HOW2GUIDE for

Wind Energy

Roadmap Development and Implementation

International Energy Agency

INTERNATIONAL LOW-CARBON ENERGY TECHNOLOGY PLATFORM

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:

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- 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.
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Foreword

The development and deployment of low-carbon energy technologies is now widely recognised as not only a crucial component in providing the integrated solutions needed to constrain global greenhouse gas emissions but also an important tool that countries can use to spur innovation and foster economic growth while enhancing access to secure, affordable energy. Technology roadmaps – or strategic-technology plans – can help provide pathways to the deployment of specific technologies identified as having great potential for a given country or region. Recognising this, the International Energy Agency (IEA) has an active programme to produce roadmaps for the enhanced deployment of critical low-carbon technologies and development of industrial sectors. Each roadmap provides a global outlook for a specific technology, including technology status, deployment scenarios up to 2050 in line with the IEA 2°C Scenario (2DS),[1] and recommended actions.

In recent years, governments and industry players in both developed and emerging economies have expressed strong interest in reaping the many benefits of renewable energy by building on the IEA global technology roadmap work to develop technology or sectoral roadmaps at the national or subnational level. In response, the IEA supplemented its global roadmap work with a summary of its general roadmap methodology in the policy manual *Energy Technology Roadmaps: A Guide to Development and Implementation,* released in 2010 and updated in 2014. Building on this foundation, the IEA International Low-Carbon Energy Technology Platform launched the *How2Guide* initiative to address the need for focused guidance in the drafting of national roadmaps for specific technologies. The *How2Guide for Wind Energy* is the first in this new series. It draws on the IEA *Technology Roadmap: Wind Energy*, first published in 2009 and updated in 2013, as well as on insights gained during several workshops with industry and government in 2012 and 2013.

As a clean and competitive source of renewable energy, many member countries of the Organisation for Economic Co-operation and Development (OECD) have already integrated a substantial amount of wind energy into their energy mix, while an increasing number of developing and emerging countries are now looking to this energy source as a central component of efforts to diversify their energy mix, and respond to the climate challenge. But much more can be done to realise the full potential of wind energy. Large-scale integration of wind power into electricity grids and markets requires a commitment to outcomes by both public and private stakeholders since the early stage of planning and implementing the appropriate policy framework. Overcoming regulatory, financing and development barriers at national and local level is crucial to achieving the target share of 15% to 18% of global electricity from wind power by 2050.

It is thus fitting that wind energy is the focus of the first publication in the *How2Guide* series. Intended as a practical tool for both policy makers and industry players interested in developing a wind power roadmap, this publication should serve as one small but important part of IEA efforts to foster a sustainable energy future.

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

Maria van der Hoeven
Executive Director
International Energy Agency

1. The *Energy Technology Perspectives* (*ETP*) 2DS sets the target of cutting energy-related carbon dioxide (CO_2) emissions by more than half in 2050 (2009 baseline), and ensuring that these continue to fall thereafter.

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Introduction

About technology roadmaps

The overall goal of a technology roadmap is to accelerate the deployment of a specific technology or group of technologies. A roadmap is simply a strategy, a plan describing the steps to be taken in order to achieve stated and agreed goals on a defined schedule. It defines the technical, policy, legal, financial, market and organisational barriers that lie before these goals, and the range of known solutions to overcome them.

The process of developing a roadmap is as important as the final document itself: it represents consensus among the full range of stakeholders consulted in its development. Ideally, a roadmap will be a dynamic document, updated as the market in question evolves and incorporating metrics to allow for monitoring of progress towards its stated goals.

About the *How2Guide for Wind Energy*

This *How2Guide for Wind Energy* (*Wind H2G*) is designed to provide interested stakeholders from both government and industry with the necessary tools to plan and implement a roadmap for wind energy technology at the national or regional level.

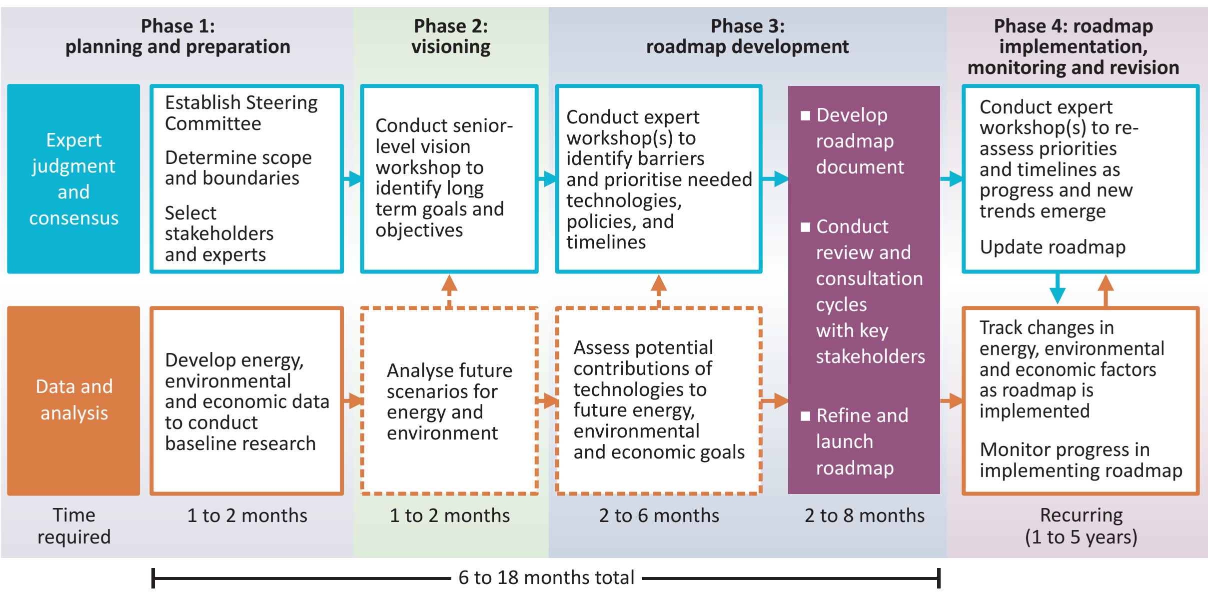
This guide is a wind-specific supplement to the IEA generic roadmap methodology manual, *Energy Technology Roadmaps: A Guide to Development and Implementation* (hereinafter the IEA *Roadmap Guide*),[2] which was released in 2010 and updated in 2014. Figure 1 below shows the general process of developing a roadmap as set out in the IEA generic *Roadmap Guide*. The *Wind H2G* explores key elements of this roadmap process with particular regard to their relevance in developing a roadmap for wind energy technology.

This publication is focused on utility-scale wind energy installations (i.e. of multiple megawatts), rather than on smaller plants for individual homes or localised communities. It is likely to be of particular interest to those seeking to grow wind energy markets, both onshore and offshore, whether in countries with limited installed capacity for wind energy, or those with experienced markets seeking to accelerate growth.

Recognising that it would be impractical to attempt to cover every aspect of wind energy technology in every national case, recommendations are illustrated throughout the guide with case studies for the reader to consider.

2. The *Wind H2G* follows the structure and content of the IEA *Roadmap Guide* (forthcoming1).

Figure 1: Roadmap process



Notes: timescales are indicative. Dotted lines indicate optional steps, based on analysis capabilities and resources.
Source: adapted from IEA (forthcoming1), *Energy Technology Roadmaps: A Guide to Development and Implementation*, OECD/IEA, Paris.

About wind energy

Onshore wind energy is a tried and tested technology that is already cost competitive with conventional power in some parts of the world, for example in Australia, Brazil and parts of the United States, among others. In 2012, USD 78.3 billion was invested in the wind energy sector globally, and while the global economic downturn continues to act as both a direct and indirect drag on investment, wind energy has nevertheless become a significant global industry in its own right (BNEF, 2013a).

Wind energy plants are being widely deployed wherever economic conditions are conducive. Wind energy can already claim to be a major source of electricity: in 2012, wind energy provided about 30% of electricity consumption in Denmark, 20% in Portugal, 18% in Spain, 15% in Ireland, 8% in Germany, nearly 4% in the United States and 2% in China (Wind Implementing Agreement, 2013d).

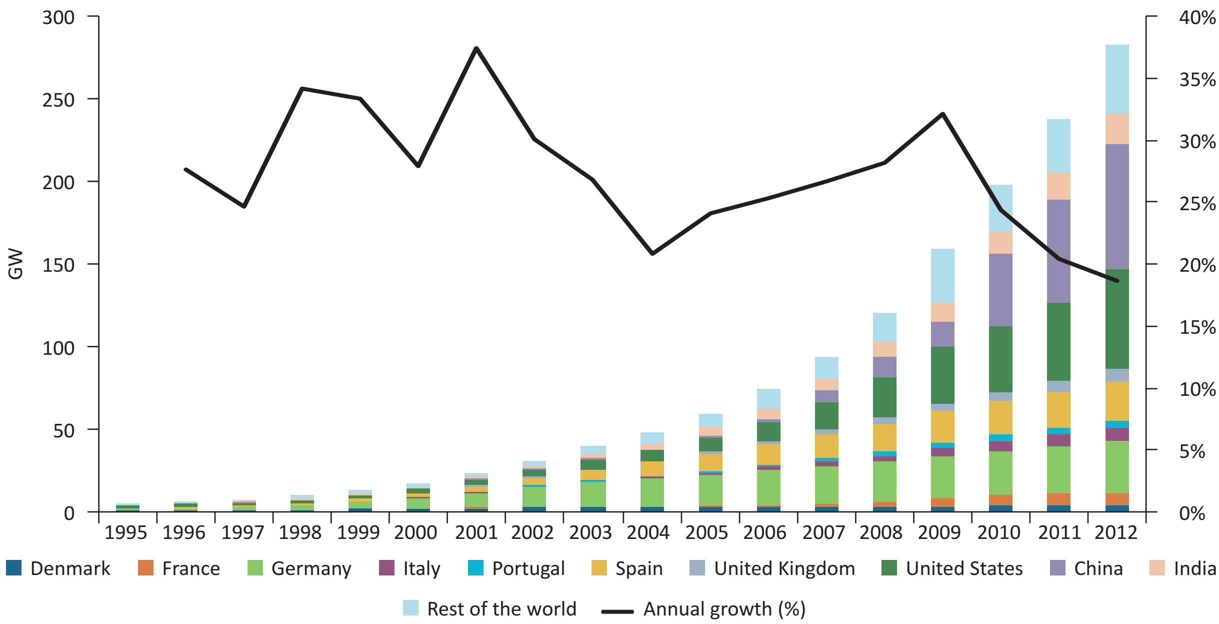
The benefits of wind energy are numerous and varied. Wind energy may provide an opportunity to diversify a nation's supply mix, to reduce reliance on fossil fuels, and to reduce environmental damage as compared with conventional energy sources. Deployment of wind power at scale can reduce dependence on imported fuels,[3] and reduce exposure to price volatility of those fuels. Additionally, wind power can generate significant value for a country's economy through supply chain investment and job creation. More broadly, there is increasing recognition of the ability of wind energy, along with other renewables, to help spur innovation and thus stable, long-term economic growth.

Wind energy began to emerge in the 1970s, partly in response to the oil crisis, and particularly in countries exposed to fossil fuel price inflation with limited reserves of their own, such as Denmark. However, up until the 1990s, global wind power capacity remained at low levels: only 1.7 gigawatts (GW) in 1990. It was not until the end of that decade that the market for wind energy really began to accelerate, reaching a global installed capacity of over 282 GW in 2012 (GWEC, 2013).

Figure 2 below demonstrates how the global wind energy market has grown cumulatively from 1995 to 2012, and provides a breakdown for the top ten global markets. The data show how rapidly growth has accelerated in the last decade, and that growth is forecast to continue.

3. Or, if the country is a net exporter of fossil fuels, it can reduce internal consumption so that more production is available for export.

Figure 2: Global cumulative growth of wind power capacity



Source: IEA (2013a), *Technology Roadmap: Wind Energy*, OECD/IEA, Paris.

Modern wind turbines and related technology have evolved rapidly over recent decades. This evolution has had several aspects, of which two are particularly relevant. First, turbines have continued to increase in size, from an average of around 1 megawatt (MW) in 2002 to 2 MW in 2012 (Wind IA, 2013d). Second, average capacity factors[4] have risen: in other words, each megawatt installed now produces more electricity than in the past. This is mainly a result of larger rotors and improved design, and to some extent also a result of improved siting, including for offshore wind turbines. Such improvements will continue to support the deployment of wind power in more remote locations,[5] will further expand the offshore market, and will support the repowering and replacement of older turbines in existing wind power plants (WPPs).

Offshore wind energy

The offshore wind energy market is far younger and less mature than the onshore one. By the end of 2012, 5.4 GW had been installed, 90% of that in northern European waters (GWEC, 2013). Generally, offshore projects present higher risks during project development, and through construction and in operation, as well as greater average costs and complexity. The major offshore wind energy markets presently face political uncertainty in the longevity and extent of support mechanisms for the technology. This is likely to impact investor confidence and national ambitions, slowing development. In spite of the uncertainties, the offshore wind energy industry is still expected to grow at a compound annual growth rate (CAGR) in excess of 15% per year in Europe over the period 2013-20 (BNEF, 2013b). According to recent IEA estimations, by 2018 offshore wind energy could reach 28 GW globally, delivering 76 gigawatt hours (GWh) of electricity (IEA, 2013b).

4. Capacity factor is usually represented as a percentage of the total electricity that would have been produced, had the generator in question been operating at rated (maximum) output for all 8 760 hours of the year.

5. One such example is the Cabeolica wind farm in the Cape Verde islands 340 km off the coast of West Africa, which was commissioned in September 2011 and now provides 25% of the country's electricity (http://eleqtra.com/projects/cabeolica-wind/).

The challenges of developing offshore wind energy are such that capital costs can be, at present, up to three times higher than for onshore, although this is offset to a degree by the higher capacity factors experienced offshore. Depending on a number of factors, including distance from the shore and water depth, recent studies indicate that investment costs for offshore wind energy span from USD 3.6 million/MW to USD 5.6 million/MW (Wind IA, 2013d; JRC, 2013). In comparison, the investment cost for land-based wind power generation ranges from USD 1.1 million/MW in China, to a high of USD 2.6 million/MW in Japan. Mid-range prices are found in the United States (USD 1.6 million/MW) and Western Europe (USD 1.7 million/MW) (IEA, 2013a).

System integration

Wind energy, like most renewable energy, is strongly dependent on weather and geography; electricity output fluctuates with the changing wind speed. Although this variation is not discernible in the range of seconds to minutes, in the space of one day the aggregated production of a country can, on occasion, ramp from near zero to near maximum, and vice versa, of the total installed wind energy capacity. Systems that incorporate a large share[6] of wind power need sufficient flexibility to respond to this variability. Flexibility comes from both resources and institutional (regulatory and market) arrangements. Flexible resources will differ from case to case, ranging from dispatchable plants (such as reservoir hydropower and gas plants, pumped hydro storage, demand-side management and response) to trade with neighbouring systems through interconnectors, and even the variable power plants themselves, as with some offshore wind energy plants in Denmark. It is not enough that such flexible resources exist: they must be available and able to respond and have incentive to do so, as and when required (Box 1).

6. Exactly what constitutes a "large" share will vary with location. Integration issues tend to become more challenging when annual shares of energy exceed approximately 10% in average-sized systems (Wind IA, 2013c).

Box 1: Grid integration of variable renewables

For several years, the IEA has sought to contribute to global thinking on system integration and management of variable renewable energy technologies. Following on from *Harnessing Variable Renewables: A Guide to the Balancing Challenge* (IEA, 2011), a second publication, *Advancing Variable Renewables: Grid Integration and the Economics of Flexible Power Systems* (IEA, 2014), analyses the technical challenges associated with the system integration of large shares of wind and solar photovoltaic electricity and provides recommendations on how to meet these challenges cost effectively. Meanwhile, "Task 25" of the IEA Wind Implementing Agreement (Wind IA, 2013c) has established an international forum for exchange of knowledge and experience related to power system operation with large amounts of wind power, defining best practice recommendations in collaboration with transmission system operators (TSOs).

The use of smart grids and smart meters may bring about significant changes in the relationship between customers and energy providers, potentially allowing for increased levels of control of energy consumption for the customer and conditions of service for the provider. Realising this potential, however, requires “smart policies” and appropriate deployment strategies. To facilitate this process at national and regional levels, the IEA is working on a *How2Guide for Smart Grids* (IEA, forthcoming2).

The roadmap development process

As set out in the *Roadmap Guide* and Figure 1 of this publication, there are four phases to developing a wind energy technology roadmap:

- planning and preparation
- visioning
- drafting
- implementation and adjustment.

This guide elaborates on some of the wind-related considerations for each phase.

Phase 1: planning and preparation

Baseline research on the chosen technology and identification of stakeholders to be involved in the roadmapping exercise is central to sound roadmap planning and preparation.

Conducting baseline research for wind energy

A roadmap should identify the desired scale and schedule for wind technology deployment, and the changes that will need to be made throughout the energy market in question to achieve that scale on time, such as grid reinforcement and expansion. To achieve this, it is first necessary to understand the present situation for wind energy in the country or region in question; solid baseline research will provide strong foundations for developing roadmap goals and tasks.

In the case of wind energy, baseline research should aim to provide a detailed overview of the status of technologies, markets and policies relevant to wind energy deployment. It should facilitate discussion and analysis of possible roadmap targets based on a common understanding of the present situation and it should determine the extent to which wind power can contribute to wider energy needs (e.g. heating and cooling or transport) as well as other objectives, such as economic growth and competitive advantage, job creation and environmental protection.

Broadly speaking, key aspects of baseline research for a wind energy roadmap will likely include the following:

- the wind energy potential within the designated geographic area, based on a resource assessment
- the extent to which the evolving energy system and market can manage wind output variability and uncertainty
- the extent to which supply chains and the available specialised workforce can match levels of ambition
- the role of wind power in the wider energy portfolio and national power market
- wider energy policy and its impact on competing energy technologies.

Table 1 sets out more detailed questions that stakeholders could consider when conducting baseline research in a given national context.[7]

7. The report *30 Years of Policies for Wind Energy: Lessons from 12 Wind Energy Markets* (IRENA and GWEC, 2012) provides further valuable information on conducting baseline research aimed at assessing the policy and regulatory adequacy of an existing system.

Figure 3: Planning and preparation phase

Notes: In this figure, and in Figure 4 and Figure 7, each arrow represents a sub-step in one of the four phases of the roadmap process set out in the IEA *Roadmap Guide* and in Figure 1 of this report. Purple-shaded arrows indicate sub-steps that are also discussed in this *Wind H2G*. Unless otherwise indicated, all material in figures and tables derives from IEA data and analysis.

Table 1: Key questions for baseline research on wind energy

	Description
Wind resource and technology	• Is there a significant wind resource that can be economically exploited? • What coverage already exists in the assessment of the wind resource? How accurate is it? Does it reflect wind speeds at the hub height of modern wind turbines? • What is the present ability of transmission and distribution grids to accommodate additional variable power generation? • What additional grid capacity and investment will be required to meet targets? Is there likely to be public opposition to new transmission? • How might current system operation practices constrain the management of wind energy? Has the operator experience with managing grids with significant shares of variable renewables? Is it likely to embrace new operating practices? • If high penetration levels of wind energy are targeted, are there plans to increase the flexibility of the power system to better manage variable power output?*
Market and energy portfolio	• What trends are having/likely to have impact on the electricity market in the roadmap time frame (e.g. demand growth, supply deficit, ageing infrastructure, public sector investment or electricity sector restructuring)? • Is the country dependent on imported fuels for electricity generation and therefore exposed to global commodity price fluctuations? • What potential exists for wind energy cost reductions during the roadmap time frame? • What is the current annual market for domestic and foreign investment in wind energy? How can this be scaled up and how quickly can such scale-up occur? • Is the market dominated by a small number of vertically integrated utilities? Can independent power producers access the market? • What is the likely impact of wind energy expansion on the operation and business models of the other power suppliers in the same system? • How strong is the wind energy supply chain, and how is it structured? Are there targets for specific associated industries? What elements are likely to be in tight supply? • How much experience does the country have in developing wind energy projects, including planning, construction and operation aspects? • Is there sufficient developer build-capacity to deliver the targeted wind energy capacity? • From where are materials, components and turbines sourced? Is the supply chain international or predominantly domestic? • What are the strengths of the existing workforce in the country? • Which are the synergies between existing industrial activities and wind energy?
Public policy	• What are the key socio-economic priorities that might be supported by wind energy (employment, industrial growth, productivity, standard of living, rural development)? • To what extent would planning for wind energy development come into conflict with other spatial planning priorities, e.g. protection of habitats, recreation, settlement? • Have the societal and economic benefits of wind energy been adequately communicated to the public, in particular to those who will be affected by the development of new wind energy installations and transmission infrastructure?

* see footnote 6

	Description
Public policy (continued)	● Is there a coherent energy strategy? Are all the relevant government ministries or agencies involved and co-operating? Have adequate personnel resources, proportionate to the scale of national ambition, been allocated within the key bodies to implement the change? Have supporting activities, such as education and training and information campaigns, been planned? ● Is there a clear and coherent research and development (R&D) policy regarding wind energy? ● Is there an incentive mechanism in place that offers support specifically to wind energy (e.g. feed-in tariffs [FIT], quota system, fixed-price tenders, capacity auctions, etc.)? ● Are there targets that are supportive to deployment of wind energy? At which level (e.g. decarbonisation of electricity in general, renewables, wind energy, offshore wind specifically, etc.)? ● Are there international or other obligations concerning greenhouse gas emissions that apply to the region in question? ● Has necessary energy sector reform been considered to allow for large-scale variable generation integration into national or regional grids?

Some countries may not have baseline data, such as wind resource maps, readily available or may lack the technical know-how "in house" to perform the long-term modelling usually employed. In such cases, while one might ideally seek to foster institutions domestically to provide such services, it may be useful at first to work with external organisations. The *Global Atlas for Solar and Wind* is a valuable resource in this regard (IRENA, 2013).

Identifying wind energy stakeholders

In most countries, there is a wide range of stakeholders essential to the growth and development of the wind energy sector. For the potential of the market to be met, there must ordinarily be close interaction among them. Not only is it important to identify these stakeholders prior to developing a roadmap, it is also important to consider how different stakeholders should be involved in the roadmapping process. As explained in greater detail in Tables 2 and 3, plotting identified stakeholders on a "RACI Chart"[8] may assist not only in the comprehensive identification of relevant stakeholders, but also in the coherent assignment of functions.

Table 3 below indicates typical wind energy stakeholders and their possible categorisation in the RACI chart.

8. The "Responsible, Authorised, Consulted and Informed" (RACI) chart is a management tool that is used to define responsibilities among a group. It is a responsibility assignment matrix.

Table 2: Stakeholders' categories and mandate: the RACI chart

Stakeholder category	*Definition*	*Mandate can include*
Responsible	This is the group that has the authority to approve the final product. The composition of this group should reflect the bodies that will be involved in implementation of roadmap recommendations. Membership should be limited to senior individuals (typically Director level) from government, industry and research. It may often be the case that the broader the membership, the greater the likelihood that the roadmap will secure buy-in. Throughout this guide, this group will be referred to as the "Steering Committee".	● Approve the roadmap goal, scope and boundaries ● Assign various roadmapping responsibilities to members of the roadmap project team (referred to as "Authorised" [see below]) ● Direct the analytical effort (including and based on the baseline research) ● 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 actually undertaking the vast majority of the work to develop 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 drafts ● Plan the necessary workshops ● Document gathered information ● Perform the analysis
Consulted	This group typically includes expert representatives from organisations that have a key role for the deployment and commercialisation of the technology, from utilities to manufacturers and bodies or non-governmental organisations (NGOs) representing individual consumers, 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 as appropriate
Informed	These stakeholders are those that 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.	● Informed about roadmap findings ● Not typically actively involved in the workshops or other activities

Source: IEA (forthcoming1), *Energy Technology Roadmaps: A Guide to Development and Implementation*, OECD/IEA, Paris.

Table 3: Stakeholder mapping for wind energy

Stakeholder type	Corresponding RACI category
Government (e.g. ministries for environment, energy, treasury, etc.) and other policy makers at national to local levels, as appropriate	Responsible and Authorised and/or Consulted
Industry groups and associations	Consulted or Responsible/Authorised (if roadmap is industry-led)
Project developers	Consulted or Responsible/Authorised (if roadmap is industry-led)
Electricity market regulating body or permit providers	Authorised
Network owners and power system operators (at transmission and distribution levels)	Authorised or Consulted
Land-use and planning decision makers (e.g. local authorities)	Consulted
Aviation authorities (civilian and military)	Consulted
Investors (e.g. development banks, other lenders, venture capitalists, pension funds, etc.)	Consulted
Landowners (public and private)	Consulted or Informed
NGOs, e.g. environmental NGOs, research institutes, universities, etc.	Consulted or Informed
Technology providers	Consulted or Informed
Electricity consumers in the residential sector	Informed
Community groups and local population at large	Informed

Box 2: South African stakeholder case study

The South African system for renewable energy procurement requires that developers apply for a series of licences, permits and quotes. This requires direct engagement with Eskom – the South African grid operator, the Department of Water Affairs, the Department of Agriculture, Forestry and Fisheries, the National Energy Regulator of South Africa and the Department of Energy.

In addition, developers are required to fulfil requirements concerning minimum percentage project equity by South African investors and minimum percentage ownership requirements by Black Economic Empowerment (BEE) partners and local communities. These conditions require wind energy plant developers in South Africa to engage in a range of stakeholder relationships, either directly with local communities and South African investors, or via intermediaries such as the Industrial Development Corporation (IDC) and the Development Bank of South Africa (DBSA).

While this policy framework may be complex, it has been designed to serve wider national objectives, in terms of optimising local content in the development of the renewable energy industry and stimulating local ownership, capacity and even manufacturing capability. As such, it creates a series of factors that must be managed carefully by the developer. Even with these complexities, the South African renewable energy market is one of the fastest growing globally, with investment in renewables rocketing to USD 5.4 billion in 2012, a rise of over 20 000% on 2011 (BNEF, 2013d).

Phase 2: visioning

The second phase in the roadmap development process is to outline a vision for wind energy technology. A successful roadmap contains a clear statement of the desired outcome, followed by a specific pathway for reaching it. Developing an overall vision of the future for wind energy in a given time frame can include environmental, technology and policy objectives, and would ordinarily focus largely on the high-level impacts that the deployment of wind technologies could have in the country or region in question. Two national examples are provided below.

The *Technology Roadmap: China Wind Energy Development 2050*, developed jointly with the IEA and the Energy Research Institute (ERI) of the People's Republic of China, is the first such example (ERI and IEA, 2011). The national vision identified in the roadmap was a move away from a coal-based energy mix to modernisation of the national energy system and the promotion of clean energy use, with a goal that by 2020, non-fossil energy sources will contribute 15% of total primary energy consumption nationally. The roadmap identified the "vigorous" promotion of wind power as one of the main avenues for achieving these national goals.

A second example is that of Canada, which pursued an industry-led, government supported approach setting out a long-term vision for the Canadian wind energy industry, identifying along the way the technology gaps and setting priorities for a major increase in the deployment of wind energy (Natural Resources Canada, 2009). The roadmap identifies a common vision in which Canada seeks to become a global wind energy leader, meeting more than 20% of its electricity needs through wind energy by 2025.

These examples demonstrate how wind technology is being pursued as a central element of national energy policy, and is increasingly being embedded in countries' overall plans to diversify their energy mix to reduce dependency on fossil fuel-based resources while developing modern and clean wind energy resources. Readers may also wish to examine the recently updated IEA *Technology Roadmap: Wind Energy* for further insights on the role of wind in meeting energy objectives globally (IEA, 2013a).

The identification of key drivers for the deployment of a technology may provide a basis for a statement of rationale for a national wind roadmap, which can in turn help determine the vision for wind energy in a given country. Despite great variation in geographic and policy contexts, the drivers to deploy wind technologies are often fairly similar across countries. Based on research and inputs from stakeholders, the list below briefly describes some of the main drivers behind deployment of wind energy in selected markets.

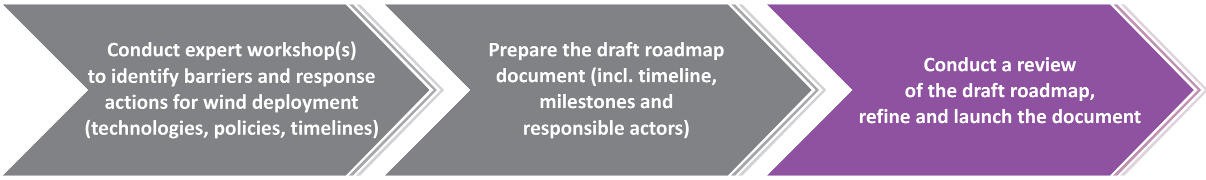
- **Brazil:** diversify energy mix and support industrial strategic priorities.
- **China:** diversify energy mix, meet CO_2 emissions reduction objectives, meet demand growth and support industrial strategic priorities.
- **Denmark:** reduce energy imports and meet CO_2 emissions reduction targets.
- **India:** diversify energy mix, meet demand growth and reduce electricity supply deficit.
- **United Kingdom and Ireland:** meet CO_2 emissions reduction targets and diversify and decarbonise energy mix.

Phase 3: roadmap development

The third phase of roadmap development concerns the preparation and review of the draft roadmap itself. As the IEA *Roadmap Guide* highlights, having set a vision, it is essential to clearly identify the specific barriers to acceleration of wind energy, the actions to address those barriers and the timelines for reaching the desired level of wind energy deployment (Figure 4). Expert judgment, gained through the hosting of roadmap workshops, will be essential in identifying barriers to the deployment of wind energy and selecting suitable and realistic response actions.

This section of the *Wind H2G* considers the kinds of barriers and response actions that one might envisage in relation to wind energy deployment. It also discusses the identification of milestones, a timeline and responsible actors for carrying out key actions in the roadmap. For specific suggestions on the structure of a draft roadmap report, see Annex.

Figure 4: Roadmap development phase



Identifying barriers and actions to overcome them

Barriers to, and related actions for, wind technology deployment can be grouped into five categories:

- planning relating to developing WPPs (including environment factors)
- development aspects (including social acceptance factors)
- electricity market and system aspects
- financial and economic aspects
- infrastructure aspects (including availability of specialised professionals).

Each category of potential barriers is described in greater detail below, with a description of the issues as well as a number of solutions, or response actions, that may be relevant. A similar approach was taken to identify the barriers in each case: (i) analysis of wind energy installations currently under development or already operating globally; (ii) interaction with stakeholders via dedicated regional expert workshops; and (iii) discussions with wind energy technology developers, financiers, policy makers and academics. The suggested response actions were generated in the same way, offering the policy maker a solution or "action pathway" for each barrier.[9]

Importantly, the occurrence of barriers and the availability of appropriate responses will vary according to geography, market maturity and policy regime. While every effort has been taken to identify a comprehensive set of potential barriers and actions, the list is not exhaustive.

9. For more details on all wind-specific terms used in the tables below, and throughout this publication, please refer to the glossary.

Planning barriers

In this guide, "planning" refers not only to the formal development process as set out within the laws of a country, but also to informal exchanges, for instance with populations local to the intended development.

Planning issues will not relate solely to the WPP. Policy makers must also factor in related infrastructure, such as works necessary for connecting to the local electricity distribution network, electrical transformers and sub-stations, and access roads and other transport infrastructure. Also included within this category of barriers are local environmental protection factors.

When identifying which issues apply in a particular jurisdiction and how one might prioritise the barriers, it may first be useful to compile a list of potential tensions between the planned WPP and other local land use. Table 4 identifies likely barriers and metrics with which to track them.

Table 4: Barriers and action options for planning considerations

Barrier	*Details*	*Action options*
Competition with other activities (existing or planned, onshore or offshore)	• Statutory restrictions apply to site; site has other economic/ landscape value • Offshore WPPs restrict other marine uses • Land may have historic value	• Reform national planning rules • Assign government to broker planning permissions • Establish national-level body to resolve disputes • Encourage creation of spatial development plans
Proximity of WPP to buildings	• Operational plants create sporadic noise • WPP has a perceived negative visual impact – landscape or shadow flicker	• Require Environmental Impact Assessments (EIA) • Fund public engagement exercises • Appoint government to resolve disputes • Establish standards for noise levels and ensure enforcement
Concerns that wind turbine operation may interfere with communication systems	• Defence radar potentially affected by WPP operation and project blocked by military • Civil aviation, telecoms or meteorological radar potential affected by WPP operation	• Assign military authorities to map areas of constraint and encourage early consultation • Establish policies for minimum distance standards for civil aviation, meteorological facilities and WPPs; investment to upgrade radars where critical*
Imbalance between environmental protection and development	• Cumulative impacts of multiple WPPs not considered • Ecology in the vicinity of the WPP disturbed/damaged during development and operation • Environmental regulation or lack of baseline environmental data may place excessively onerous requirements on developers	• Conduct Strategic Environmental Assessment (SEA) on regional/national basis • Develop national research projects to address general concerns • Assign national body to resolving disputes • Maintain balance between pragmatism and environmental considerations
Planning process may be overly burdensome	• Involvement of multiple and conflicting government bodies makes licensing process overly complex and lengthy • Institutions lack capacity to manage applications • Wind project developers lack competence in preparing planning application	• Rationalise and align policies at every level of government. Co-ordinate between authorities and make sure all authorities have adequate information for processing applications • Modify planning system to manage conflicts between developers and local population • Establish one-stop shop to streamline planning processes • Educate and train developers in application process

* Ideally, developers and aviation authorities (civil and military) should consult early in the planning process. If all necessary data on the wind energy project and radar system are disclosed, it should ordinarily be possible to determine jointly the ideal wind installation layout and any necessary mitigation measure that may need to be applied to the WPP and to the communication system.

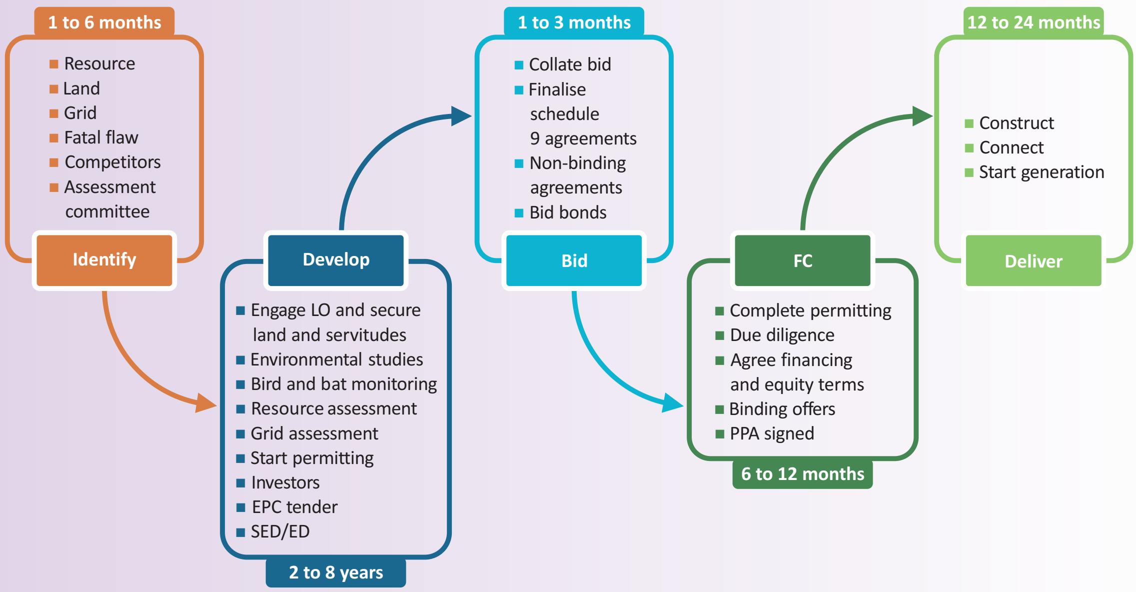
Box 3: Typical wind energy business case

Business cycle and developer milestones

Below is an illustration of the process for developing an onshore wind energy project. It highlights the complexity of the development process and the time required, demonstrating that in some instances it may take as many as eight years for a project to be realised. Offshore, lead times may exceed this.[10] Figure 5 is an illustration of the wind energy development process, based on material provided by a developer in South Africa. It sets out the timeline for the development process, as demonstrated by the arrows, and the steps implemented along the way: **Identifying** the site, **Developing** the project, **Bidding**, **Financial Closure (FC)** and **Delivery**. While this is an illustration from one country, many of the steps therein may be considered typical for wind energy development elsewhere, although the time taken to implement and conclude steps will vary greatly from one country to another. A key message is that planning a wind energy installation takes time and requires the involvement of a great variety of stakeholders on diverse issues from land permits to grid assessment, financing and so on. Also, the permitting lead time for major transmission projects is much longer than for wind energy installations. Where wind energy targets require significant transmission system expansion, the development cycle for new transmission lines will need to be taken into account.

10. In an extreme example, the 468 MW Cape Wind project planned off the coast of Massachusetts in the United States required twelve years for planning and has yet to arrange financing, let alone construction, which may well extend the project a further 2-3 years (BNEF, 2013c).

Figure 5. An Illustration of the wind energy installation development process in South Africa, from a developer's perspective



Source: adapted from Mainstream Renewable Power South Africa (2013), "Challenges facing project development in the region: Experience of building projects from the earliest stage of conception through to securing planning consent", presentation at the IEA-SANEDI expert workshop on the *How2Guide for Wind Energy,* Johannesburg, South Africa, 28 October 2013.

Note: The following acronyms stand for: LO = landowner; SED = socio-economic development; ED = economic development; FC = financial close; PPA = power purchase agreement.

Box 3: Typical wind energy business case (continued)

Factors affecting the business case for wind energy projects

The business case for a WPP depends on the financial appraisal of the development. As part of this, the investor seeks to determine the risk profile of a wind energy project, considering issues such as wind resource assessment, technology selection, planning and permitting, the construction process and timetable, lifetime cash-flows, and operation and maintenance plans. The investor needs to be sure that the project developer is able to secure rights to land and grid access, has clear permitting requirements, and can manage stakeholders. Until such issues and others are addressed, it is unlikely that any financial commitment on the part of an investor will be forthcoming.

The process of reviewing all these issues is referred to as the "due diligence evaluation" of a project.

It is crucial that the policy maker understands the full extent to which his/her actions can support the wind energy business case. Probably the greatest policy impact on the cash flow of a project will result from a regulated FIT or other financial or fiscal incentive. But an enabling environment is also of the utmost importance. Clarity and brevity of planning processes, and adequate transmission infrastructure, are two of the most important facilitators; they are discussed in detail in Table 4 and Table 9 of this *Wind H2G*.

Development barriers

Barriers encountered in the development phase of WPPs mainly concern issues faced by developers, including both technical and social acceptance factors. Policy makers can act in concert with the range of appropriate stakeholders to diminish these. Barriers range in scale from site-specific to regional and national. Barriers likely to be encountered are set out in Table 5.

Table 5: Barriers and action options for development aspect

Barrier	Details	Action options
Inaccurate or inaccessible mesoscale data on the strength and distribution of wind resources	• Absence of public data on energy content of wind resource limits attractiveness to developers • Absence of data on resource quality; i.e. climatic conditions limit attractiveness to investors and developers	• Develop or procure publicly available national wind atlas, including long-term mean wind speeds and direction data and time-series data if possible • Establish national platform for anonymous data-sharing to improve access to and accuracy of wind data • Make accessible all existing meteorological and wind resource assessment data
Obstacles to WPP siting (additional to those under "Planning" in Table 4)	• Data on land or seabed topography and geology are inaccurate or unavailable • Desirable sites are inaccessible to construction and maintenance teams • Opposition of local population affected by the new wind power installations	• Undertake geological and topographical survey in priority areas; ensure public access to existing data • Develop new access infrastructure if appropriate • Implement communications strategy targeting local population and media with factual information about the positive impact of wind energy on jobs, the economy and the environment*

* Among others, the following publications can be useful for building solid arguments in support of new wind power installations and communicating the benefits of wind energy to society: Devine-Wright, 2005; EWEA, 2013, 2012 and 2009b; IRENA, 2012; and Wind IA, 2013b.

Barrier	Details	Action options
Connection to grid is constrained	• Transmission and/or distribution grid owner may not wish (or lack capacity) to connect • Offshore connection costs may be prohibitive • Connection fee may be inappropriate • Local opposition prevents construction of new grid connection • Point of connection may be disputed among developers or with transmission owner • Long distance between potential site and grid node can be a barrier due to cost or existing rights of way	• Regulate monopoly control to allow access for Independent Power Producers (IPP) • Educate local population on benefits of wind power (GHG reduction, green jobs) • Consider underground power lines • Regulate system operators to ensure rates reflect costs • Distinguish connection costs from grid reinforcement costs and assign appropriately • Engage with local stakeholders to manage trade-off between new grid infrastructure and benefits of wind power
Operational aspects	• Wind turbines present health and safety challenges (e.g. ice throw) • Assignment of decommissioning costs • Repowering demands grid upgrade • Shortage of qualified personnel for the operations and maintenance (O&M)	• Ensure interface with planning process to avoid conflicts and provide contact point for local residents • Ensure wind energy policy addresses end-of-life issues (decisions regarding recycling or decommissioning equipment versus repowering) • Ensure that O&M training programmes exist at national or regional level that are consistent with the desired level of wind energy deployment

Electricity market and system barriers

The third category of barriers covers the design of the electricity market and system. This category includes barriers to the efficient management of electricity generated by WPPs, as outlined in Table 6. This set of barriers and the action options to address them are closely intertwined. An effort has been made here to distinguish among them, but the best approach to this classification process may vary considerably from case to case.

Table 6: Barriers and action options for electricity market and system considerations

Barrier	Details	Action options
Wind electricity generated is prevented from getting to the market (curtailed)	• (Excessive) curtailment may result from insufficient space in the market (even if public-private agreement [PPA] is in place) • Combined ownership of generation and transmission may hinder access to transmission capacity • (Excessive) curtailment may result from grid bottlenecks/ congestion	• Revisit ”must run” classification of conventional power plants and consider according “must run”/priority dispatch status to WPPs • Separate ownership of generation and transmission assets • Use nodal or locational pricing to signal congested areas and transmission bottlenecks • Encourage trade to wheel surplus wind energy across borders • Optimise re-dispatch procedures and reduce opportunities for gaming by capping congestion management prices • Consider flexibility and efficiency improvements in the energy system – at higher penetration levels in particular, incentivise demand-side management and energy storage to provide ancillary services
Wind energy may result in increased system operation challenges above a certain threshold (e.g. 10%-20%)*	• System operators (TSOs and DSOs) may not have adopted international best practice, which itself may act as a barrier to change • Wind power may have impact on local or regional grid voltage and power quality • Variability of wind power may have a negative impact on system-wide balancing and frequency • WPPs may exacerbate (low voltage) fault conditions by disconnecting**	• Advocate system operators’ adoption of state-of-the-art practice, and a comprehensive suite of plans and measures to progressively deal with increasing levels of wind energy penetration, including wind forecasts and on-line monitoring in dispatch and operations • Improve policy maker understanding of the issues to better manage operators’ concerns • Revise grid code to include voltage control and active power control by wind energy plants • Encourage enhanced control and communication technologies, such as storm control function, to reduce output ramp rate • Have system operators deploy power electronics for voltage control near large WPPs if this is more cost-effective than the WPP providing the service • Actively involve distribution grid managers in managing power flows

* The identification of this share is complex and subtle. Many factors will have a bearing here, including the size of the power system, the make-up of the generation portfolio and correlation of load and wind profiles, among others.

** Although in most cases this should no longer be an issue, it is common industry practice to include so-called “fault-ride-through” capability in modern wind turbines.

Barrier	Details	Action options
Large shares of wind energy may bring need for power market modification	• The output of a WPP portfolio may ramp up steeply • Wind power output is predictable with less accuracy than conventional power on a day-to-day basis • Electricity market may be dominated by vertically integrated utilities (VIU) • Electricity trade may be tied up months, seasons, or years ahead • Most electricity may be traded bilaterally and confidentially over the counter (OTC) • Imbalance prices paid by WPP owners may not reflect actual cost to system	• Encourage holistic planning of wind and other variable generation for minimal correlation of outputs to reduce aggregated variability • Encourage market reform for development of exchanges and futures markets, including proper design of intraday and balancing markets • Introduce shorter trading time horizons; set "gate closure" as close as possible to delivery time • Consider unbundling vertically integrated utilities (generation, transmission and system functions) or other regulatory measures to enhance competition • Encourage wider market collaboration in balancing markets or merging balancing areas • Encourage power exchanges wherein participants have the opportunity to trade openly (as well as OTC) • Reflect real cost to the system through imbalance pricing and enable wind power producers to aggregate their offers to reduce imbalance • Encourage uptake of latest forecasting techniques
Large shares of wind energy have consequences for generation portfolio planning	• Wind energy (alone) provides a lesser contribution to system adequacy than conventional plants • In the short term, the replacement of existing power plants (conventional baseload) with wind power may increase the overall operational cost of the power supply system	• Plan for and encourage wide geographic distribution of WPPs • Consider use of market mechanisms to compensate for lost revenue with payments to plants offering flexible capacity • Consider market reform to reward flexibility from different sources in order to encourage fast power plants, demand-side management and response, interconnection and storage

Financial and economic barriers

The analysis now moves on to financial and economic barriers. Two distinct types of investor are of interest to policy makers when seeking to encourage investment in a wind energy market: those providing commercial investment, and public investors. To attract investors to wind energy projects within a country or region, policy makers should seek to reduce the risks and improve returns on investing through the adoption of various support mechanisms.

It is worth noting that investment in new generation – whether wind or any other energy technology – needs to be co-optimised with the concomitant investment required in the transmission service of that asset. If the transmission cost is too great, alternative options may be appropriate.

Support mechanisms should not only focus on incentivising investment, but should also incentivise best long-term operation and management (O&M) practices that will allow the WPP to operate to its full potential design life, possibly long after the investment horizon. Table 7 below summarises the range of support mechanisms used in twelve wind energy markets. It should not be taken as an exhaustive representation of all policies used in these jurisdictions.[11]

11. For example, a feed-in tariff was also used in Italy, auction or tendering systems were also applied in Portugal, and a public tender procedure was run by the Danish Energy Agency in Denmark.

Table 7: The range of support mechanisms used in twelve wind energy markets

	Country	*Brazil*	*China*	*Denmark*	*Germany*	*Greece*	*India*	*Ireland*	*Italy*	*Portugal*	*Spain*	*United Kingdom*	*United States*
	Indicative summary of the range of support mechanisms used historically												
Remuneration	Feed-in tariff	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	
	Premium or adder system			✓	✓						✓		
	Auction or tendering system	✓	✓					✓			✓	✓	
	Tax based (electricity) production incentives												✓
	Spot market trading			✓	✓			✓	✓		✓	✓	
	Investment subsidy or tax credit			✓		✓	✓						✓
	Tradable Green Certificate (e.g. REC/ROC)						✓		✓			✓	✓
	Concessionary finance through goverment supported agencies	✓	✓		✓		✓				✓		✓
	Concession on import duty	✓	✓				✓						

Source: adapted from IRENA and GWEC (2013), *30 Years of Policies for Wind Energy: Lessons from 12 Wind Energy Markets*, IRENA, Abu Dhabi.

The power of the policy maker to support renewable energy markets is widely in evidence. One has only to look to the huge jump in investment volumes in South Africa from tens of millions of dollars in preceding years to USD 5.4 billion in 2012, following the conclusion of the first rounds of its renewable energy programme.

By the same token, policy can also undermine such markets. Spain, for example, has radically reformed its system of support for renewable energy and recently applied a tax on revenues. According to some analysts, this may result in a 16% to 18% reduction in the value of WPPs commissioned between 2009 and 2012 (BNEF, 2013e). This type of retroactive change in policy may also have knock-on effects for a country's ability to attract private investment and may subsequently slow the deployment of wind energy.

Table 8 below provides a summary of potential barriers and related action options one could consider to tackle financial and economic considerations in a roadmapping exercise for wind energy.

Table 8. Barriers and action options for finance and economic considerations

Barrier	Details	Action options
High upfront costs prevent wind energy development	• Technology risk considered too high by investors • Lack of infrastructure may make WPPs financially unviable • Lack of previous investment experience in target country makes commitments too risky	• Tackle structural market distortions by removing subsidies for fossil fuels • Invoke government support for wind power in the form of tax incentives, credit guarantees or access to affordable finance • Ensure national government prioritises investment in energy infrastructure • Establish or mandate public bank to support investment in wind energy projects where private investors regard the risks as too high, e.g. by underwriting risk
Investor uncertainty	• Instability in the policy and/or regulatory framework • Absence of reliable spot market price makes identifying representative electricity price difficult • Lack of or too few PPA counterparties prevents contracting at a reasonable price • The Levelised Cost of Energy (LCOE) of wind may be uncompetitive relative to other sources of power	• Establish stable government support mechanism to address LCOE issues (e.g. FIT, production tax credit, mandatory purchase price, quota obligation system or tradable certificate) • Implement national policy to support liberalised energy market • Incite national government or its bodies to buy power purchase agreements s directly • Require utilities or large energy users to buy power purchase agreements s from suppliers • Reform energy market to remove direct and indirect subsidies for conventional sources of electricity • Address wind resource uncertainty with national wind atlas or measurement database • Address technology uncertainties (O&M costs) by R&D and requirement for the producers to report to a failure statistic database
Lack of finance for WPP developments	• Project promoter or developer unable to provide equity into the project • Lack of bond finance for projects • Investment banks may be unwilling to offer project finance • Shortage of tax investors • Utility financing of project scarce (reluctance to finance on balance sheet)	• Establish or mandate public bank to support investment in wind energy projects, e.g. underwriting risk • Institute government intervention to reduce cost of loans through grant funding, credit guarantees, tax incentives • Urge government to support development of domestic or regional bond market in low-carbon goods • Build utilities' confidence via long-term policy certainty

Box 4: Brazilian wind energy case study

Brazil is the largest economy in Latin America and in 2011 this country generated 9% of its electricity from renewable resources other than large hydro, which is its largest single source of power.

In 2002, Brazil launched the Program for Encouraging Alternative Sources of Energy (Proinfa), a FIT scheme that drove the development of 52 wind power projects, representing 1 300 MW of capacity. The Proinfa programme was, however, hampered by several practical issues: (i) delays in obtaining environmental licences; (ii) land disputes; (iii) delays in grid connections; (iv) domestic supply chain problems; (v) existence of a cap (originally 1 100 MW) which made it uninteresting for companies to enter the market; and vi) a system easily gamed by speculators.

In 2009, the Brazilian government acknowledged these shortcomings and introduced a more streamlined approach, an auction regime administered by the Ministry of Mines and Energy. This system of auctions together with a highly supportive policy of loans and guaranteed purchase contracts from the Brazilian National Development Bank (BNDES) has driven rapid growth of wind power installation to an expected total of 5 300 MW in 2013.

Brazil has a "Ten-Year Energy Plan", published in 2011, which sets out a path for the steady growth of renewables, with 18 GW of new installations targeted by 2020. Challenges remain in the Brazilian wind energy sector; these include (i) the need for increased financing for projects, (ii) increasing the manufacturing capacity of the sector domestically and adapting to the national context, and (iii) improving the efficiency of the wind technology supply chain.[12]

12. Refer to GWEC (2012), "Analysis of the regulatory framework for wind power generation in Brazil" for further details.

Infrastructure barriers

A number of key infrastructural elements, on which a wind power development depends, but which are not directly within the control of the developer, make up a fifth category of potential barriers. Here, the role of policy makers and public sector institutions is critical in mediating among stakeholders, and bringing about appropriate solutions. Availability of skilled workforce – as a vital support for the necessary infrastructure to support wind energy development – has also been included here. Table 9 lists potential barriers and solution options.

Table 9. Barriers and action options for key infrastructure considerations

Barrier	Details	Action options
Supply chain is insufficient to meet the demands of the wind energy industry	• Lack of skilled or experienced workforce to support development • Shortage of WPP components	• Develop high school and university curricula, advanced degrees, and training to meet skills requirements of the wind energy sector • Remove trade barriers (e.g. import duties) • Encourage technology exchange with mature wind energy markets • Encourage adoption of international state-of-the-art technology by domestic providers • Support domestic manufacturing as appropriate and possible • Encourage foreign firms to locate manufacturing facilities in the country • Initiate targeted research project or work with developers to identify appropriate technologies
Transport infrastructure is insufficient to meet the needs of developers	• Long distance and/or difficult land transport of key components to site from manufacture is constrained and costly • Inadequate port infrastructure for offshore development	• Prioritise new trunk roads, rail links and inland waterways that access development areas • Fast-track remediation of width and height restrictions on trunk roads • Encourage investment in specialised port facilities • Build investor confidence to foster investment in specialist offshore installation vessels
Transmission and /or distribution grids' infrastructure are insufficient or inadequate	• Distribution grids in wind energy development areas may need reinforcement; transmission losses are excessive • Transmission grid does not reach high resource areas • Public opposition to new transmission lines is high • Transmission and distribution technologies are outdated • Individual parties and/or network users may not share assets in optimal manner • "Leading with transmission" may be difficult when cost recovery is unclear	• Encourage improved O&M of grid assets • Ensure interface with local government on infrastructure planning • Enforce regulation to reduce electricity theft • Provide access to investment for the upgrade of distribution assets • Undertake grid connection studies to improve grid operator capacity • Carry out an in-depth wind energy integration study • Make key transmission corridors a national priority together with offshore grid development where applicable • Consider leading with roll-out of new transmission assets before WPPs* • Engage in measures to promote social acceptance of new transmission, including compensation for those most affected

* The Brazilian government held auctions for new transmission capacity to resource rich areas in 2012, prior to the wind power auctions in 2013. See also Box 5.

Box 5: Texan Competitive Renewable Energy Zones (CREZ) case study

In 2005, in the framework of Texas's Renewable Energy Program, the Public Utility Commission was directed to consult with the Texan independent system operator, ERCOT (Electric Reliability Council of Texas), and other appropriate regional transmission organisations to designate the best areas in the state for renewable energy development.

In response, the Public Utility Commission established five CREZs in Texas (at McCamey, Central, Central West, "Panhandle A", and "Panhandle B"). A CREZ is a geographic area with optimal conditions for the economic development of wind power generation facilities. The Public Utility Commission designed a number of transmission projects to be constructed to transmit wind power from the CREZs to urban areas. The completed CREZ transmission projects will eventually transmit approximately 18 500 MW of wind power. The costs for transmission expansion are borne by ratepayers.

Selecting actions for wind energy deployment

The barriers and actions described in Tables 4 to 9 represent experiences with developing wind power in many wind energy markets, but not all will apply in every country. Roadmap drafters should identify which barriers are likely to be most applicable in their own situation (as well as others not mentioned here) and should then prioritise the order in which they are to be addressed according to their own objectives and schedule.

Similarly, some actions may suit a country context better than others. In identifying appropriate actions, a number of criteria can be helpful:

- potential effectiveness – regardless of cost or available resources (e.g. human or financial)
- cost-effectiveness
- technical feasibility, given the country's existing energy infrastructure and resources
- likelihood to be implemented inside the roadmap time frame
- degree of stakeholder support for the solution.

When finalising the set of action options for each barrier, and to secure stakeholder buy-in and thus strong foundations for implementation, the project team should pay close attention to stakeholder input. Transparency about choices made, and clear reasons for discounting any proposed actions, are important.

Setting milestones and identifying responsible players for wind energy deployment

The electricity market, like any other, is made up of institutions and individuals. The stakeholders leading the roadmapping exercise need to consider if and how institutions will be able to adapt to the roadmap's identified actions. For example, requiring planning authorities to accelerate the issue of permits may in itself take time. The speed with which administrators can assess tariff applications or modify policy will depend on resources: its acceleration may not be possible without the injection of more human resources, or a fundamental redesign of how the task is approached. Moreover, there may be good reasons for the design of permitting processes: an acceleration to enable wind power may impact other policy areas. Such changes may be brought about more quickly, and be less likely to lead to unintended consequences, if the institutions in question are involved in the roadmapping process from the outset.

A strong roadmap usually identifies metrics (e.g. permitting and licensing processing times, number of grid connections made, etc.) to gauge the speed at which change can be effected before milestones are set. These milestones are best identified through discussion with stakeholders, rather than being imposed. Some examples of key stakeholders and the processes likely to be affected are listed below:

- **transmission and distribution grid owners, system operators, vertically integrated utilities:** grid connection practices' requirements and regulations, grid upgrades and extensions, power purchase agreements, and investment plans

- **energy ministry, other relevant ministries/ agencies:** process and award of price-support and operating licences and permits
- **planning authorities:** process for award of permissions
- **developer representatives, industry bodies:** development process and R&D funding
- **turbines and component manufacturers:** support or development of the supply chain
- **private investors, development banks**: financial appraisal, risk assessment and investment decision-making
- **local population, affected by the installation of wind power:** building of public support, and communication of economic and societal benefits
- **educators**: training and upskilling of the workforce and education of diverse professionals needed in the wind energy sector.

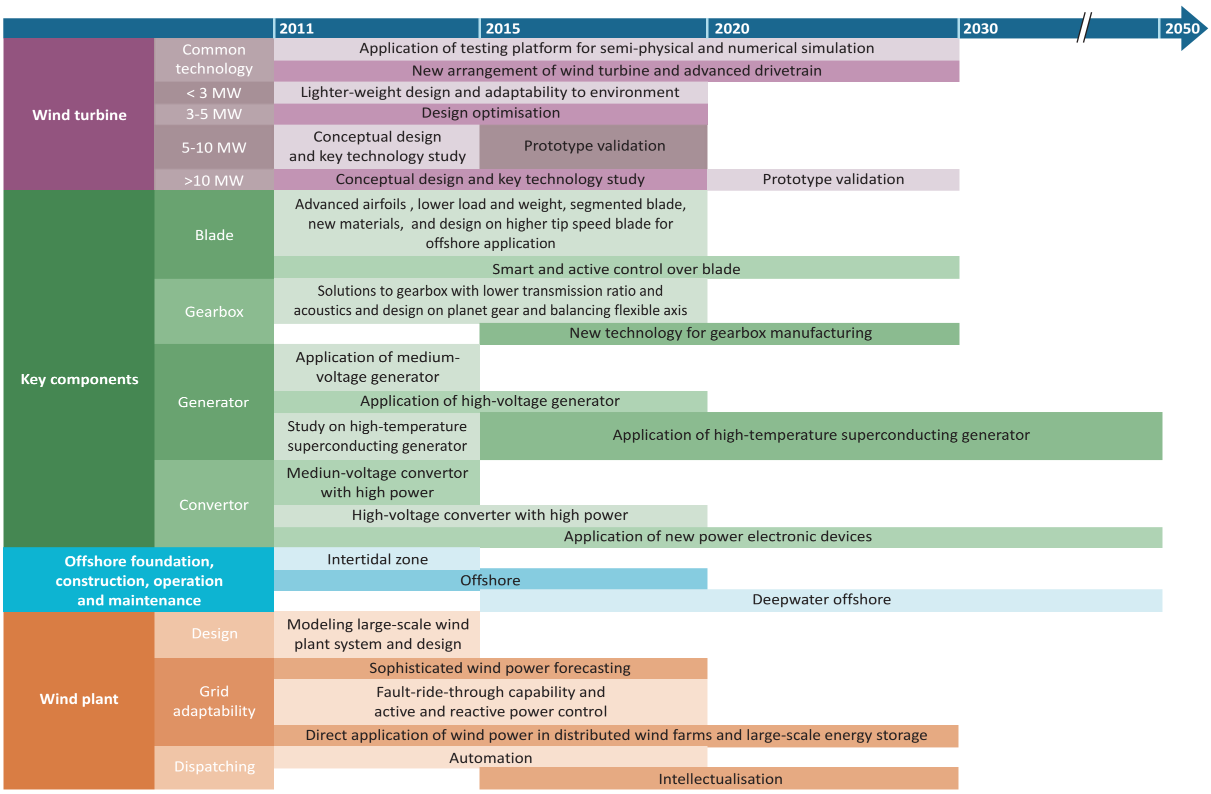
An effective roadmap is a critical path to achieving the desired deployment of wind power, but it should not be set in stone. Unexpected events and outcomes will require that milestone dates be revised to accommodate delays or changes in the wider energy system. Stakeholders' involvement is once again crucial for defining and endorsing such changes.

Each task within the roadmap should ordinarily be the responsibility of a specific party or group of parties. Such groups should agree on timescales and measure the actions against their own capabilities, experience and agendas. Top-down assignment of actions may lead to less effective implementation.

Figure 6 is taken from the Chinese wind roadmap developed in 2011 by the ERI of China's National Development and Reform Commission, together with the IEA (ERI and IEA, 2011). It describes actions on a timescale up to 2030, divided into four categories. Although the categories included are specific to the Chinese market, the underlying approach is what matters – and the approach to scheduling tasks is a useful example.[13]

13. See also Wind IA, 2013a.

Figure 6: Key milestones specific to the Chinese market for wind power technology RD&D



Source: ERI and IEA (2011), *Technology Roadmap: China Wind Energy Development 2050*, OECD/IEA, Paris.

Phase 4: implementation, monitoring and revision

The IEA *Roadmap Guide* points out that a crucial fourth phase in the life of a roadmap is to monitor implementation of the roadmap and to consider whether the roadmap itself needs adjusting in light of experiences gained through implementation itself (Figure 7). Building on that, this section of the *Wind H2G* suggests, in Table 10, a series of qualitative and quantitative indicators one could use to track and monitor progress in implementing a wind energy roadmap. Precisely which progress indicators the roadmap adopts will to some extent be a function of the country-specific context and constraints.

While the use of such indicators comes into play in the fourth phase of the roadmap development and implementation process, in fact, the initial identification of such indicators and the teams responsible for monitoring them are usually best identified earlier on in the roadmapping cycle.

Figure 7: Roadmap implementation, monitoring and revision phase

Note: The sub-step "track and monitor progress" is noted twice in Figure 7 to highlight that this is an ongoing process.

Table 10: Quantitative and qualitative indicators for monitoring progress

Indicator type	*Description*
Wind technology deployment	• Megawatt hours (MWh) generated per annum • Share of wind energy (percentage) in the total yearly electricity production • MW capacity installed and number of wind turbines • Share of wind energy (percentage) in the total installed power capacity • Availability of wind turbines (percentage of hours annually) • Number of hours WPPs are curtailed per year • Construction lead times (number of months) • New patents and technical innovations related to wind energy • Public and private R&D investment in wind energy
Financial	• Total investment volume in wind energy sector per year • Value of state-backed investments per year (e.g. via development banks) • Annual spending on public financial incentives • Annual spending on supporting renewable energy • Ratio of public to private investment • Value of certificates traded per year • Cost of support mechanisms (e.g. FIT) • Domestic investment committed per year • Development in the cost of wind technology

Indicator type	*Description*
Processes	• Number of training workshops organised • Number and success rate of the research, development and innovation programmes • Number of useful new institutions created • Number and effectiveness of awareness-raising campaigns organised • Reduction in lead times for essential permits and licences • Success rates within the permitting processes
Policy	• Policies defined and adopted • Long-term stability of the policy framework • Sectoral strategies developed to implement identified milestones • Risk management strategy and implementation
Socio-economic and environmental impacts	• Net jobs created in the domestic wind energy supply chain and annual turnover • Social projects supported • Contribution of the wind energy industry to GDP • Percentage increase in population connected to electricity grid • Avoided cost of imported fossil fuels • Percentage reduction in carbon intensity of electricity generation • Avoided GHG emissions per year, in particular CO_2

For each indicator, it will be useful to identify stakeholders responsible for monitoring and reporting, as well as verification mechanisms. Robust data and transparent analysis are important. This may be challenging where new metrics are created and data series are short. Specific resources may need to be allocated to bolster data collection and verification.

Of particular importance will be data compiled by the owners of new WPPs. Ideally, owners should be obliged to report production and availability data for each turbine. Statistics of production failure will be of particular value in the assessment of progress and evaluation of ongoing priorities. The collection of such data must, of course, take account of commercial sensitivities. Data can be anonymous, although increased transparency for publicly subsidised projects may yield both greater accountability and faster learning curves for the entire industry.

Conclusions

Wind power has the potential to contribute up to 18% of the world's electricity supply by 2050, saving up to 4.8 gigatonnes of CO_2 emissions per year (IEA, 2013a). At the national level, wind power can also attract investment, provide energy security through diversification, spur technological innovation and and enhance stable economic growth. While wind energy is developing towards a mainstream, competitive and reliable technology, several barriers could delay progress including financing, grid integration issues, social acceptance and aspects of planning processes. Increasing the cost-effective penetration of wind energy into the electricity supply requires considerable co-operation among decision makers and stakeholders of the energy sector, ongoing public support engendered by positive encounters with the wind sector, and thorough analysis and consideration of all aspects addressed in this publication.

National and regional roadmaps can play a key role in supporting wind energy development and implementation, helping countries to identify priorities and pathways which are tailored to local resources and markets. This *How2Guide for Wind Energy* is a tool that policy makers and industry stakeholders can use as a reference manual when developing their own national strategy for wind energy deployment. It has been developed equally as a starting point for newcomers and a checklist for those with more experience of wind power who may wish to update or improve an existing strategy.

This guide is specific to wind energy; however, IEA analysis suggests that such a roadmapping exercise should not be undertaken in isolation, but rather in co-ordination with other energy sector strategies, and with wider economic objectives in mind. Efforts should be made in harmony with the deployment of other low-carbon energy technologies, with co-generation technologies, and with measures to improve energy efficiency. The integration of variable output power plants into an existing power system is a relevant example: failure to consider the impacts of wind energy elsewhere in the power system is likely to have unintended consequences.

Regardless of the mix of energy supply, efficient, competitive markets are crucial to minimising the cost of energy. Whether in the established power systems of the OECD or the dynamic growing economies of China, India, Brazil, South Africa and the Middle East, governments are looking beyond fossil fuels to new ways to power their economies. National low-carbon energy roadmaps will be pivotal in determining whether or not new energy technologies are developed and effectively deployed, and whether global CO_2 emissions reduction goals are achieved.

Glossary

Active power control: this refers to a number of services, including controlling power output to support system frequency and controlling the rate at which output power increases or decreases (ramp rate) as the wind picks up or falls away.

Baseline research: analysis of the current situation to identify the starting points for roadmap development.

Environmental impact assessment (EIA): the systematic identification, predication and evaluation of impacts from a proposed development, including the analysis of its viable alternatives.

Feed-in tariff (FIT): a feed-in tariff is an energy supply policy measure generally aimed at supporting the development of new renewable energy projects by offering long-term purchase agreements for the sale of renewable electricity.

Grid code: the Grid Code covers all material aspects relating to connections to, and the operation and use of, the electricity transmission system.

Power electronics: power electronics in wind turbine systems cover a range of technologies, including inverters and converters to control the quality of output power, enabling active power control.

Strategic environmental assessment (SEA): strategic environmental assessment is a systematic decision support process, aiming to ensure that environmental and other sustainability aspects are considered effectively in policy-, plan- and programme-making. SEAs are conducted prior to EIAs.

Vertically integrated utility (VIU): a utility that owns its own generating plants, transmission system and distribution lines, providing all aspects of the electricity service.

Wheel surplus wind: to move power through the transmission system from one grid area (e.g. utility area or control area) to another.

Wind power plant (WPP): a WPP is a single wind turbine or group of wind turbines erected to harness the power of the wind for the purpose of generating electricity.

Abbreviations and acronyms

2DS	2°C Scenario
BNEF	Bloomberg New Energy Finance
CAGR	compound annual growth rate
CO_2	carbon dioxide
CREZ	competitive renewable energy zone
DSO	distribution system operator
ED	economic development
EIA	environmental impact assessment
ERI	Energy Research Institute of the National Development and Reform Commission of the Popular Republic of China
ETP	*Energy Technology Perspectives*
FC	financial close
FIT	feed-in tariff
G8	Group of Eight
GDP	gross domestic product
GHG	greenhouse gas
GW	gigawatt (1 million kW)
GWh	gigawatt hour (1 million kWh)
H2G	*How2Guide*
IA	implementing agreement
IEA	International Energy Agency
IPP	Independent Power Producers
IRENA	International Renewable Energy Agency
JRC	Joint Research Centre of the European Commission
kW	kilowatt
kWh	kilowatt hour
LCOE	levellised Cost of Energy
LO	Landowner
MWh	megawatt hour (1 thousand kWh)
NGO	non-governmental organisation
OECD	Organisation for Economic Co-operation and Development
O&M	operation and maintenance
OTC	over the counter
PPA	power purchase agreement
PPA	public-private agreement
RACI	Responsible, Authorised, Consulted and Informed
REC/ROC	Tradable Green Certificate
R&D	research and development
RDD&D	research, development, demonstration and deployment
SEA	strategic environmental assessment
SED	social-economic development
TSO	transmission system operator
UNEP	United Nations Environment Programme
USD	United States dollar
VIU	vertically integrated utilities
WPP	wind power plant

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Annex:
Possible structure of a wind energy roadmap

Executive summary
- Key findings of the wind roadmap

Introduction
- Roadmap concept and rationale for wind energy in the country
- Objectives, process and structure of the roadmap

Current situation of wind energy in the country
- Essentially a summary of the baseline research

Vision for deployment of wind energy
- Scenario or set of scenarios for wind deployment in the country by an identified time frame
- Barriers to achieving that vision
- Possible response actions and selected actions, with rationale for those choices

Implementing the vision for wind energy: actions and time frames
- Identified actions with corresponding milestone dates to achieve them, identifying responsible parties, and the cost and benefits of those actions
- This section may have sub-headings such as wind technology development, system integration, policy, finance, public acceptance and/or international collaboration

Monitoring and adjusting this roadmap
- Agreed approaches to monitoring progress, with specific metrics where possible
- Identified parties tasked with monitoring implementation

About the IEA International Low-Carbon Energy Technology Platform

Created at the request of the G8 and IEA Ministers, the International Low-Carbon Energy Technology Platform (Technology Platform) is a tool for engagement on fostering the deployment of low-carbon technologies between IEA member countries and emerging and developing economies. The Technology Platform serves as a means to disseminate and adapt analyses of expert organisations and policy recommendations, which are often technical and/or global in nature, for the deployment of low-carbon technologies at the national and regional levels. It also serves to share international best policy practice.

About the *How2Guides*

Under the Technology Platform, the IEA launched an initiative to produce a series of manuals to guide policy makers and industry stakeholders 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 global level roadmap recommendations to the national level.

Building on the IEA roadmap methodology presented in the generic manual, *Energy Technology Roadmaps: A Guide to Development and Implementation* (IEA, forthcoming1), each *How2Guide* provides technology-specific guidance on considerations of importance when developing a roadmap. These include specific questions one could investigate to assess the country baseline, the identification of stakeholders to involve in a national roadmapping exercise, the identification of key barriers and response actions for the deployment of a given technology, and indicators for tracking the implementation of the roadmap.

A second phase of the *How2Guide* initiative is the dissemination of its guidance through training seminars under the IEA Energy Training and Capacity Building Programme. This provides an excellent means of helping build the capacities of national and local governments, as well as private sector planners and programme managers, in the area of energy technology planning. The IEA welcomes collaboration with its member and non-member countries, the private sector and other organisations for both phases of this initiative.

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HOW2GUIDE for Wind Energy Roadmap Development and Implementtation

technology

stakeholders

policy

visioning

planning

barriers

monitoring