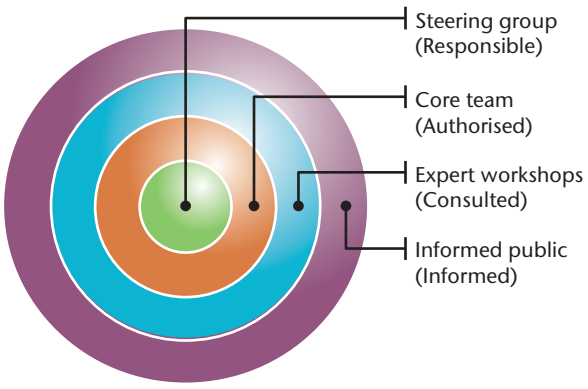
Select stakeholders and experts

Selecting and engaging stakeholders and experts early in the process better informs the development of the roadmap and raises the likelihood of buy-in

and commitment once the document is written. For vision workshops, it is typical to select 10 to 40 individuals to represent the senior leadership of an industry group, technology area or public policy issue. For expert workshops, 50 to 200 practitioners are usually recruited to provide input on barriers, needs and paths forward (Figure 4).

Identifying the roles and responsibilities of organisations and individuals is an important first step in selecting stakeholders. Using the scope and objectives of the roadmap as a guide, the organisation and steering committee should choose representative organisations and individuals who could help to develop the roadmap. These should be people with appropriate levels of responsibility and expertise who are well known by their peers. If chosen properly, these stakeholders can serve as "roadmap ambassadors" who educate others about the content and process during the roadmap document review cycle and later during the implementation phase.

Figure 4: Stakeholder involvement strategy



The roadmapping project leader must also identify and engage a group of process and subject-matter experts, often with input and guidance from the steering committee. During the roadmap development process, there is usually a need for people with expertise in such areas as energy analysis and forecasting, workshop facilitation, partnership development and support, technology assessment, market analysis, public policy, and social science analysis. The capabilities of these experts will depend on the purpose and scope of the roadmap, but it is important during the preparation process to identify these individuals and how to include them.

Identifying and engaging with all interested stakeholders is a key element in the success of a roadmap, in terms of both its development and its implementation. At the same time, a delicate balance must be struck between maximising the chances of the "buy-in" necessary for successful implementation and ensuring that a roadmap project is manageable in size and scope.

A simple chart can help to organise the wide array of people and organisations that may be interested in taking part in the roadmapping effort. Standing for Responsible, Authorised, Consulted and Informed, a RACI chart[3] divides stakeholders into one of four categories as described in Table 4.

In inviting participation, it is important to be inclusive to encourage open dialogue, including with those who may be affected by the roadmap as well as those who can support its implementation. The RACI chart helps to ensure that communication to all interested stakeholders is carried out properly and that they are involved in the roadmapping process in the most relevant manner.

Phase 2: Visioning

Setting a vision is the process of defining the desired pathway for a technology's deployment. This process includes modelling and scenario analysis, which are important tools used to define possible future states. Modelling assesses fundamental data on national population growth, shifting projections on natural resources and economic growth to suggest different energy futures and environmental consequences of those futures. Such analyses can also tell organisations what future states are possible and/or likely to evolve. While visioning can be accomplished without such analyses, modelling is a valuable tool for developing the vision and long-term goals of the roadmap.

Successful roadmapping processes often include a vision workshop where leading experts meet to discuss and ultimately define by consensus the desired future state of the nation, sector or organisation under consideration. Typical vision workshop participants include government leaders, senior industry representatives and leading researchers. At these workshops, participants consider the trends that are driving the evolution

3. The RACI chart is a management tool that is used to define responsibilities among a group. It is a responsibility assignment matrix.

Table 4: Stakeholders categories and mandate: The RACI chart

Category	*Definition*	*Mandate can include*
Responsible	This is the group that holds the authority to approve the final product. The ideal size and composition of this "steering committee" should be determined by considering how the roadmap will be implemented and who must be involved. It should be composed of senior representatives (typically director level) from government, industry and research in order to make sure the roadmap has the best chances to be implemented. In addition, the broader the cross-section of people involved, the more likely the roadmap will secure buy-in from all stakeholders designated to implement it. In the guide, this group will also be referred to as the "steering committee"	• Approve the roadmap goal, scope and boundaries • Assign the members of the roadmap project team (referred as "Authorised") • Direct analytical effort (incl. on the basis of the baseline research data) • Approve the RACI chart • Approve communications to the wider stakeholder community in the "Informed" category • Track progress of the project
Authorised	This is the core team that is actually undertaking the vast majority of the work on the roadmap. Also referred to as the "project team", this group should mirror the composition of the "Responsible" category but at a working level. A project leader should be identified to lead and co-ordinate the activities of the project team and should lead all communication activities with stakeholders	• Manage the project (project leader) • Communicate with stakeholders (project leader) • Organise consultation cycles • Develop the drafts • Plan the necessary workshops • Document all of the gathered information • Perform the analysis
Consulted	This group typically includes expert representatives from organisations that have a key role in the deployment and commercialisation of the technology, from utilities to manufacturers and bodies/NGOs representing individual consumers, and who will need to be involved in the implementation of the roadmap recommendations and milestones	• Attend workshops • Provide inputs • Review roadmap drafts • Be actively involved in the process, when appropriate
Informed	These stakeholders are those who have an interest in the technology and who can bring added value to the roadmapping analysis. They will not be directly involved in the implementation of the roadmap recommendations and milestones, but will however be affected by the roadmap and thus need to be informed	• Be informed about roadmap findings • Are not typically actively involved in the workshops or other activities

of low-carbon energy in their country or sector, examine baseline data and scenario forecasts for future developments, and then decide upon long-term goals and objectives for growth of the technology.

At vision workshops, participants can use the results of data analysis to consider alternative scenarios and projections if available. It is important to provide these results before the workshop so that participants have time to become acquainted with forecasts. Scenario developers typically present assumptions, methodologies and results at the beginning of the workshop to help ensure that participants have a common and consistent understanding of scenarios and projections. In the absence of such data, vision workshops rely on the collective expert judgement of the participants.

When using scenario analysis, it is often necessary to develop projections and forecasts that cover local energy and economic conditions, market realities, and public policy priorities. For example, the technology roadmaps developed by the IEA contain scenarios for global markets broken down by region. In most cases, this level of analysis will be too broad for a specific country's or organisation's roadmap. As a result, further analysis or other approaches may be appropriate in order to break these scenarios down to reflect local energy supply-and-demand conditions, economic development circumstances, and energy and environmental policies.

When developing more specific, customised projections and scenarios as the primary mechanism for establishing the roadmap vision and long-term goals, an organisation requires capabilities in energy and economic data analysis. If such capabilities are available, the scenario analysis can be accomplished during the vision phase. If baseline data, models and analysis tools are not in place, the analysis is often carried out in the early stages of roadmap implementation. In such cases, the initial roadmap vision and long-term goals may need to be refined once the roadmap is under way.

Phase 3: Roadmap development

Once a vision is established, the roadmap development phase begins, drawing on analysis and expert judgement to define the activities, priorities and timelines required to reach the desired vision.

Hold a roadmap workshop or workshops

Workshops are a way to gather the stakeholders and experts identified in the planning and preparation phase in one place to solicit their ideas through highly structured brainstorming and analysis sessions. For the more complex national-level roadmaps, several workshops addressing different aspects of the problem and involving appropriate expert groups are often held. For example, a first workshop may focus on technology issues and involve research scientists, engineers and technology developers, with a second workshop focusing on financial, policy and regulatory issues and involving bankers, regulators, policy makers, advocacy groups and related stakeholders.

Roadmap workshop planning

One of the first steps is developing the workshop process, including identifying the framing presentations, discussion topics and questions, and the format for managing and recording participant interventions. Facilitators can be engaged to assist in creating a workshop model that will deliver the desired results while also managing the human dynamics of dominant or timid personalities, or positioning based on specific agendas.

The mix of participants is arguably the factor that determines the success and value of a roadmap workshop. In addition to ensuring that the right expertise is present, workshop organisers also need to balance organisational representation within and across the industry, government, academic and NGO communities. Participants can be approved by the steering committee and invited by personal letter; open attendance workshops run the risk of becoming unbalanced or unmanageable and should be avoided. Roadmap workshops typically include 30 to 50 people, but in some cases can be as large as 200 when it is focused on stakeholder engagement or at the start of a roadmapping process.

Parallel working sessions, called breakout sessions, allow participants more time to speak and can help to obtain more active participation from all participants. Breakout sessions can be devoted to specific aspects of the overall topic (e.g., for a workshop on carbon capture and storage [CCS], three potential breakout topics could be carbon capture, carbon transportation and carbon storage), or the breakout sessions can overlap in topic and scope, which allows organisers to see how different groups of people answer the same questions.

Before the workshop, the roadmap team should send a background document to participants that frames the main questions the workshop hopes to answer and includes a clear statement of the workshop's purpose, scope, process and expected outcomes, as well as selected references.

Elements of a roadmap workshop background document

- Purpose and objectives
- Expected outputs
- Agenda
- List of questions to be answered during discussions
- Scope and boundaries
- Guidance for how participants can prepare
- List of participants
- Links to relevant background documents
- Logistical information

Roadmap workshops usually begin with a plenary session that familiarises participants with the topic and task at hand by presenting the results of the baseline research, modelling and scenario analysis, and the vision workshop, as well as other aspects of the issue. Facilitators finish this session with a brief outline of the workshop's logic process and what is expected of the participants. Participants then often gather in smaller groups of 10 to 25 people who define the necessary activities and initiatives, estimate their timing and sequence for implementation, and assign relative priorities. The workshop should conclude with a plenary session where participants can listen to reports from smaller groups and jointly discuss next steps.

It is essential to ensure that workshops are recorded; this can be done in a variety of ways. If it is not done, the ideas generated at the workshop often fade with time and are difficult to reconstruct in the draft roadmap document. One or more people from the project team should be in charge of taking notes on the workshop discussions and prepare a workshop report to be submitted for feedback to workshop participants. To encourage open and frank dialogue, many workshops are conducted under the rule that specific comments will not be attributed to individuals.

Prepare the draft roadmap document

A milestone in any roadmap development process is the point at which the analysis, modelling and results from expert workshops are brought together in a draft document. This step is perhaps the easiest to describe — write a document — and yet the most challenging to perform. Roadmap authors are required to assess and combine a large amount of information in a way that tells a compelling story of possibilities and describes a rational, consistent sequence of activities that can lead to the desired future state.

Roadmap documents can vary greatly in length (from 20 to 100 pages or more), in their amount of quantitative detail and in the nature of their text. The most effective roadmaps combine these elements with simple, compelling graphics that communicate key concepts to expert and non-expert audiences alike. Most national-level roadmaps are 30 to 60 pages long and contain some data without overwhelming readers with too much technical detail. Many roadmaps also provide more detailed information for technical audiences by including links to additional data sources, analyses or reference documents in a dedicated appendix.

In drafting a roadmap, authors should keep a variety of audiences in mind. Overly technical, jargon heavy roadmaps are inaccessible to important financial, political and regulatory audiences. Likewise, roadmaps that rely on complex legal language may be difficult to understand. Clear, concise, simple language and figures are the most effective way to reach the full range of audiences needed to implement a national roadmap.

Conduct a roadmap review

A carefully constructed review process maximises the contributions and support of stakeholders without becoming unmanageable. Once the first draft of a roadmap is developed, a series of three expanding review cycles can be used to involve experts or stakeholders who could not participate in the roadmap's initial development.

First review

Typically, the first draft of a roadmap is shared among all contributors to date (e.g., project champions, steering committee members, workshop participants) for review and comment. Although a few individuals who have not yet contributed to the roadmap effort may be included, the first review is usually limited to those who have already been involved. The draft roadmap is emailed to reviewers for comments with a deadline of two to four weeks. The draft usually remains a word processing document at this stage to facilitate easy commenting and revision, but it is helpful to include key charts or graphics to solicit comments on these, too.

The roadmap developers collect and assess all comments and incorporate those that strengthen the draft. Different reviewers often provide conflicting comments and suggestions. Resolving such conflicts can be one of the most challenging and controversial tasks for the development team. The origin of the conflicting comments determines the lengths to which the roadmap authors go to resolve them. In the most extreme instances, authors engage in conference calls or in-person meetings, but consensus-based resolution is not always possible. In such instances, roadmap authors have two choices: 1) choose one position, based on the views of the majority or the ultimate decision maker; or 2) present the opposing views in the roadmap, noting the minority viewpoint, if applicable. When an expert community is strongly and equally divided, further consensus-building is needed before publishing the final roadmap, through additional analysis, stakeholder meetings and other steps that bring the two sides closer.

The authors then prepare a revised draft. The extent of revision between the first and second drafts varies considerably, from minor wording changes to fundamental reorganisations and reassessments of goals and development pathways. This can be frustrating for the authors, but it is important to remember that the ultimate success of the roadmap will be measured by the actions it generates and the degree of alignment it creates among all stakeholders. It is better to uncover and address fundamental issues during the review cycles rather than after the roadmap is finalised and launched, so that the final roadmap benefits from maximum support and commitment.

External review

The external review draft should be sent to a wider audience of subject-matter experts for review and comment. This second review cycle can engage as few as ten reviewers or as many as hundreds. Whatever the number of reviewers, it is vital to seek responses from people who have not yet been involved in the roadmap process; they often bring fresh perspectives that can improve the document. External comments that verify and support the roadmap help to confirm that it is complete, accurate and ready for publication.

The external review draft roadmap is usually presented in close-to-final format, in colour and incorporating graphics and other layout elements. This helps reviewers to fully understand and appreciate the roadmap. A well-designed document gives a positive overall impression and shows that the draft is near completion.

Lessons learned: Review cycles

- Conduct one review with roadmap contributors and at least one external review.
- Engage wider audiences in later reviews to extend reach and gain additional support.
- Create clear timing for review comments; limit each review cycle to two to four weeks to maintain progress.
- Define in advance how you will resolve conflicting comments received during reviews, either through selecting one position or documenting the minority view.

As with the first review, the authors establish a clear deadline for comments, usually two to four weeks. Authors then assess and incorporate comments to produce a final draft roadmap, which is reviewed by the roadmap sponsor or steering committee to resolve any final outstanding issues and approve publication.

Phase 4: Roadmap implementation and adjustment

Launching the roadmap and putting in place tracking systems are the steps in the fourth and final phase: roadmap implementation and adjustment.

Launch the roadmap

Roadmaps can be formally launched in many ways. At a minimum, the intended audience of the roadmap must be made aware that the document has been finalised and is available. Such a launch typically includes a press release, selective electronic distribution of the final roadmap and accompanying materials, and public remarks by roadmap leaders at relevant meetings and conferences. National roadmaps that are expected to influence broad communities receive more elaborate launches. Formal, high-profile events or press conferences with speeches from dignitaries and roadmap leaders can be accompanied by commitments to action from key decision makers and widespread print, Internet and radio/television coverage. Whichever approach is taken, the critical outcome is awareness among those responsible for acting upon its recommendations.

Begin implementation

The final roadmap outlines a set of priorities — research projects, technology demonstrations, policy advances, regulatory changes and financial commitments — that are needed over a defined time frame to achieve the roadmap's goals. The first stage of implementation is to begin those activities. The mechanics of funding research projects or pursuing regulatory changes is highly dependent on an organisation's unique characteristics and is not the focus of this guide. Whatever the mechanism of project initiation and management, engaging stakeholders to address near-term priorities is a key first step in implementing the roadmap.

Because the steering committee typically consists if representatives from industry and government, it sometimes evolves into the body that oversees and tracks implementation of the roadmap and initiates adjustments to the document as needed. These stakeholders are identified as "Responsible" under the RACI chart (Table 4). The implementation body is also commonly designated as a specific organisation within the appropriate ministry or industry sector organisation.

Monitor progress and adjust the roadmap

Ideally, the roadmap implementation body tracks the efforts of various stakeholders, gathers results as projects are completed and serves as a centralised source of information about progress. However, given the broad scope of national-level technology roadmaps and the thousands of diverse stakeholders involved in implementation, it may be difficult for one organisation to track all initiatives. In many sectors, business competitors will pursue different approaches and will not share details about plans or progress for fear of losing a competitive advantage.

In the absence of full information about all efforts under way, many roadmap implementation bodies conduct analyses and/or solicit expert views to understand how progress is evolving. Analyses should include the monitoring of leading energy, economic and environmental indicators to assess changes and trends towards or away from roadmap goals. For example, if a roadmap states a ten-year goal of achieving a 20% reduction in energy use, an implementation body can analyse this metric annually to monitor progress, taking annual reductions of 1% to 2% as a sign that implementation is on track. Identifying a set of progress indicators is an important task within each roadmap process. These indicators will vary significantly from one technology to another,[4] but some common elements can be identified and are summarised in Table 5.

Another approach is to assign tasks to specific stakeholder groups in the roadmap, as is done in the IEA technology roadmaps. If consensus and support are obtained for such assignments during the development process, stakeholders will often accept and act upon tasks more reliably. This approach facilitates monitoring, as the actions of the responsible stakeholder group can be tracked in a targeted way.

Those stakeholders involved in the roadmap via the Responsible and Authorised categories are most likely to be those appropriate for revising the roadmap milestones and re-evaluating the chosen project types based on initial implementation. Periodic roadmap adjustment workshops, at which experts revisit goals, priorities and timelines to determine what changes should be made, if any, should be

4. The *How2Guides* provide a suggested list of metrics and indicators tailored to a given technology.

Table 5: Indicators for tracking progress against roadmap milestones

	Indicator
Technology development and deployment	Number of projects developed
	Installed capacity added
	Energy/electricity production
	Efficiency improvement
	Technology improvement
	Cost per installed capacity or per unit
Financial	Annual or cumulative investment in new capacity
Emissions	Annual or cumulative emissions reduction associated with technology or enabled by technology

included as part of the roadmapping process. The frequency of adjustment workshops depends on the rate of change being pursued; for national-level energy roadmaps, conducting workshops ever y three to five years is appropriate. For more rapidly developing economies or nations that are making significant investments in their energy infrastructure, more frequent adjustment workshops may be justified. Whatever their frequency, adjustment workshops are essential in order to continue to engage the expert community in updating the roadmap as progress is made and more information becomes available. Many roadmapping efforts fail because they do not reconsider their priorities on a regular basis, causing 20-year plans to become irrelevant after only a few years.

Manage expectations

Even the best implementation processes seldom follow the roadmap completely. While a roadmap outlines the actions that should be taken to achieve specified goals, often the entire set of actions is not implemented because of gaps in the stakeholder group, incomplete information or, most commonly, resource limitations. Often, only certain priorities are acted upon while others are addressed in pieces or ignored. While a technology breakthrough, regulatory update or policy innovation can lead to faster progress than anticipated, progress is often slower than envisaged in the roadmap. Rather than viewing such delays as failures, roadmap developers should regard them as reflecting the limitations of long-term planning. Indeed, these limitations are among the most important reasons for regularly adjusting a roadmap to maintain focus on its ultimate goals as situations evolve.

Lessons learned: Roadmap implementation and revision

- Approach roadmapping as a “living process” that continues past the roadmap’s initial publication.
- Plan a successful roadmap launch to build awareness and create momentum needed to stimulate action.
- Designate the roadmap implementation body early in the process.
- Monitor key energy, environmental and economic indicators to track progress.
- Conduct regular roadmap revision workshops to adapt roadmap goals and priorities to changing circumstances.

Tailoring the roadmap process

There is no right way to develop a roadmap. Some processes engage large groups of stakeholders who spend long periods gathering many diverse contributions and building consensus on priorities. Others are developed by a small group of knowledgeable analysts and experts who work intensively for a short period to integrate available data, analysis and insights into a logical framework.

Each approach has its merits, and the organisation or community responsible for developing the roadmap must determine which one works best for its situation. This section outlines the steps and key questions that national roadmapping leaders should consider in designing a roadmap process that will lead to the development and uptake of low-carbon energy technologies in their country.

Key factors to consider

There are six vital aspects to consider when designing a roadmap process:

- stakeholder participation
- resource constraints
- critical inputs
- roadmap design
- buy-in and dissemination
- monitoring and tracking.

A country can determine the best approach for developing a national energy roadmap by answering a series of critical questions for each factor, which are shown in the accompanying text boxes.

Identifying the level of **stakeholder participation** is the most important step in designing a roadmap process. Strong central governments that have sufficient financial resources to fund technology development and provide supporting economic and energy policies can often pursue shorter processes with a smaller number of stakeholders. The funding resources of the government can provide the necessary stimulus to attract market participants and spur technology development and implementation. The involvement of external stakeholders may be less critical to the success of achieving energy and carbon-reduction goals. For many countries, however, achieving national goals is a shared responsibility of the public and private sectors. Neither the government nor industry has sufficient expertise or financial resources to research, develop, implement and track technology progress. In these cases, a roadmap process that includes wide stakeholder participation in expert workshops is vital to build support for implementation.

Stakeholder participation

- Who will set roadmap goals and milestones?
- Who will be responsible for ensuring that goals are met?
- What human resources are available to accomplish roadmap activities and priorities?
- Who will be responsible for carrying out activities?
- Which stakeholders will be critical in ensuring roadmap success?

Resource constraints may also shape the roadmap development process. Developing and maintaining the roadmap requires funding, personnel, skills, tools and time. An analysis-driven roadmap process needs skilled analysts with expertise in energy and economic modelling; appropriate funding to gather, model and analyse data; and access to technology experts. A process that relies more heavily upon a cross-section of expert judgement requires time to identify and convene technology and energy experts, skilled facilitators to guide diverse groups to consensus, personnel to manage the overall process, and funding to support the development effort.

Resource constraints

- What skills and tools will be needed to prepare the roadmap?
- What funds are available to develop the roadmap?
- Is there enough time for broad stakeholder engagement?
- Are sufficient personnel available to manage and implement the roadmap development process?
- Are appropriate data and analytic tools available to support analysis?

A technology roadmap requires certain **critical inputs** to establish a sound baseline of current energy use, provide a basis for defining future technology and carbon targets, and evaluate technology choices. For an analysis-driven roadmap, the process requires reliable national energy data, modelling and analysis tools and capabilities, and detailed engineering and cost per formance information for competing energy technologies. A process that relies more heavily on expert judgement requires the involvement of key technology, policy and business leaders with the insights, experience and knowledge needed to set quantitative carbon-reduction targets, evaluate future scenarios and assess alternative technology portfolios. Contributions from other stakeholders, such as community leaders and technology developers, may be needed to ensure effective technology absorption and acceptance.

Critical inputs

- What data are needed to establish baseline conditions, set goals and targets, and prepare forecasts?
- Are essential analytic capabilities and tools available to evaluate alternative scenarios?
- What technical expertise is needed to evaluate technology per formance and limitations?
- Which regulators and policy leaders can provide insight on factors affecting technology adoption?
- Which private entities will be critical to technology success?

The **roadmap design** includes the type of information contained in the roadmap and how it is used to achieve results. The most effective technology roadmaps contain date-based, quantitative goals and milestones that enable the country to articulate and build support for its energy and environmental policies. They present these on a timeline showing advances sought in the near, medium and long term. The IEA roadmaps accomplish this visually using a four-page fold-out that shows technology penetration rates and corresponding reductions in carbon emissions. The ideal roadmap includes enough detail to identify the specific technologies that will be adopted; their contribution to meeting energy, environmental and economic targets; and the respective roles and responsibilities of the partners and organisations that will fund, develop and implement them.

Roadmap design

- Will goals and milestones include date-based, quantitative targets?
- What information must be included in the roadmap?
- What level of detail is needed for effective implementation and action?
- What supporting information and data are needed?
- Will activities be assigned to organisations for action?

The **buy-in and dissemination** of a roadmap is particularly important. The wide scope and considerable time needed to adapt a country's economy and energy profile to a low-carbon future require the co-operation and co-ordination of many government, industry and community partners. Approval should be built in to the roadmap design by engaging the needed technologists, policy leaders, scientists and business leaders early in the process. Engagement should continue throughout the process with particular attention to how the document and results will be shared with a large community and the public. Key messages need to be developed, with special attention given to using appropriate communication media. Countries must determine what resources and skills will be needed for effective outreach, which stakeholders and groups are most critical to reach, and how the value of the roadmap can be reinforced.

Buy-in and dissemination

- How will the roadmap be communicated to convey key messages and engage critical partners?
- What methods and media will be used to disseminate the roadmap and build support for its goals?
- What key stakeholder groups need to be reached and what is the best mechanism for reaching them?
- What techniques will be used to reinforce the value of the roadmap and create buy-in?
- What resources, skills and tools will be needed for effective communication?

Although often overlooked, **monitoring and tracking** of the roadmap is essential to ensure that desired outcomes are achieved. The long time frame required to develop and integrate low-carbon technologies into a country's economic system increases the likelihood that market and technology conditions will change, which may alter the relative attractiveness of competing energy choices. The use of date-based milestones that specify technology per formance and market penetration rates creates a way to measure roadmap progress at different points in time and make adjustments based on new data and information. A good technology roadmap also defines the critical metrics used to measure progress and indicate the data sources they are drawn from. In any process, a deliberate plan should be developed to monitor, track, update and maintain the roadmap throughout its life cycle.

Monitoring and tracking

- Who will be responsible for tracking progress towards roadmap goals and milestones?
- What data and analysis tools will be needed to create and track roadmap metrics?
- What new information will be needed to adjust technology scenarios as time advances?
- Who should be involved in re-evaluating technology pathways at regular intervals?
- How will national policies be adjusted if roadmap targets are not being met?

Appendix: international technology collaboration

Several multilateral initiatives have emerged in recent years to facilitate collaboration on cross-cutting technologies, including the IEA Implementing Agreements (now also known as multilateral technology initiatives), the European Union's SET Plan and the Clean Energy Ministerial (CEM) initiatives, and the IEA International Low-Carbon Energy Technology Platform described below.

The 40 multilateral technology initiatives (Implementing Agreements) supported by the IEA are a flexible and effective framework for IEA member and non-member countries, businesses, industries, international organisations, and NGOs to research breakthrough technologies, bridge existing research gaps, build pilot plants, and carry out deployment or demonstration programmes.[5] The Implementing Agreements encourage technology-related activities that support energy security, economic growth and environmental protection. All of the IEA Implementing Agreements manage joint research programmes; countries and private organisations can participate in joint research on specific projects of interest.

5. For more information see www.iea.org/techinitiatives.

IEA Implementing Agreements

End-use technologies: buildings

- Energy in Buildings and Communities (IEA-EBC). (www.iea-ebc.org/).
- District Heating and Cooling (www.iea-dhc.org).
- Energy Storage (www.energy-storage.org).
- Heat Pumping Technologies (www.heatpumpcentre.org).
- Efficient Electrical End-Use Equipment (www.iea-4e.org).

End-use technologies: electricity

- Demand-Side Management (www.ieadsm.org).
- Electricity Networks Analysis, Research and Development (ENARD). (www.iea-enard.org).
- High-Temperature Superconductivity (HTS). on the Electric Power Sector (www.superconductivityiea.org).

End-use technologies: industry

- Industrial Energy-Related Technologies and Systems (www.iea-industry.org).

End-use technologies: transport

- Advanced Fuel Cells (www.ieafuelcell.com).
- Advanced Materials for Transportation (www.iea-ia-amt.org).
- Advanced Motor Fuels (www.iea-amf.com).
- Emissions Reduction in Combustion (www.ieacombustion.net).
- Hybrid and Electric Vehicles (www.ieahev.org).

Renewable energy technologies

- Bioenergy (www.ieabioenergy.com).
- Geothermal (www.iea-gia.org).
- Hydrogen (www.ieahia.org).
- Hydropower (www.ieahydro.org).
- Ocean Energy Systems (www.iea-oceans.org).
- Photovoltaic Power Systems (www.iea-pvps.org).
- Renewable Energy Technology Deployment (www.iea-retd.org).
- Solar Heating and Cooling (www.iea-shc.org).
- SolarPACES (www.solarpaces.org).
- Wind Energy Systems (www.ieawind.org).

Fossil fuels

- Enhanced Oil Recovery (www.iea-eor.ptrc.ca).
- Fluidized Bed Conversion (www.iea-fbc.org).
- IEA Clean Coal Centre (www.iea-coal.org.uk).
- Gas and Oil Technologies.
- Greenhouse-Gas R&D Programme (www.ieaghg.org).

Cross-cutting (data, modelling, technology transfer).

- Climate Technology Initiative (CTI) (www.climatetech.net).
- Energy Technology Data Exchange (ETDE) (www.etde.org).
- Energy Technology Systems Analysis Program (ETSAP) (www.iea-etsap.org).

Fusion power

- Co-operation on Tokamak Programmes.
- Environmental, Safety and Economic Aspects of Fusion Power.
- Fusion Materials.
- Nuclear Technology of Fusion Reactors.
- Plasma Wall Interaction.
- Reversed Field Pinches.
- Spherical Tori.
- Stellarator-Heliotron Concept.

Central to the activities of the CEM are 13 action-driven, transformative clean energy initiatives. The initiatives work to achieve three key goals: increase energy efficiency, expand clean energy supply and enhance clean energy access. They are grouped into three categories: initiatives that are working to improve energy efficiency, initiatives that are working to expand clean energy supply and cross-cutting initiatives.

Energy efficiency

- The Global Superior Energy Performance Partnership (GSEP).
- The Super-Efficient Equipment and Appliance Deployment (SEAD) Initiative.

Clean energy supply

- The Bioenergy Working Group.
- The Carbon Capture, Use and Storage Action Group (CCUS).
- The Multilateral Solar and Wind Working Group.
- The Sustainable Development of Hydropower Initiative.

Integration

- The 21st Century Power Partnership.
- The Electric Vehicles Initiative (EVI).
- Global Sustainable Cities Network (GSCN).
- The International Smart Grid Action Network (ISGAD) (also an IEA Implementing Agreement).

Human capacity

- The Clean Energy Education and Empowerment (C3E) women's initiative.
- The Clean Energy Solutions Center.
- The Global Lighting and Energy Access Partnership (Global LEAP).

Created in 2010 by the G8 and IEA ministers, the International Low-Carbon Energy Technology Platform is a tool for IEA engagement on low-carbon technologies, with IEA members and with emerging and developing economies. The platform serves as a means to disseminate IEA analyses and policy recommendations on low-carbon technologies, and to share international best policy practice, for the deployment of low-carbon technologies globally. Under this framework, the IEA recently launched the How2Guide initiative to produce a series of manuals, which alongside this publication aim to guide policy makers in developing and implementing technology-specific roadmaps at the national level. Building on the Agency's global, high-level energy technology roadmap series, this project responds to the growing number of requests for IEA assistance with the development of such roadmaps that are tailored to national frameworks, resources and capacities. It also represents a new stage in the IEA roadmap work itself — a move towards implementing and adapting the IEA's global level roadmap recommendations to the national level.

In addition to the IEA Implementing Agreements and these cross-cutting multilateral initiatives, many technology-specific initiatives have emerged to focus international collaborative efforts in these areas. A partial list is provided in the sections that follow.

Advanced vehicles

The Advanced Vehicle Leadership Forum (AVLF) is a new global effort that will bring together governments, cities, auto manufacturers, electric utilities and other stakeholders to create a systematic effort to share information and planning on global development of electric vehicles (EV) and plug-in hybrid electric vehicles (PHEV). Among other things, the AVLF will address technical standards and practices; assess current and potential domestic and international joint efforts in research, development and demonstration (RD&D), in particular, multi-country demonstration projects; and explore opportunities to initiate public, private and public-private research and development (R&D) collaborations in the near term.

The Global Fuel Economy Initiative works to achieve a 50% reduction in global fuel economy by 2050 by promoting research, discussion and action to improve fuel economy worldwide, with a focus on raising awareness and capacity building (www.50by50campaign.org).

Carbon capture and storage

The Carbon Sequestration Leadership Forum (CSLF) is a multilateral effort designed to advance CCS as a viable greenhouse-gas mitigation technology. The CSLF's Technical Group fosters RD&D for CCS projects reflecting its members' priorities, working with industry, government and academic experts (www.cslforum.org).

The European Union Zero Emissions Programme (ZEP) provides advice on technical, policy and commercial matters related to expansion of CCS to meet EU targets. The ZEP involves industry and other stakeholders on all technology issues, including recommendations for next-generation CCS technologies, taking into account experience gained from the EU CCS Demonstration Programme.

The Global CCS Institute was launched in 2009 by the Australian government as an international centre for CCS. Its primary focus is on accelerating deployment through large-scale demonstration. Global CCS Institute activities include knowledge sharing, strategic analysis to fill gaps in knowledge, and project funding and support.

Energy efficiency

The International Partnership for Energy Efficiency Co-operation (IPEEC) was created in 2009 to identify areas of joint actions to maximise the impact and synergies of individual national actions. The IPEEC intends to enable joint R&D into key energy efficient technologies, including application in developing countries. In addition, the IPEEC aims to exchange information on measures that can strengthen public-private co-operation to advance energy efficient technology research, development, commercialisation and deployment (http://ipeecshare.org).

The Sustainable Buildings Network (SBN) was created in 2009 at the G8 Summit in Italy. A collaboration between major economies, the SBN is a network of networks managed by the Renewable Energy and Energy Efficiency Partnership (REEEP) that aims to identify policies to improve energy efficiency in buildings in different regions around the world. It also serves as a reference portal for information on energy efficient practices and use of renewable energy in buildings. During 2010-12, the SBN focused on three topics: intelligent architecture in tropical regions, zero-energy buildings and policy packages for existing buildings (www.reeep.org/43.16674/ sustainable-buildings-network-keeping-it-cool- intelligent-architecture-for-tropical-buildings.htm).

Nuclear energy

International Thermonuclear Experimental Reactor (ITER) is an international project to design — and build — an experimental fusion reactor that aims to produce up to 500 megawatts from fusion power. While ITER enables an integrated fusion experiment and testing environment, several key elements needed for power generation have yet to be developed before building a demonstration reactor (referred to as DEMO), which aims to produce electric power in the gigawatt range. These key elements for power generation are currently being researched in the national research facilities of the Contracting Parties to the IEA fusion Implementing Agreements under the guidance of the IEA Fusion Power Co-ordinating Committee. The fusion Implementing Agreements have proven to be highly effective in facilitating advances in fusion energy research (www.iter.org).

Renewable energy

In Europe, the Wind Energy Technology Platform (TPWind) builds collaboration among industry and public sector participants and is also one of a range of different technology platforms established in partnership with the European Commission with cross-cutting activities. TPWind has developed a research agenda and market deployment strategy up to 2030, which provides a focus for EU and national financing initiatives, such as the multibillion-euro European Wind Initiative, established under the European Strategic Energy Technology plan. A German-Danish-Swedish Co-operation Agreement exists with specific focus on offshore wind energy RD&D.

The Global Wind Energy Council (GWEC) is a wind industry trade association, providing a representative forum for the wind energy sector at the global level. Its focus is on policy analysis, trends and outreach to emerging markets.

The International Partnership for Geothermal Technology (IPGT) brings together representatives from Australia, Iceland and the United States to accelerate the development of geothermal technology. The IPGT provides a forum for government and industry leaders to co-ordinate efforts to develop new technologies and pursue projects. Partners share information on results and best practices to avoid blind alleys and limit unnecessary duplication (http://internationalgeothermal.org).

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation established in 2009 that today has over 140 country signatories. The IRENA promotes increased adoption and

sustainable use of all forms of renewable energy by facilitating access to information, including technical, economic and renewable resource potential data. The Agency also shares experiences on best practices and lessons learned regarding policy frameworks, capacity-building projects, available finance mechanisms and renewable energy-related energy efficiency measures (www.irena.org).

The International Solar Energy Society (ISES) is a United Nations–accredited NGO which brings together industry, science and politics and aims to create international structures to facilitate co-operation. The ISES supports its members by, among other things, stimulating and encouraging fundamental and applied research in solar energy (www.ises.org).

The Global Bioenergy Partnership (GBEP) brings together bioenergy stakeholders to organise, co-ordinate and implement targeted international RD&D and commercial activities related to production, delivery, conversion and use of biomass for energy, with a focus on developing countries. The GBEP has made progress developing sustainability criteria, as well as indicators and a methodological framework for measuring greenhouse-gas savings. Technology co-operation among governments on the co-ordinated development and implementation of national bioenergy technology action plans for RD&D represents a new focus area, which aims to ensure the co-ordination of international RD&D efforts and to seek opportunities for joint RD&D projects (www.globalbioenergy.org).

The Asia Pacific Economic Cooperation (APEC) Biofuels Task Force helps Asia-Pacific Economic Co-operation member economies better understand the potential for biofuels to displace oil in transport. It focuses on joint analysis of key issues affecting the development of biofuels, such as resources, economics, infrastructure, vehicles and trade opportunities (www.biofuels.apec.org/task_force.html).

The European Biofuels Technology Platform engages with biofuels stakeholders, research projects funded by the European Commission and global biofuels organisations in a range of activities relevant to the RD&D of sustainable advanced biofuels in Europe. The platform produces a strategic research agenda and conducts mapping of research and demonstration activities (www.biofuelstp.eu).

Abbreviations, acronyms and references

Abbreviations and acronyms

APEC	Asia Pacific Economic Cooperation
AVLF	Advanced Vehicle Leadership Forum
CCS	carbon capture and storage
CEM	Clean Energy Ministerial
CSLF	Carbon Sequestration Leadership Forum
CTI	Climate Technology Initiative
ENARD	Electricity Networks Analysis, Research and Development
ETDE	Energy Technology Data Exchange
GBEP	Global Bioenergy Partnership
GWEC	Global Wind Energy Council
HTS	High-Temperature Superconductivity
IEA	International Energy Agency
IPEEC	International Partnership for Energy Efficiency Co-operation
IPGT	International Partnership for Geothermal Technology
IRENA	International Renewable Energy Agency
ISES	International Solar Energy Society
ITER	International Thermonuclear Experimental Reactor
NGO	non governmental organisation
PHEV	plug-in hybrid electric vehicles
R&D	research and development
RACI	responsible, authorised, consulted, informed
RD&D	research, development and demonstration
RDD&D	research, development, demonstration and deployment
REEEP	Renewable Energy and Energy Efficiency Partnership
SBN	Sustainable Buildings Network
SEAD	Super-Efficient Equipment and Appliance Deployment
SPT	Sustainable Energy Policy and Technology
ZEP	Zero Emissions Programme

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