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A Risk Management Approach to Climate Adaptation in China

China and Mongolia Sustainable Development
Sustainable Development Department
East Asia and Pacific Region

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This background paper was prepared as an input to a series on Climate Risk Management and Adaptation in China (CLIMA). Each of the papers in the CLIMA series outlines a framework for managing risks posed by present-day climate variability, extreme weather events, and future climate change to an individual sector in China, including transportation, urban water utilities, and forestry. The CLIMA series papers are an initiative of the Sustainable Development Department of the East Asia and Pacific Region of the World Bank.

A growing body of scientific evidence shows that China's climate is indeed changing, especially when climate is viewed at the regional level. Temperatures are rising, precipitation regimes are changing and shifts have occurred in the distribution of extreme weather events. The effects of extreme weather events, present-day climate variability, and future climate change cut across many different sectors of China's economy. China's government estimates that direct economic losses from extreme weather events cost the country 1–3 percent of gross domestic product each year. As China's economy continues to grow, its exposure to weather-related hazards is expected to increase, especially without policies to limit building in hazardous areas such as floodplains and alleviate non-climate pressures such as overuse of freshwater resources. Effective risk management policies and investments are crucial to reducing the sensitivity and increasing the resilience of the country to extreme weather, climate variability, and long-term climate change.

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About the East Asia and Pacific Sustainable Development Discussion Paper Series

Sustainable development issues are an integral part of the development challenge in the East Asia and Pacific (EAP) region. The World Bank's Sustainable Development Strategy for the region provides the conceptual framework for setting priorities, strengthening the policy and institutional frameworks for sustainable development, and addressing key environmental, social, and rural development challenges through projects, programs, policy dialogue, nonlending services, and partnerships. The EAP Sustainable Development Discussion Paper series provides a forum for discussion of good practices and policy issues within the development community and with client countries.

ABSTRACT

This discussion paper provides the analytical backdrop for a series of papers on managing climate- and weather-related risks in China. It reviews and synthesizes the growing literature on risk-based management approaches to climate change adaptation and offers guidance on a process for decision-making. Managing risks from severe weather, present-day climate variability, and future climate change is integral to China's development. While the effects of future climate change are deeply uncertain, this uncertainty should not preclude action. Risk management is in essence a process for designing, implementing, and evaluating policies in the face of such uncertainty.

The paper begins by defining key concepts and establishes the context for climate risk management and adaptation in China. It then outlines a step-by-step process for a risk-centered approach to adaptation. The focus of the process is on planning for adaptation, not policy implementation. The papers that follow in the series take the general framework set out by this paper and apply it to different sectors, including transportation, water utilities, urban planning, and forestry.

ABBREVIATIONS

CBA	cost-benefit analysis
CCCPC	Central Committee of the Communist Party of China
CLIMA	Climate Risk Management and Adaptation in China
CMA	Chinese Meteorological Administration
DRM	disaster risk management
EAP	East Asia and Pacific
ESMAP	Energy Sector Management Assistance Program
FYP	Five-Year Plan
GCM	general circulation model or global climate model
GDP	gross domestic product
IEUA	Inland Empire Utilities Agency
IPCC	Intergovernmental Panel on Climate Change
IRS	Institutional Readiness Scorecard
M&E	monitoring and evaluation
MOST	Ministry of Science and Technology
OECD	Organisation for Economic Co-operation and Development
NARCC	National Assessment Report on Climate Change
NDRC	National Development and Reform Commission
NGO	nongovernmental organization
NPV	net present value
R&D	research and development
RDM	robust decision making
ROA	real options analysis
UKCP09	UK Climate Projections 2009
UNFCCC	United Nations Framework Convention on Climate Change

INTRODUCTION

This discussion paper provides the analytical backdrop for a series of papers on managing climate- and weather-related risks in China. It reviews and synthesizes the growing literature on risk-based management approaches for climate change adaptation and offers guidance on a process for decision making. Managing risks from severe weather, present-day climate variability, and future climate change is integral to China's development. While the effects of future climate change are deeply uncertain, this uncertainty should not preclude action. Risk management is in essence a process for designing, implementing, and evaluating policies in the face of such uncertainty.

The paper begins by defining key concepts and establishes the context for climate risk management and adaptation in China. It then outlines a step-by-step process for a risk-centered approach to adaptation. The focus of the process is on planning for adaptation, not policy implementation. The papers that follow in the series take the general framework set out by this paper and apply it to different sectors, including transportation, water utilities, urban planning, and forestry. The primary audience for the paper includes development planners and practitioners in public agencies in China who are responsible for making investments, plans, and policies in climate-sensitive sectors. The risk management approach to climate change adaptation is still relatively new in China, though it is beginning to gain traction. This paper aims to strengthen the case for risk-based adaptation planning in China by demonstrating how the process works within the Chinese context and providing practical examples from other countries. The secondary audience for this paper includes planners and practitioners in the World Bank and other international donor organizations. The World Bank was one of the early proponents of climate risk management. It now requires that climate risks be considered in its country strategies as well as projects in sensitive sectors (van Aalst 2006; Carter et al. 2007; see also IDA Executive Directors 2011).

1. Risk, Uncertainty, Risk Management, and Adaptation

In everyday usage, the idea of risk is invariably tied to the possibility of suffering some form of danger, harm, or loss. From a strictly technical perspective, though, risk is defined more broadly as the product of how likely an event is to happen and what the consequences of that event are. [1]

Uncertainty is closely tied to the concept of risk. In a way, risks and uncertainties represent different levels of ignorance about the future. At one end of the spectrum are risks—or "known unknowns" for which we have definite knowledge about the chance of an event occurring and whose likelihood can be described with a single set of probability distribution curves. Such routine variability is employed by engineers in designing infrastructure, for instance in building a dike to protect against a one-in-100-year flood (that is, a level of river flooding that has a 1 percent chance of being reached in any given year). At the other end of the spectrum are uncertainties—events for which probabilities are ambiguous, imprecise, or immeasurable.[2] **Deep uncertainty** exists where there is ignorance or disagreement about "(1) the appropriate conceptual models that describe the relationships among the key driving forces that will shape the long-term future, (2) the probability distributions used to represent uncertainty about key variables or parameters in the mathematical representations of these conceptual models, and/or (3) how to value the desirability of alternative outcomes" (Lempert, Popper, and Bankes 2003, xii).

How the earth's climate will change many decades or centuries in the future is deeply uncertain. There are at least three sources of uncertainty associated with climate change (Hallegatte et al. 2012):

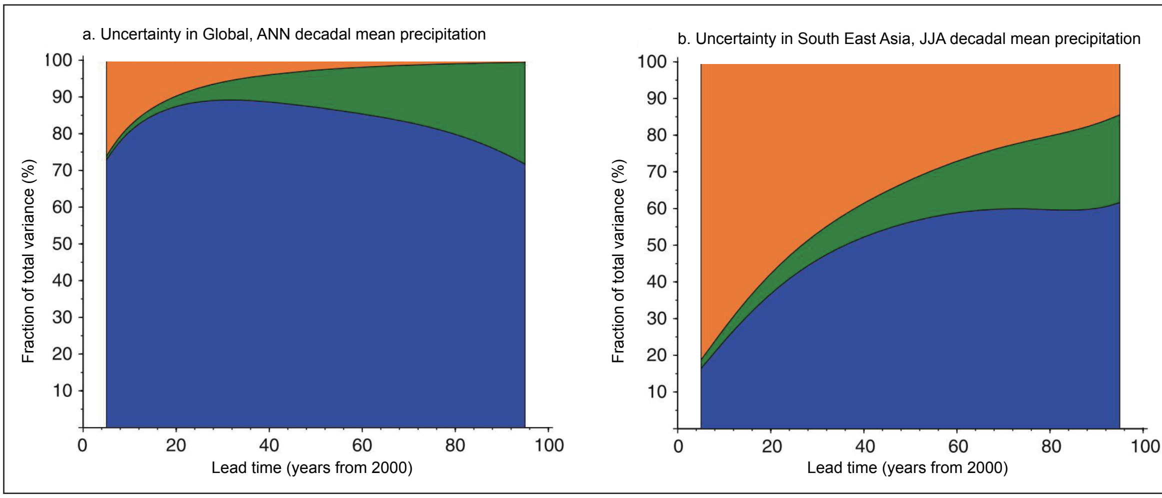
- **Development pathways,** or demographic and socioeconomic trends that affect emissions of greenhouse gases and the resilience of societies to the resulting changes in the climate;
- **Scientific uncertainty,** which reflects our limited knowledge about how the earth's climate and other natural systems function; and
- **Natural variability,** referring to the "chaotic behavior of the climate system" and inherent unpredictability or randomness of weather.

The degree to which each of these sources of uncertainty contributes to the overall envelope of uncertainty varies. At the micro or regional scale and in dealing with time frames of a few years, the biggest source of uncertainty is usually natural variability associated with local or regional weather, topography, and hydrology. At the global scale and in dealing with time frames of many decades or centuries, the unknown pattern of future development and limits to scientific knowledge are the dominant sources of uncertainty (see figure 1; Yip et al. 2011).

[1] This definition is based on ISO 31000:2009, "Principles and Guidelines on Implementation," issued by the International Organization of Standards to offer guidance on managing risk.

[2] These two levels of ignorance were famously described by economist Frank H. Knight in his 1921 book Risk, Uncertainty, and Profit. Knight distinguishes between what he calls "risk," which is measurable, and what he calls "true uncertainty," or "that higher form of uncertainty not susceptible to measurement and hence to elimination" (Knight 1921, I.I.15, III.VII.47). Others have pointed out that beyond Knightian uncertainty, where we at least know what is uncertain, there is an even more fundamental level of ignorance, where even the event itself is a surprise (see Dobes 2012).

Figure 1: Sources of Uncertainty in Projections for Changes in Decadal Mean Precipitation, Globally and in Southeast Asia



Source: Hawkins and Sutton 2011.

Note: Orange shows natural variability (or what Hawkins and Sutton call "internal variability") as a share of total uncertainty or variance in the climate model results; green represents uncertainty from development pathways ("scenario uncertainty"); and blue is scientific uncertainty ("model uncertainty").

Climate risks are potential impacts from severe weather, variability in the kinds of weather experienced, or long-term changes in the weather.[3] Climate risks are both physical and social in nature. The physical dimension of climate risk has to do with the existence of weather- and climate-related hazards. A hazard is defined simply as the potential for a harmful event to occur. Hazardous climate events range from discrete, recurrent events such as tropical cyclones, to gradual shifts such as drier winters, to previously unseen events such as the collapse of the Antarctic ice sheet. The physical profile of climate hazards may be described in terms of intensity, frequency, timing, persistence, or geographic distribution.

There is strong evidence that climate change is altering the profile of hazards (IPCC 2012; see figure 2). In China, for example, the observed frequency and severity of extremely heavy rain storms since the 1950s have significantly increased across the South and Southwest (Wang and Qian 2009; Zhai et al. 2005). In the North and Northeast, future climate scenarios show that interannual variability in rainfall may increase along with rainfall from short, intense storms. More than three-quarters of the precipitation in the North and Northeast could come from days of heavy rain (Shi et al. 2010; Gao, Shi, and Filippo 2011; Gao et al. 2012a, 2012b; NARCC 2011).[4] These shifts imply that recent

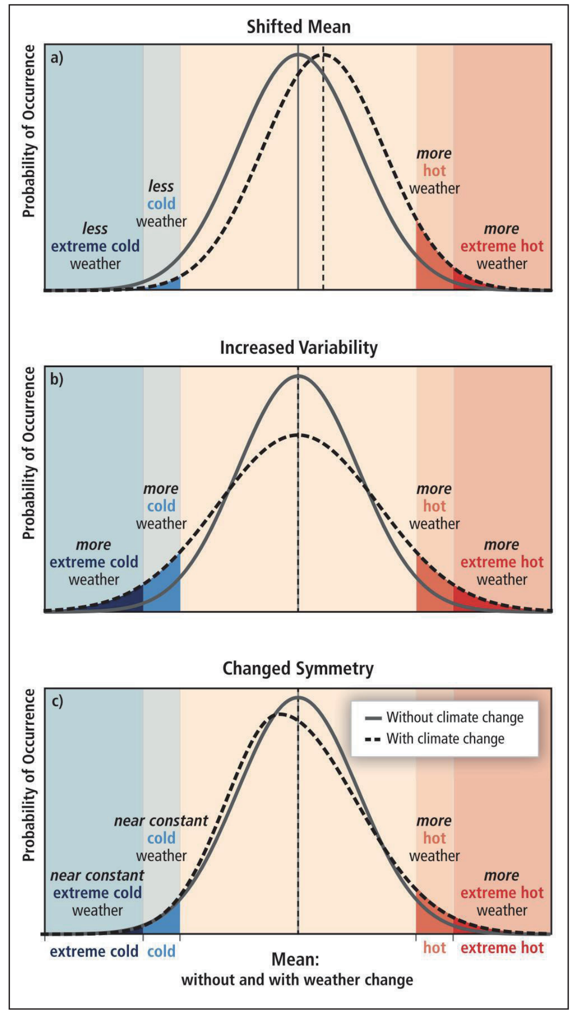
[3] These impacts cannot easily be classified as "good" or "bad." In both popular and scientific discussion on climate change, there is a strong tendency to stress negative outcomes and underplay positive ones, but this is not helpful for any serious analysis of risks. An increase in average temperatures may be associated with a higher probability and/or severity of heat waves (causing heat-related illnesses) or droughts or tropical storms, all of which will increase the level of weather-related losses. But, equally, it may be associated with lower heating requirements, a longer growing season, higher crop yields, and less damage to roads and other structures caused by freeze-thaw cycles. Any analysis of climate risks that focuses solely on the probability of negative outcomes and neglects positive outcomes will give a misleading impression of the distribution of the overall impact of climate change on income or welfare.

[4] For more details on observed and expected trends in climate hazards in China, please see Sall (2013).

history is becoming less useful as a guide for the future, especially over the longer term as the effects of deep uncertainty become more pronounced, and climate conditions diverge more from what is considered normal today (see box 1).

The shifts illustrated in figure B1.1 do not imply that climate change will be gradual or will occur evenly across all regions (see Solomon et al. 2007). Climate change is nonlinear. As global temperatures rise more than 2°C above preindustrial levels, social and ecological tipping points will be crossed, and the possibility for surprises and abrupt changes will increase (Potsdam Institute 2012). Abrupt changes include the massive die-off and disintegration of corals as atmospheric concentrations of carbon dioxide (CO_2) rise and ocean waters become much more acidic. It is virtually impossible to predict when such "regime shifts" (or sudden, catastrophic, and lasting changes to ecosystem structure and function) will occur, given the inherent complexity of natural systems, limited scientific knowledge, and the effects of other pressures (Folke et al. 2004; Elmqvist et al. 2010; Scheffer and Carpenter 2003; Scheffer et al. 2001).

Figure 2: Effects of Changes in Temperature Distribution on Extreme



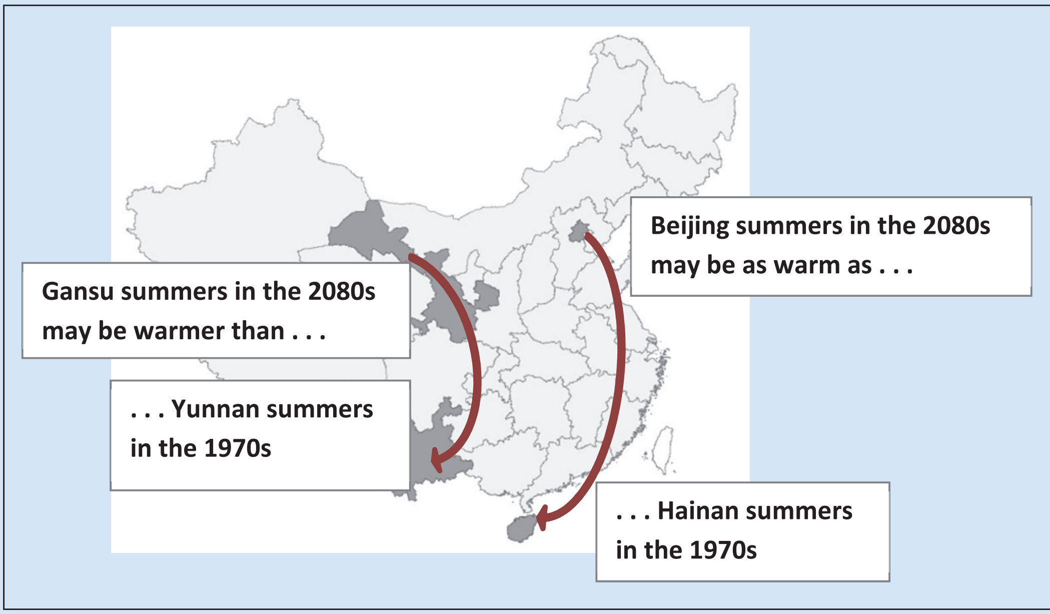
Source: IPCC 2012

Obviously, the mere occurrence of severe climate or weather events such as storms or flooding does not by itself explain the damage these events inflict. Weather disasters are not really "natural" as much as the result of uneven development processes that heighten exposure and vulnerability (World Bank and UN 2010; Cardona et al. 2012). **Exposure** refers to the location of people or assets in hazard-prone areas. Levels of exposure are influenced by patterns of social and economic development. Construction in floodplains, mass migration to densely populated cities in coastal deltas, destruction of mangroves and coastal wetlands that buffer against storms, and the weak enforcement of building or zoning codes can heighten exposure. Given a certain level of exposure, **vulnerability** is the degree to which people or assets are susceptible to being harmed or unable to adjust to the effects of climate hazards. There are many dimensions to vulnerability—including social, cultural, political, economic, and

Box 1: Climate Analogues—Will Beijing and Gansu Be Like Hainan and Yunnan?

One way of putting shifts in weather and climate conditions in perspective is to think of climate "analogues." For example, the climate of Paris in the 2080s could be a lot like that of Madrid in the 1970s (Hallegatte, Hourcade, and Ambrosi 2007; Kopf, Ha-Duong, and Hallegatte 2008). An architect in Paris designing a building meant to last 80 years or more would face the challenge of dealing with a much wider range of climate conditions than experienced in the past. As figure B1.1 shows, average summer temperatures in Beijing in the 2080s are projected to be the same as summer temperatures in Hainan during the 1970s (about 27°C). Likewise, summer temperatures in Gansu in the 2080s are projected to be warmer than those observed in Yunnan in the 1970s (about 20°C).

Figure B1.1: Projected Summer Temperatures in 2080s versus Temperatures in 1970s



Source: Downscaled climate projection data for China obtained from The Nature Conservancy's "Climate Wizard" site, http://www.climatewizard.org/ (accessed June 2013)..

Note: Projections for average summer (June-August) temperatures for Beijing and Gansu in the 2080s represent the median values of 30-year averages generated by an ensemble of 16 global climate models for a middle-of-the-road emissions scenario. Temperatures in the 1970s represent an average of observed values for 1950-2002. No data are available for Taiwan.

environmental—and many ways of framing its causes. The factors that contribute to vulnerability are both context dependent and multiscale (Adger 2006; Adger et al. 2007; Cardona et al. 2012). At the household level, vulnerability is often linked to poverty, poor health, lack of education, weather-sensitive livelihoods (such as rain-fed farming), social marginalization, and lack of access to safety nets such as public crop insurance schemes. At the sector level, vulnerability may be the product of low levels of public investment in building or maintaining existing infrastructure, weak enforcement of standards, poorly coordinated planning processes, and the sensitivity of outcomes (for example, agricultural income or hydropower production) to weather and climate conditions. Table 1 shows some of the different factors affecting different types of vulnerability.

Table 1: Types of Vulnerability and Influencing Factors

Type of vulnerability	Influencing factors
Individual or household vulnerability	Low education, poor health, old-age dependents in household, livelihood tied to weather conditions (e.g., rain-fed agriculture), past disaster experience
Social vulnerability	Poverty, isolation, racial discrimination, lack of access to social security services
Institutional vulnerability	Ineffective policies, disorganized and noncommitted public and private institutions
Economic vulnerability	Financial insecurity, lack of national income and funds for disaster prevention and mitigation
Physical vulnerability	Poor environmental practices, unprecedented population growth and migration

Source: World Bank 2012a.

Climate risks are but part of the broader array of risks that can affect a country's development (van Aalst 2006). Climate risks are compounded by other pressures, such as the loss or degradation of natural habitat, the overdraft of scarce water resources, and pollution. There are numerous examples in China of how climate impacts have been amplified by other pressures. Nutrient loading from inland agricultural runoff and lower oxygen levels due to higher temperatures have created "dead zones" in coastal waters in the Southeast (Wei et al. 2011). In the South and Southwest, the rapid expansion of monoculture plantations, along with hotter conditions and more frequent extreme precipitation events, have made forests more susceptible to pests and disease outbreaks (Allen et al. 2010; Sturrock et al. 2011; Xu et al. 2009). In the North and Northeast, annual flow volumes measured in the Songhua, Liao, Hai, and Yellow Rivers have declined since the 1950s. Only part of this decline is due to drier conditions; rapid growth in the demand for water by cities, agriculture, and industry has played an even larger role (NARCC 2011).

Actions to reduce or manage climate risks are often grouped into two broad categories: mitigation and adaptation. **Mitigation** activities reduce climate risks by reducing emissions of greenhouse gases, thus limiting the possibility of long-term global warming. However, the overwhelming scientific consensus is that the global climate is already changing (IPCC 2007). With the current level of CO_2 concentrations in the atmosphere and the inertia of the global climate system, continued change is inevitable—even if emissions are cut to zero today. Moreover, countries are already exposed to varying high levels of risks from extreme weather events and present-day climate variability. Thus, the imperative for **adaptation**—a "process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities" (IPCC 2012, 5)—is clear.

Adaptation covers a wide range of responses to actual or anticipated changes in climate conditions. From a risk management standpoint, anticipatory measures help a society **avoid** damages from weather- and climate-related hazards. Reactive adaptation measures help societies **withstand** or **recover** from the impacts of hazardous events. A mix of both **hard** (capital-intensive) and **soft** (institution- and policy-based) solutions is needed. As researchers from the World Bank have commented, "There is no point in building the best type of road in the wrong place, while the best institutions will provide no protection against a storm that destroys buildings or power lines" (World Bank 2010b, 94).

In many ways, development is still the best form of adaptation, but this does not mean development as usual (World Bank 2010b). As Ranger and Garbett-Shiels (2012, 298) argue, "Climate change strengthens the case for pushing faster and harder on development priorities and investments... with a greater awareness of long-term risks". Economic development provides resources and opportunities for people to adapt to change. Managing risks from severe weather and climate variability enhances adaptability to change and improves welfare. Planning for future climate change safeguards the long-term gains of development and better prepares a society for the range of uncertain environmental, economic, and social impacts associated with rapid urbanization and growth.

2. Overview of Climate Change Adaptation and Disaster Risk Management in China

Since first appearing on the political agenda in China in the 1980s, climate change has been increasingly viewed by China's government as an important domestic issue.[5] The growing concern over the risks posed by climate change to China's social and economic development is evident in the 12th Five-Year Plan (FYP) (2011–2015), which groups climate change together with energy security and natural resource security as key challenges to sustainability.

The guiding principles and priorities for climate change adaptation in China are articulated in China's National Climate Change Program, released in 2007 (NDRC 2007). The program states that climate change adaptation should be placed "within the framework of sustainable development," given equal priority with mitigation (in reducing the risks of climate change to development), and "integrated" (mainstreamed) with other areas of policy making. Priority areas for climate adaptation as identified in the program are agriculture, water resources, forestry, ecosystems management, and coastal zone management. China's Second National Communication on Climate Change, submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in 2012, also lists public health as a priority for climate adaptation (NDRC 2012b). After the National Climate Change Program was introduced, many provinces followed by developing their own climate change strategies. An updated national strategy on climate change for 2011–2020 and national climate adaptation strategy are being drafted, but they have not yet been finalized or made public as of the time of writing.[6]

At the top of China's institutional hierarchy for climate change adaptation is the National Leading Group on Climate Change,[7] a superministerial group of 27 agencies and entities that is headed by the premier (State Council 2007). Since the National Leading Group was established in 2007, 28 of the 31 provinces[8]—and many more municipalities and counties—have also set up climate change leading groups. Leading groups for climate change have also been established within line ministries and agencies, including the State Forestry Administration. The leading groups are in a unique position to coordinate climate risk management actions across sectors. However, in practice, leading groups in the provinces have given relatively low priority to climate change adaptation and have instead concentrated their attention on renewable energy investments, Clean Development Mechanism projects, and other initiatives that are seen as yielding more immediate benefits to the local economy (Ye et al. 2008).

The secretariat for the National Leading Group is housed in the Climate Change Office of the National Development and Reform Commission (NDRC). The NDRC

[5] See Stensdal (2012) for a summary of the evolution of China's climate change policies and interests.

[6] See "Xie Zhenhua Opening Remarks at State Council Press Office Press Conference," http://www.china.com.cn/zhibo/zhuanti/ch-xinwen/2012-09/17/content_27184746.htm; see also NDRC (2012a).

[7] Formally referred to as the "National Leading Work Group on Climate Change, Energy Conservation, and Reducing Emissions."

[8] These figures include provincial-level cities and other provincial-level administrative regions.

exercises wide-ranging powers over social and economic development policy in China and has assumed a dominant role in the making of climate change policy (Heggelund 2007; Rommeney 2008; Stensdal 2012). Besides the NDRC, the Ministry of Foreign Affairs is leading China's participation in international climate talks. The Ministry of Science and Technology (MOST) handles the technical aspects of the international talks and, together with the NDRC and the Ministry of Finance, oversees public support for researching, developing, and deploying new climate-relevant technologies. The State Forestry Administration and Ministry of Water Resources are the key agencies responsible for developing policies and strategies to manage climate risks to natural resources and ecosystems. Together with MOST and the Chinese Academy of Sciences, the Chinese Meteorological Administration (CMA) has taken the lead in researching the impacts of severe weather, climate variability, and climate change.[9] The CMA has also played a leading role in advocating the principles of climate risk management, especially in relation to the risks from weather disasters.

The disaster risk management (DRM) community in China has its own institutional hierarchy apart from the climate adaptation community. At the helm is the National Committee on Disaster Reduction, composed of leaders from 34 different entities—including the Central Committee of the Communist Party of China (CCCPC), State Council, NDRC, People's Liberation Army, all of the ministries, and Red Cross Society of China— and currently chaired by Wang Yong, CCCPC and State Council member.[10] Twenty-seven of the 31 provinces have also established committees for disaster reduction. Guiding principles and priorities for action on DRM in the 12th FYP are laid out in the National Plan for Comprehensive Disaster Risk Reduction (2011–2015) (State Council 2011).

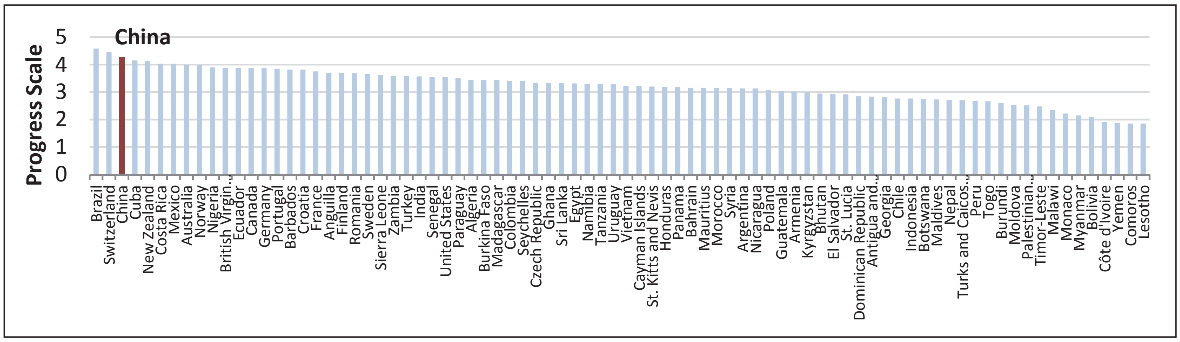
China is a vast country, spanning many different regional climates, with hundreds of millions of people living in hazard-prone areas, such as in low-lying deltas and along active fault lines. Annual losses from weather-related disasters average 1 to 3 percent of gross domestic product (GDP).[11] China's high level of exposure to natural hazards and long history of disasters no doubt play a large role in the high priority attached to DRM. As evidence of its commitment, China has done better than most countries on indicators of progress toward implementing the Hyogo Framework for Action on DRM (figure 3). These indicators include measures of government and institutional arrangements for DRM, investments in risk reduction measures, identification and provision of risk information (for example, early warning systems), and planning and support for disaster response.

[9] For a description of the respective roles played by the various ministries and agencies, see the most recent of the annual progress reports on climate change, issued by the NDRC each year since 2008 (NDRC 2012a).

[10] The secretariat for the National Committee is housed in the Ministry of Civil Affairs.

[11] See the companion paper on trends in weather and climate risks (Sall 2013).

Figure 3: Progress of Countries toward Implementing the Hyogo Framework for Action (2011)



Source: UNISDR 2011.

Note: A score of 5 indicates "comprehensive achievement" of framework commitments.

Like many countries, China continues to focus its DRM efforts primarily on the episodic rather than continuous treatment of risk.[12] Disaster response commands the greatest attention, particularly for local governments (Dong 2011). There are signs of a change, however, and a growing emphasis on risk management as a process. For example, the Regulations for Prevention and Reduction of Meteorological Disasters, issued by the State Council in 2010 (State Council 2010), require that provincial, municipal, and county governments integrate DRM into local development planning (such as local FYPs and urban master plans) and that they provide budgetary support for DRM activities. Each level of government is responsible for drawing up a weather disaster risk reduction plan that assesses current risks in the local areas and establishes targets, priorities, and plans for disaster prevention and management. Following administrative regulations issued by the CMA in 2008 (CMA 2008), local governments are also required to perform "climate feasibility" assessments for major infrastructure and development projects. A number of provinces and municipalities have already issued or are currently drafting implementation rules for the national regulations on preventing and reducing weather disasters. [13]

One of the challenges for climate risk management in China will be to reconcile the two disparate policy spaces occupied by the climate adaptation and DRM communities. None of the leaders in the National Disaster Reduction Committee are part of the National Leading Group on Climate Change, for example.[14] The CMA, which carries primary regulatory authority for managing risks from weather disasters and plays a leading role in researching and providing information on climate change trends and impacts, has so far acted as the main bridge between the two communities. The lack of integration between the communities is a challenge that China shares with many other countries (Lal et al. 2012). Linking these communities will be crucial for ensuring coordinated planning and action across sectors for risk management.

[12] See Ranger and Fisher (2012) for efforts of other countries.

[13] The provinces in question include Guangdong, Tianjin, Guangxi, Yunnan, Hebei, Hubei, Guizhou, Fujian, and Anhui. The municipalities include Suzhou, Xiamen, and Dalian.

[14] This is because the members of the National Disaster Reduction Committee are all of lower administrative rank than members of the National Leading Group on Climate Change.

3. A Risk-based Approach to Climate Change Adaptation in China

Sector-level planning for climate change adaptation is about making decisions in the face of deep uncertainties. The problem of deep uncertainty is not unique to climate change. Policy makers deal with deep uncertainties all the time when making decisions contingent on unpredictable future situations such as international exchange rates, energy costs, research and development (R&D) outcomes, and actions by other countries. The mere existence of deep uncertainty should not prevent policy makers from making decisions now about how to manage climate risks (Hallegatte 2009), and waiting for improved knowledge to reduce uncertainties before acting is not a viable strategy. While progress in climate science and technology will help reduce uncertainty about climate change over the long term, this reduction will not happen within a few years. Over the past 40 years, as knowledge of the climate has improved, and the climate models have grown more complex, the envelope of uncertainty in projections has not narrowed (Weaver et al. 2013). More fundamentally, the climate science cannot solve the problem of predicting societal choices, long-term development pathways, and technological change (World Bank 2010b). The China of 2030 or 2050 will look very different from the China of today, and it is impossible to forecast with confidence how these changes will unfold.

Policy decisions that are most affected by the deep uncertainties of climate change include the following:

- Long-lived investments with high sunk costs (such as in the sectors listed in table 2),
- Decisions with irreversible consequences (related to species loss or regime shifts in ecosystems, for example)
- Decisions that constrain future options (related to land use in flood plains, for example)
- Decisions with long lead-in times (especially for large infrastructure projects)

Moreover, the effects of natural variability of local weather, topography, and hydrology mean that the sensitivity of policy decisions to climate change uncertainty may be even higher for policies targeted for specific locations.

Table 2: Sectors Sensitive to Climate and Weather Hazards with Long Investment Time Scales

Sector	Typical investment decision lifespan
Water infrastructure (e.g., dams and reservoirs)	30–200 years
Land use planning (e.g., in flood plains or other hazard-prone areas)	More than 100 years
Coastline and flood defenses (e.g., dikes and seawalls)	More than 50 years
Building and housing (e.g., thermal design properties)	30–150 years
Transportation infrastructure (e.g., ports, roads, and bridges)	30–200 years
Urban spatial planning	More than 100 years
Energy production (e.g., thermal power plants)	20–70 years

Source: Based on Hallegatte 2009.

The risk-based approach to climate change adaptation is underpinned by the belief that uncertainty—even deep uncertainty—can be managed. In broad terms, the risk management process of planning for adaptation involves four main steps: (1) framing the decision; (2) assessing risks; (3) identifying and prioritizing adaptation options; and (4) planning for implementation. As illustrated in figure 4, the process is iterative. Each step is interconnected, and conclusions reached at earlier steps may need to be adjusted when information generated by later steps is taken into account. The process works best when it is designed to support the achievement of existing goals and priorities and is made part of existing policy-making processes (that is, when it is mainstreamed). [15]

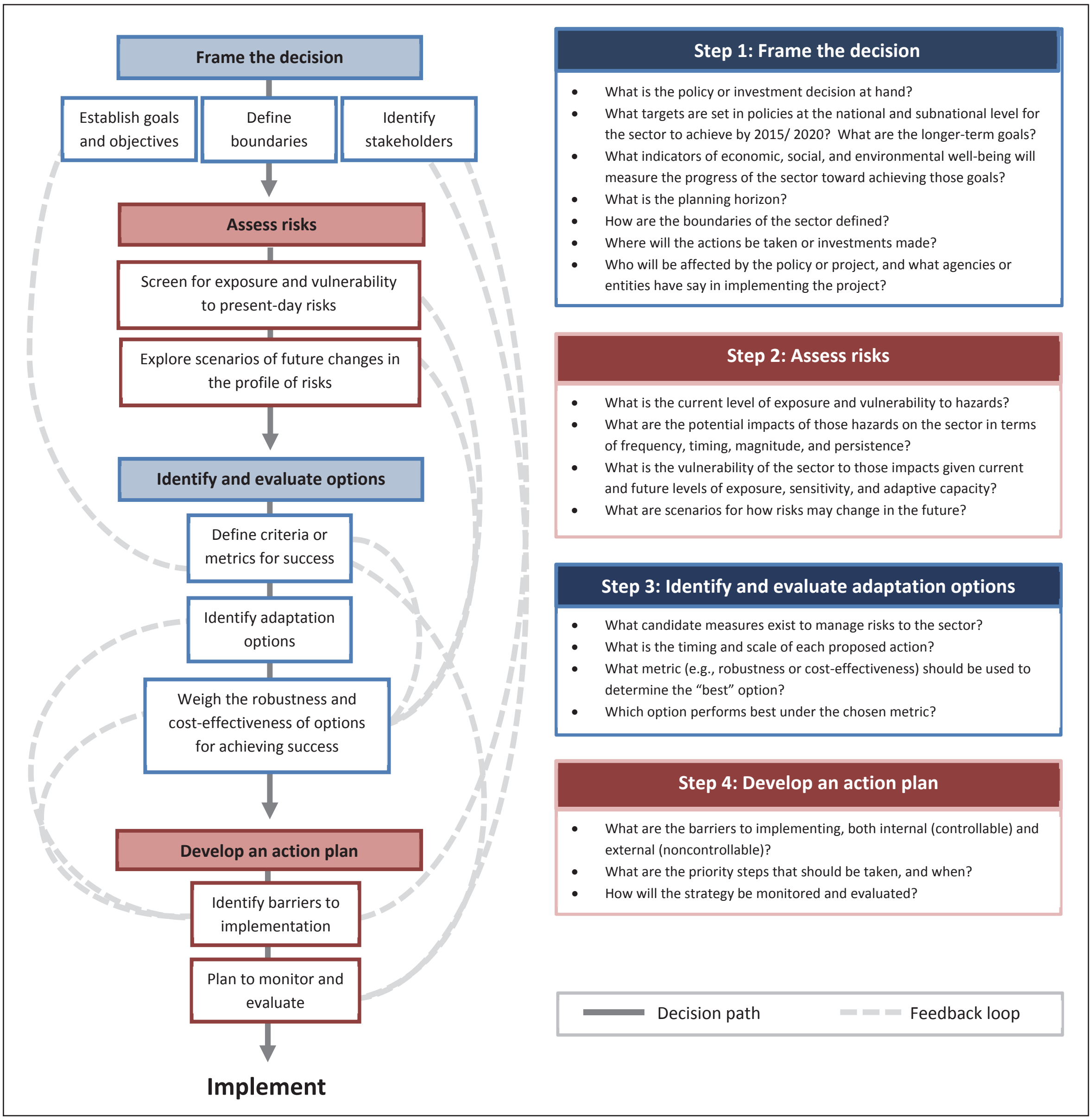
The process aims to answer some practical questions faced by the adaptation planner making decisions in the face of deep uncertainty. These include questions about timing, robustness, and flexibility:

- Timing. Is it necessary to make a long-term decision now? What is the payoff from waiting in order to collect more information relative to the reduction in costs or damages that might be achieved by acting now? If there is a case for waiting, what information should be collected to inform a future decision, and what threshold should be set for taking such a decision?
- Robustness. What kinds of policy or investment make sense under a wide range of economic and climate scenarios? In particular, is it possible to identify "no regrets" measures that can be justified under almost any future development outcomes?
- Flexibility. Is it possible to adjust policies or the design of investment programs so as to preserve flexibility to respond to changes in circumstances? For example, what is the additional cost of upgrading coastal defenses progressively rather than trying to forecast the extent of sea-level rise over the next 50 or 100 years?

Aiming to answer these questions, the risk management process is driven by policy, not prediction (Jones and Preston 2011; Ranger et al. 2010; Dessai et al. 2009; Wilby and Dessai 2010; Carter et al. 2007). Here, it is worth pointing out how the policy-driven approach differs from more traditional, prediction-led approaches to climate change adaptation. The risk management process begins by framing the policy context—establishing what the goals are for the development of the sector and how these goals may be jeopardized by severe weather, climate change, and other risks such as the loss of natural ecosystems. The nature and context of the decision determine what kind of scientific information is needed, what economic or decision-support tools will be used, and how adaptation options will be evaluated. By contrast, the standard "predict-then-act" or "science-first" approach begins with a set of predictions or projections of future climate change impacts, typically using outputs from global climate models (GCMs). The decision is then defined according to these impacts.

[15] The process outlined in this paper draws primarily from Willows and Connell (2003) and Ranger et al. (2010).

Figure 4: Risk Management Process for Adaptation Planning



Source: author, drawing from Willows and Connell (2003) and Ranger et al. (2010).

The seven-step climate impact assessment process of the International Panel on Climate Change (IPCC) is a classic example of the standard approach (see Carter et al. 1994).

The distinction between risk-based and traditional impact-led approaches may seem subtle, but it is important in practice. One of the key differences between the two approaches is how information about climate risks enters into the adaptation policy decision (Weaver et al. 2013; Brown et al. 2012). The predict-then-act approach puts the scientific impact assessment out in front of the decision, while the policy-led approach fits the scientific assessment within the decision-making process, with the belief that scientific information is more likely to be effectively utilized when it is viewed as "credible, salient, and legitimate" by the people who use it (Weaver et al. 2013, 42). Because it is not prediction based, the policy-led approach is also more amenable to the "exploratory" use of climate models. Model outputs are treated as plausible (though not necessarily probable) scenarios for how the climate could change under certain assumptions about the future world, and then vulnerabilities of policy decisions under these scenarios are explored.

Decision-support tools are available to assist policy makers at various steps of the adaptation planning process.[16] The World Bank's online Climate Change Knowledge Portal offers a useful entry point to access a range of tools and climate data resources.[17] In addition, the World Bank is developing a framework to assess vulnerability to climate change in all of its country strategies and analyze potential climate impacts on projects in sensitive sectors such as agriculture and water resource management. The sector guidelines will provide development practitioners in World Bank and International Development Association client countries with a structured, questionnaire-based process to screen projects for potential climate risks—essentially "due diligence" for climate-smart development (see box 2).

Even though rigorous economics-based methods and tools exist to aid in decision making, the risk management process is ultimately as much art as science. Policy makers will invariably have to make normative choices about how much risk is acceptable and for whom (Jones and Preston 2011). Values and preferences play an increasingly important role in cases where there are no objective probabilities and uncertainty is pervasive (Anand 2002). Consulting and communicating with stakeholders is thus a core part of the risk management process (Jones 2001; Carter et al. 2007; Jones and Preston 2011). Key points for stakeholder input include framing the decision (that is, setting goals), defining risk thresholds, and establishing criteria for selecting the "best" adaptation option.

Step 1: Frame the Decision

The risk management process begins with questions about what needs to be decided and what the priorities are, and about "what really matters" with regards to the development of the sector. Asking the right questions at the outset and articulating the process increase the likelihood that the policy-making process will be successful (Jones and Preston 2011). Elements of framing the decision include setting goals, defining boundaries, and identifying key stakeholders.

Define the decision. Severe weather, present-day climate variability, and future climate change represent but a piece of the broader spectrum of risks to development in China. In broad terms, the question for Chinese policy makers "is not 'How can we minimize

[16] Hammill and Tanner (2011) have evaluated a variety of decision-support tools, which they group into three categories: **process-based tools** that guide users through the steps of the decision, data or information tools that provide information on risks, and **knowledge-sharing tools** that allow users to exchange experiences and ideas for adaptation. For a collection of decision-support tools and practical guidance on what kind of tools can be used for different kinds of project and policy decisions, see the "Climate Planning" meta-tool developed by Ecofys and the Institute of Development Studies for the Climate and Development Knowledge Network at http://www.climateplanning.org/.

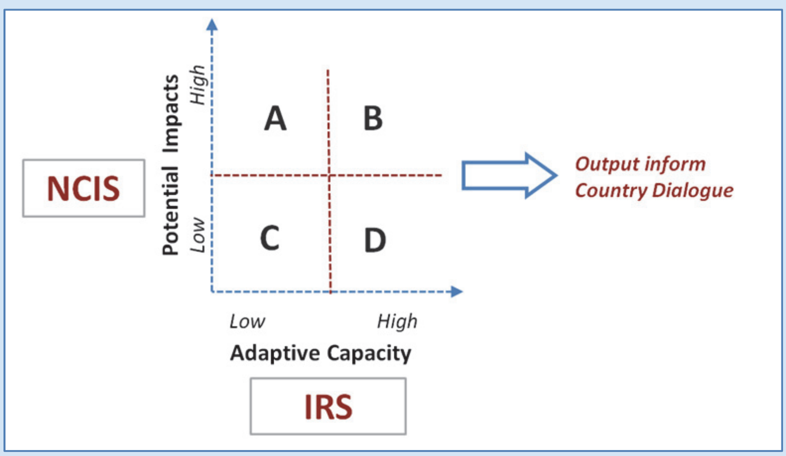
[17] The Climate Change Knowledge Portal can be found at http://sdwebx.worldbank.org/climateportal/index.cfm.

Box 2: Screening for Climate Risks in World Bank Operations

The World Bank is developing climate risk screening tools to help client countries better prepare for and deal with risks and associated impacts of a changing climate. The tools are intended to ensure that actions to manage risks and associated impacts are consistent with the climate change mitigation and adaptation strategies of the country. Countries have historically adapted to climatic contexts that included seasonal variability and extreme events. However, historical variability is no longer the norm, as we have experienced an increased rate of change in climate conditions during the past several decades. This trend is likely to further accelerate as the world continues to emit large amounts of CO_2 and other greenhouse gases into the atmosphere. The impacts of an increasingly warmer world are described in a recent World Bank report entitled *Turn Down the Heat: Why a 4°C World Must Be Avoided* (Potsdam Institute 2012).

A National Climate Impact Screening (NCIS) tool enables countries to systematically identify the **climate vulnerabilities** of national programmatic activities and development goals; it also enables them to identify sector and geographic hotspots. The tool builds on existing information, including that of the World Bank's **Climate Change Knowledge Portal**. It is complemented by the **Institutional Readiness Scorecard** (IRS), which provides a rapid assessment of clients' institutional and capacity needs for understanding and acting on information about climate risks at the strategic level. By allowing countries to characterize potential climate impacts and capacity (figure B2.1), the two sets of information inform dialogue on the importance and urgency of addressing climate risks and facilitate a systematic response to capacity challenges and resilience building.

Figure B2.1: Adaptation Imperative—Comparing Potential Climate Impacts and Adaptive Capacity



At the project level, sector-specific screening tools have been developed to better understand the risks from climate change and climate variability that the investments may be exposed to. Screening for potential climate risks at early stages of project design has been developed for six key subsectors (urban water and sanitation, irrigation and drainage, dams and reservoir, land and soil management, roads, and coastal flood protection). These tools are currently being tested, and once finalized will be made widely available through various knowledge platforms, including the Climate Change Knowledge Portal at http://climateknowledgeportal.worldbank.org.

Source: Kanta Khumari, World Bank.

the damage from climate hazards?' but rather 'How can we reach our development targets while accounting for current and future risks?'" (Economics of Climate Adaptation Working Group 2009, 27).

Define sector policy goals and targets. As Ranger and coauthors (2010, 27) write, "Objectives are not necessarily adaptation specific and in fact using broader objectives can be useful in helping to mainstream adaptation into organizational decision-making." The essential starting point for setting objectives is to identify how climate risk management and adaptation objectives support existing development priorities. The integration of risk management and adaptation objectives into sector policy goals is a consensus-building process and can elevate the profile of risk management and adaptation on the political agenda.

The extent to which climate risk management objectives have already been mainstreamed into organizational decision making is evident in the 12th FYP, for 2011–2015. The 12th FYP mandates that China reduce the CO_2 per unit of GDP by 17 percent in 2015 compared to 2011 and calls for the development of a national adaptation strategy. The plan sets broad-based goals for improving DRM in a number of sectors, including urban planning and flood prevention. Additional goals for DRM during the period of the 12th FYP are specified in the National Comprehensive Disaster Reduction Plan (2011–2015) (State Council 2011). The plan sets a goal of reducing losses from natural disasters each year to less than 1.5 percent of GDP (annual losses from weather disasters alone averaged 2 to 3 percent of GDP during the previous FYP).

The sector FYPs offer a crucial point of entry for mainstreaming adaptation objectives into sector-level policies. They also illustrate the importance of balancing potential trade-offs. For example, the 12th FYP for forestry states that taking action on climate change is one of the guiding principles for the development of the sector (SFA 2011b).[18] Two main goals for forestry during the 12th FYP are to (1) increase natural carbon stores by scaling up tree-planting efforts; and (2) stem the loss of biodiversity by strengthening China's network of natural protected areas. Yet increasing carbon stores does not necessarily lead to more biodiversity. Tree-planting efforts so far have largely relied on exotic species and monocultures. Plantation forests exhibit lower levels of biodiversity and are more susceptible to pests and disease. As a result, only one-quarter of the trees planted as part of afforestation and reforestation efforts between 1952 and 2005 have survived (Cao 2008; Cao et al. 2011).

Set boundaries. Clearly defining the boundaries of the policy decision up front can make the adaptation problem more tractable. Different elements of boundaries include the following:

- **Time frame.** The time frame depends on the planning horizon for sector goals, the functional lifespan for investments, and decision lead-in times. As illustrated in table 2 above, long-lived investments may increase the sensitivity of the decision to deep uncertainties about the future.
- **Geographic extent.** Mapping where the people, assets, businesses, and other entities that make up the sector are located can help define who and what will be affected by the policy decision. Often, the spatial boundaries of the sector do not conform to political or jurisdictional boundaries. As with many environmental problems,

[18] Priorities for both mitigation and adaptation are further defined in the "Key Action Points for Forestry in Addressing Climate Change" during the 12th FYP (SFA 2011a).

actions by governments in one area may generate externalities that extend far beyond local borders (for example, downriver flood protection). There is thus a need for cross-border cooperation in the risk management process, for example, involving watershed or basin-scale authorities such as the Yellow River Conservancy Commission in sector plans for water resources.

- **Institutional authority.** Institutional mapping can be useful for identifying key public agencies and other entities and their responsibilities. It will also shed light on where cross-sector coordination is needed. The question for the sector planner is, "Who else has decision-making powers that could affect the outcome of this policy or investment and should be involved?" Answering this question is not always an easy task and will require identifying where overlapping or unclear responsibilities exist.

Identify stakeholders. Defining the boundaries of the policy decision will help reveal who the key stakeholders are. Relevant stakeholders include those outside the government. In China, for example, research centers and environmental groups have played an increasingly important role as advocates and information providers in the realm of climate policy making.[19] Consulting with research centers, environmental nongovernmental organizations (NGOs), financial institutions, and private enterprises at this early stage in the decision-making process is especially important for setting goals. However, the process of consultation with stakeholders in adaptation must be carefully structured to ensure that it is meaningful (box 3).

Box 3: Examples of Guidelines and Tools for Stakeholder Engagement in Adaptation Planning

The following resources are available to help those undertaking adaptation planning structure consultations with stakeholders:

- Slocum, Nikki. 2003. *Participatory Method Toolkit: A Practitioner's Manual*. United Nations University, Comparative Regional Integration Studies, Belgium. http://unu.edu/hq/library/Collection/PDF_files/CRIS/PMT.pdf.
- CoastalAdaptation.eu. "Stakeholder Engagement." Innovative Management for Europe's Changing Coastal Resources (IMCORE) Project. http://www.coastaladaptation.eu/index.php/en/plan-to-adapt/stakeholder-engagement.
- Gardner, John et al. 2009. "A Framework for Stakeholder Engagement on Climate Adaptation." Working Paper No. 3, Climate Adaptation National Research Flagship, CSIRO, Australia. http://www.csiro.au/files/files/pph1.pdf.
- Holstein, Age Neils. 2010. "Participation in Climate Change Adaptation." GRaBS Expert Paper 2, EU Regional Development Fund and INTERREG IVC Programme. http://www.grabs-eu.org/downloads/Expert_Paper_Climate_Participation_FULL_VERSION(mk3).pdf.
- Bizikova, Livia, Samantha Boardley, and Simon Mead. 2010. "Participatory Scenario Development Approaches for Identifying Pro-Poor Adaptation Options." World Bank, Washington, DC. http://climatechange.worldbank.org/sites/default/files/documents/PSD-Pro-Poor-Adaptation_EACC-Social%20.pdf.
- CARE. 2012. "Participatory Monitoring, Evaluation, Reflection, and Learning for Community-Based Adaptation: PMERL Manual, A Manual for Local Practitioners." CARE and IIED. http://www.careclimatechange.org/files/adaptation/CARE_PMERL_Manual_2012.pdf.

[19] For a discussion of the role of think tanks and environmental nongovernmental organizations in shaping China's climate change policy, see Stensdal (2012), Heggelund (2007), Yu (2004), and Glaser and Saunders (2002).

Step 2: Assess Risks

As emphasized in the climate risk management framework developed for the United Kingdom by the UK Climate Impacts Programme with Defra and the Environment Agency, an assessment of climate risks should follow a tiered approach that begins with an initial, "light-touch" screening of climate risks (Willows and Connell 2003; Ranger et al. 2010). The sensitivities of the sector to weather and climate are identified and scenarios of future change are explored to provide a sense of how the policy decision may be affected by climate risks before launching into a detailed, quantified analysis of options to deal with those risks.

There is a tendency for climate risk information to be underutilized by decision makers (see Weaver et al. 2013). This may be because the information is at the wrong scale, is poorly understood, or is not seen as credible. Engaging with climate scientists and other technical experts to identify appropriate, "fit-for-purpose" risk information for the assessment of climate risks is thus essential to guiding decisions. Failure to take full account of climate risks due to poor uptake or lack of appropriate information can lead to poor decisions and a waste of resources (Ranger, Muir-Wood, and Priya 2009, Ranger et al. 2010). Information needs will largely be determined by how the scope and nature of the decision are defined in the previous step. Varying information needs for different kinds of climate risk management decisions are illustrated in table 3.

Screen for risks. The initial screening starts by looking at the sector's current level of exposure and vulnerability to severe weather events and climate variability. This step accomplishes two things. First, it gives a sense of how the sector is already affected by weather- and climate-related hazards. Second, it sheds light on how the sector may be affected in the future by illuminating the sensitivities of the sector to weather and climate. Box 4 offers an example of an initial screening for sensitivity to climate risks that was performed by the World Bank for Vietnam's energy sector.

Table 3: Comparison of Risk Information Needs for Different Management Decisions

Risk assessment information needs	Single-location infrastructure design	Emergency response planning	Land use planning	Natural resource management strategies (e.g., water supply)	Engineered risk reduction strategies (e.g., building codes and flood defenses)
Accuracy	Medium	Low	Medium	Medium	Medium
Consideration of multiple hazards	Medium	High	High	Medium	High
Spatial resolution	High	Low	Low	Low	Medium to high[a]
Need for probabilistic information	Medium	Low	Low to medium	Medium to high[a]	High[a]
Presentation	Site-specific hazard data	Hazard map	Hazard map	Hazard and risk map	Risk map and modeling

Source: Based on Ranger, Muir-Wood, and Priya (2009), with modifications.
a. In these categories, there will be higher information needs where cost-benefit analysis is performed.

One way of identifying sensitivities is to reflect on how the sector was affected by severe weather events and other climate-related hazards in the past. For example, in developing a climate-resilient strategy for improving urban drainage in Beijing, one could consider the flood of July 2012. Ten hours of heavy rain—the worst in six decades—inundated much of the city and killed a reported 79 people. The city's storm drain system, which was engineered in the early 1950s and consists of underground pipes designed to handle one-in-two- or one-in-three-year storm events, was simply not up to the task. As existing canals, moats, waterways, and green spaces have been filled in, this has increased runoff into the outdated piping system. The construction of drainage infrastructure has also failed to keep pace with development in newer areas of the city. This suggests that the sector is already highly sensitive to heavy storm events; this sensitivity may increase as the built-up area of the city expands and if older infrastructure is not repaired or replaced (*Economist* 2012; *Southern Weekend* 2012; *People's Daily* 2012).

Box 4: Screening Vietnam's Energy Sector for Climate Risks

The World Bank's Energy Sector Management Assistance Program (ESMAP) has developed a tool for performing an initial screening of climate risks to a country's energy supply system. The tool evaluates the imperative of adapting the energy sector to climate change according to (1) physical exposure and sensitivity of the sector to climate-related hazards; and (2) the capacity of the sector to adapt. Countries are scored in both dimensions to determine the level of adaptation imperative using a matrix similar to that illustrated in figure B2.1. The ESMP tool has been or is being applied to Vietnam, Zambia, Nepal, and Mozambique.

A rapid assessment of Vietnam's energy sector using the tool demonstrates that adapting the sector to climate change is highly imperative for Vietnam. The country's energy sector already faces a high level of exposure to tropical cyclones and floods, and its energy supply system is highly sensitive to changes in weather and climate conditions. Some of the indicators used to assess the sensitivity of Vietnam's energy sector to climate change are illustrated in table B4.1. The sector also possesses a relatively high level of economic, technical, institutional, and informational capacity to adapt. Thus, the screening indicates that adapting the energy sector in Vietnam is both necessary and feasible.

An initial screening of a country's energy supply system using the ESMAP rapid assessment typically requires up to six person-weeks, while a more detailed, quantitative analysis of risks may require up to six months.[20]

Table B4.1: Indicators for the Sensitivity of Vietnam's Energy Sector to Climate-related Changes

Indicators of energy system sensitivity to climate-related changes	Responses and scores
Energy system-level concerns	
Energy sector water intensity	Unknown
Energy supply efficiency	Low
Country energy intensity	High
Fossil fuel resource extraction and processing	
Presence of coastal, offshore or inland extraction/processing plants prone to flooding and storms	Yes
Presence of processing plants in water-stressed areas	Yes
Energy supply	
Contribution of hydropower to power supply	Considerable
Contribution of small reservoirs or run-of-the-river plants to total hydropower output	Small
Contribution of thermoelectric facilities to power supply	Considerable
Contribution of thermal power plants with open-circuit cooling to total thermoelectric output	Unknown
Contribution of woodfuel to household cooking	Considerable

Source: ESMAP 2012.

[20] Personal communication with Wang Xiaoping, ESMAP, World Bank, March 27, 2013

Nonclimate pressures should be considered as part of the initial screening of sensitivities. These pressures may amplify the effects of severe weather, climate variability, and future climate change. For example, in the case of Beijing, the sensitivity of the urban drainage system to heavy rainfall events has been amplified by inadequate investment in maintenance and repair of existing storm drains and pipes, as well as paving over of natural drainage areas due to rapid construction.

As part of the initial risk screening, mapping can help decision makers visualize which areas of the sector are most exposed to weather- and climate-related hazards and what the relative levels of risk are. A **hazard map** provides information about the geographic footprint and magnitude of hazardous events (for example, the extent of a one-in-100-year floodplain in a city, or the area of cropland affected by a particularly bad drought). An excellent example of hazard mapping being used to improve public awareness of climate- and weather-related hazards is provided by the Water Resources Bureau of Guangxi Province, which has published online flood hazard maps for each of the province's municipalities.[21] A second type of map, a **risk map**, combines a hazard map with information about exposure and vulnerability.[22] Insurance companies use risk maps to estimate expected annual property losses from severe weather events in different areas. Risk maps are generated using meteorological and hydrological data, inventories of assets and structures, property values, and reported losses from historic events. Vulnerability curves are then fitted using these data to estimate the probability that a certain level of damages will occur.

Representing vulnerability in terms of expected economic losses from severe weather events has its limitations. This approach is most appropriate for areas with high levels of urbanization, widespread insurance, accurate reporting of disaster losses, and effective institutional mechanisms for recovery and reconstruction. However, it may underestimate losses from severe weather and other climate-related hazards in poor and rural areas. Estimates of direct losses also do not consider the ripple effects that severe weather events have on the economy (for example, flood waters may cause sewage spills and contaminate local water supplies, leading to illness and lost wages(see Ranger et al 2011)).

Previous research has shown that poor people tend to suffer more from the effects of climate change and natural disasters because (1) they are more likely to live in hazard-prone areas; (2) they are often subject to multiple, overlapping risks, and even small, every-day disturbances may overwhelm their ability to cope and produce disproportionately large impacts on welfare;

[21] The Guangxi Water Resources Bureau site also provides real-time storm information, flood warnings, and notice of water releases from reservoirs, as well as historical data and hazard ratings for landslides and flash floods in different municipalities. See http://www.gxwater.gov.cn/.

[22] In 2011, a group of researchers headed by Shi Peijun, deputy director of the National Disaster Reduction Commission, published China's first national atlas of risk maps for natural disasters. Risk maps for typhoons, floods, landslides, snow, hailstorms, and other hazards were created from "hundreds of years of records on natural disasters and related losses" (People's Daily 2011; MWR 2011).

(3) risk-minimizing livelihood strategies adopted by poor people in response to frequent hazards result in lower average incomes; and (4) poor people lack access to services, networks, and resources that are designed to assist in recovery from shocks (Mearns and Norton 2009; World Bank and UN 2010; World Bank 2011; Adger et al. 2007; Cannon, Twigg, and Rowell 2003; Adger and Kelly 1999).

Especially in poor and data-scarce environments, it may be more appropriate to screen for vulnerabilities through bottom-up methods that focus on the social, cultural, economic, and environmental factors leading to differential exposure to hazards, impacts, and capacities to cope and adapt to future threats. These methods aim to show not only who and where the vulnerable are, but also why they are vulnerable and what their capacity to adapt is (Downing and Patwardhan 2004). An example of a bottom-up vulnerability assessment for Surat, India, is provided in box 5. The wealth of tools and resources available to assist in bottom-up assessments of vulnerability is shown in box 6.

One commonly used method for assessing vulnerability is to create an index that captures indirect measures of the social dimensions of vulnerability (see Moss, Brenket, and Malone 2001; Downing and Patwardhan 2001; Adger et al. 2004; Hahn, Riederer, and Foster 2009). The advantage of these indexes is that they allow for easy comparisons between different regions and across different time periods. It is also possible to use indicators to create vulnerability maps to see how vulnerability is distributed spatially (WRI et al. 2011). The disadvantage is that vulnerability, especially social vulnerability, is highly context dependent, and indicators such as GDP per capita may not accurately reflect the unique factors that contribute to the vulnerability of different social groups in one region versus another. Moreover, vulnerability indexes only capture snapshots of vulnerability at a given time and place; they do not describe processes that contribute to vulnerability and how these are changed over time.

Box 5: Assessing Vulnerability to Flood Risks in Surat, India

Surat is a large coastal city about 250 kilometers north of Mumbai at the mouth of the Tapti River. About 20 percent of the city's population lives in slums, many of which are crowded along tidal creeks and river banks and experience frequent flooding. A citywide assessment of the vulnerability of slum dwellers and migrants to flooding and other risks revealed the following:

- Low levels of schooling act as a barrier to awareness raising.
- About one-third of slum dwellers have highly unstable sources of income, which can be easily disrupted by floods or other shocks.
- Slum dwellers usually lack insurance coverage and have little access to the services of NGOs, microfinance groups, or other social service providers; slum dwellers and migrants also tend to have weaker social support networks than others.

The assessment showed policy makers that investing in social interventions aimed at reducing the vulnerability of the city's slum dwellers will be essential to flood risk management in the city.

Source: World Bank 2012a.

Box 6: Examples of Tools Used to Screen for Vulnerabilities to Climate Risks

The following are a few examples of the many tools and resources available for conducting bottom-up assessments of vulnerability:

- International Red Cross and Red Crescent Societies. "Vulnerability and Capacity Assessment Guidelines." http://www.ifrc.org/Global/Publications/disasters/vca/Vca_en.pdf.
- CARE. 2009. *Climate Vulnerability and Capacity Analysis Hand Book*. http://www.careclimatechange.org/cvca/CARE_CVCAHandbook.pdf.
- United Nations Development Programme. 2010. *Mapping Climate Change Vulnerability and Impact Scenarios: A Guidebook for Sub-National Planners*. http://europeandcis.undp.org/uploads/public1/files/Mapping%20CC%20Vulnerability%20publication%20-%20November%202010.pdf.

Conducting a vulnerability assessment can provide an entry point for local stakeholders to participate in the risk management process. Members of the local community, including private households, businesses, NGOs, and government officials, are best positioned to identify both the ways in which they are affected by climate variability and the barriers that prevent them from anticipating, withstanding, or recovering from the impacts of adverse weather (World Bank 2010a).

Explore future scenarios of change. The previous step in the screening focused on present-day risks to understand how the sector is already affected by weather, climate, and other pressures. The step under discussion here focuses on creating a wide range of plausible scenarios to explore how these risks may change in the future.

At the most basic level, scenario analysis can involve qualitative story lines or projections to describe a range of "risky" futures. At the most advanced level, it makes use of complex statistical modeling to test hundreds or thousands of different climate scenarios and isolate key vulnerabilities that lead to poor sector performance (Wilby et al. 2009; Lempert, Scheffran, and Sprinz 2009). Yet greater complexity does not necessarily equal more accurate or useful results. The key is to work with experts to identify projections that satisfy the needs of the decision maker, and in this way ensure that the information will be effectively used. Box 7 offers a best-practice example from the United Kingdom of decision-tailored climate projections.

Factors to consider in judging the utility of climate projections include the following (Stainforth et al. 2007a, 2007b; Ranger et al. 2010):

- **Relevance.** Do the projections represent the factors and processes that are most likely to affect the performance of the policy? Is the causal connection between weather and climate and the performance of the policy well understood?
- **Scale.** Are the projections at the right spatial and temporal scale, and can they provide reliable information at that scale? Methods used to downscale GCMs to finer spatial resolutions can introduce additional uncertainty

and bias. Over shorter time frames, the climate change "signal" in the projections may be washed out by natural variability and randomness (see figure 1). Developing projections at the right scale requires striking a balancing between the information needs of the decision maker and the scientific limits of the models, especially if the policy or investment is place specific and highly sensitive to local weather and hydrology.

- **Range.** Do the projections capture a wide enough range of plausible scenarios to inform the decision about potential risks? And are the results of the projections likely to change over time as knowledge about weather- and climate-related processes improves?
- **Multiple pressures.** Aside from weather- and climate-related variables, do the projections take account of other pressures that could influence the decision (for example, rates of population growth or water demand by industry)?

In exploring future scenarios of change, decision makers may consider the possibility of crossing key impact thresholds. Thresholds may be defined by stakeholders in terms of acceptable or unacceptable levels of impact.[23] This was done for the Great Lakes region on the border of the United States and Canada. Technical working groups were convened by an international commission to evaluate the impacts that changes in water levels would have on ecosystems, recreational

Box 7: Creating User-Oriented Climate Change Projections: The UK Climate Projections 2009

In 2009, the fifth generation of climate change projections for the United Kingdom (UKCP09)[24] was released by a consortium of nine organizations, including the UK Met Office, UK Environment Agency, UK Climate Impacts Programme, and a number of research institutes and laboratories. For each region of the United Kingdom, UKCP09 provides information on observed climate trends and makes projections about future change in the climate and marine and coastal environment.

The UKCP09 projections were designed with adaptation planning in mind and aim to provide decision makers and organizations in the United Kingdom with a state-of-the-science understanding of weather and climate impacts that could affect their activities. The launch of UKCP09 reflected the culmination of several years of consultation and engagement with stakeholders to identify and respond to their needs.

One of the main challenges in the consultation process was balancing the expectations of users. According to UK Climate Impacts Programme staff members who were involved in the process, "There will always be a tension between the users' desire and the limits of robust science. Balancing the two often ends in conflicting demands that need to be finely managed . . . These kinds of trade-offs need to be made clear to the users from the outset . . . When users' requirements cannot be met, a full explanation should be given so users do not become disillusioned with the process" (Steynor, Gawith, and Street 2012, 14).

Source: Steynor, Gawith, and Street 2012

[23] Many kinds of thresholds exist, from the biophysical to the social (Jones 2001). Note that the concept of user-defined thresholds here differs from that of natural tipping points. The role of user-defined thresholds is to encourage decision makers to think about what level of impact is tolerable—not to predict when and where they think tipping points will be crossed and trigger sudden, dramatic changes.

[24] See the UK Climate Projections website at http://ukclimateprojections.defra.gov.uk/.

boating, commercial navigation, water supply, and other areas. The working groups determined a range of water levels that were acceptable or unacceptable for the different areas (Moody and Brown 2012). A similar threshold-setting exercise was performed for an investment program by the World Bank in Nigeria. Stakeholder countries in the Niger River basin gathered at a workshop to decide what would be a tolerable level of decline in the performance of the proposed investment due to change in climate conditions. The stakeholders decided that a 20 percent loss from baseline performance was unacceptable. Modeling was then done using a full range of GCM projections to examine whether such a large decline was likely given the current state of the climate science (Brown 2011).

Because the varying results of climate models represent a "lower bound" of the full range of uncertainty, assigning objective probabilities to impacts based on an ensemble of model results may be misleading (Stainforth et al. 2007a, 2007b; see also Weaver et al. 2013). It may also lead to overconfidence, and basing investment decisions on ambiguous or unclear probabilities creates the danger of maladaptation (Hall 2007). Instead, scientists and other experts may use their best judgment to assign subjective probabilities to risks based on the current state of evidence, as was done for the UK Climate Projections 2009 (UKCP09). This in turn requires careful communication of what the uncertainties are, how they are represented, and how they affect the results of the projections.[25]

To represent a fuller range of uncertainty, scenarios may be created to explore potential surprises and abrupt changes. This approach was taken for scenarios of sea-level rise created for the climate change impact review by the New York City Panel on Climate Change in 2010. The scenarios considered the effects of the thermal expansion of ocean waters under a range of higher temperatures and local land subsidence in the city; the gradual melting of glaciers, ice caps, and ice sheets; and the circulation of ocean currents for a range of future emission pathways and temperatures. Recognizing the limitations of the current generation of climate models in accounting for tipping points, researchers also created a scenario of rapid sea-level rise in which the Greenland and Antarctic ice sheets melted much faster than expected (Horton, Gornitz, and Bowman 2010; Solecki, Patrick, and Brady 2010). Based on these projections, the panel recommended that New York City revise its flood protection standards and zoning to account for higher seas.

[25] See Mastrandrea et al. (2010) for guidance on the communication of uncertainty.

Box 8: Knowledge-sharing Databases for Identifying Climate Change Adaptation Policies and Practices

- European Climate Adaptation Platform: http://climate-adapt.eea.europa.eu/web/guest/adaptation-measures.
- UNFCCC, Adaptation Practices Interface: http://unfccc.int/adaptation/nairobi_work_programme/knowledge_resources_and_publications/items/4555.php.
- UNFCCC Database on Ecosystem-based Approaches to Adaptation: http://unfccc.int/adaptation/nairobi_work_programme/knowledge_resources_and_publications/items/6227.php.
- UNFCCC Database on Local Coping Strategies: http://maindb.unfccc.int/public/adaptation/.
- UNFCCC NAPA Priorities Database: http://unfccc.int/adaptation/workstreams/national_adaptation_programmes_of_action/items/4583.php.
- UNFCCC Private Sector Initiative—Database of Actions on Adaptation: http://unfccc.int/adaptation/workstreams/nairobi_work_programme/items/6547.php.

Step 3: Identify and Evaluate Options to Reduce Risk

Once risks to the sector from weather- and climate-related hazards are identified, the next step is to identify and evaluate options to reduce or transfer risk. The UNFCCC and others have compiled databases to share best practices, case studies, and cost information for climate change adaptation policies and practices (box 8). Given these extensive resources, this section focuses on how decision-makers can choose among different policy options despite facing conditions of deep uncertainty about the future climate.[26] Emphasis is placed on the need for robustness and the importance of balancing robustness with other requirements (for example, cost-effectiveness).

The evaluation of policy options should begin with a conversation about priorities and about the criteria that will be used to define successful adaptation and the management of risks. The overall policy objectives identified in framing the decision in step 1 can help guide this conversation. Criteria for defining successful adaptation as suggested by previous studies include feasibility, effectiveness, efficiency, timeliness, equity, sustainability, and appropriateness (Brooks et al. 2011; Fankhauser and Burton 2011).

As a rule of thumb, in planning for adaptation under uncertainty, priority should be given to low-regret strategies that offer benefits regardless of how the climate changes. "Many of these **low-regrets** strategies produce co-benefits, help address other development goals, such as improvements in livelihoods, human well-being, and biodiversity conservation, and help minimize the scope for maladaptation" (IPCC 2012, 13). Low-regret measures are typically those that build adaptive capacity and enhance resilience, such as restoring degraded mangroves near densely populated coastal cities or improving access to safe drinking water. Examples of low-regret measures to manage risks to urban water utilities in China are highlighted in table 4. As the table shows, there are many

[26] The discussion in this section of robustness and decision making under uncertainty draws extensively from Hallegatte et al. (2012) and World Bank (2012b).

Table 4: Low-regret Climate Risk Management and Adaptation Options for Urban Water Utilities in China

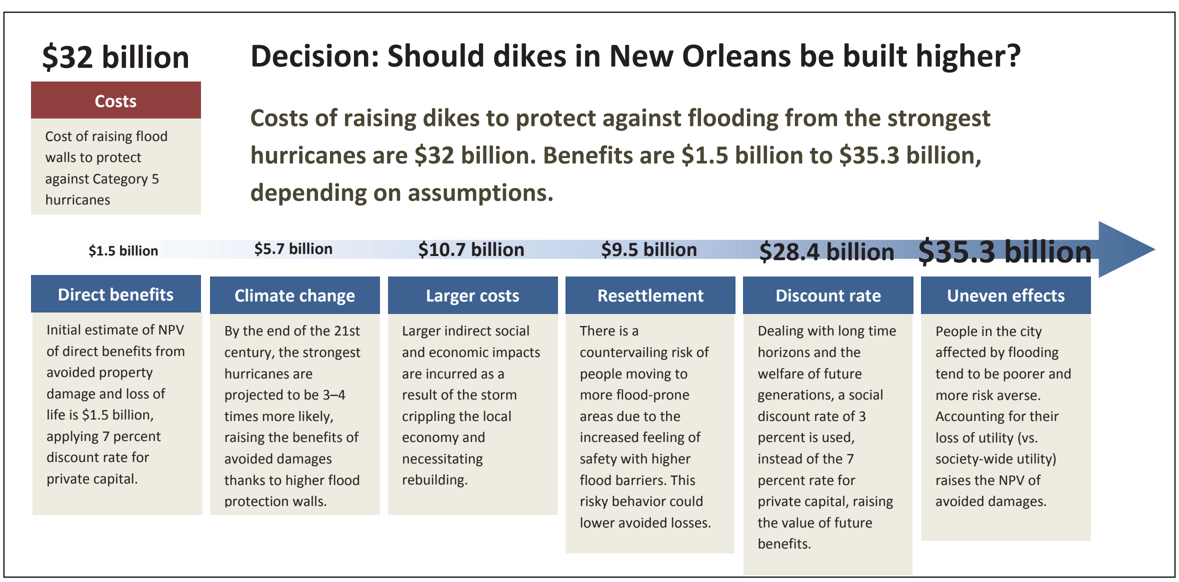
Area of activity	Options
Knowledge of climate change risks	• Survey surface water and groundwater resources, with follow-up monitoring by provincial and local environmental protection and water resources bureaus
	• Prepare flood risk maps and make these available to the public
	• Conduct public information campaigns on flood risks and emergency management plans
Institutional strengthening	• Create single urban drainage authority for each municipality, merging responsibilities for wastewater treatment
	• Increase decision-making autonomy of utilities
Design and performance standards	• Establish a national utility benchmarking program
	• Strengthen national requirements for utility information disclosure
Adequacy of water supplies	• Develop national and provincial regulations to restrict groundwater abstraction
	• Conduct R&D for expanding desalinization capacity
	• Develop guidelines for rollout of storm-water recycling by utilities
	• Review regulatory framework and develop guidelines for decentralized rainwater harvesting
Improvement of resource efficiency	• Establish tighter water-efficiency standards in building codes
	• Establish a national target for energy generation from wastewater and sludge
	• Reduce leakage in water distribution systems
	• Raise tariffs to improve utilities' operating cost recovery
	• Create incentives to encourage industrial water recycling
Pollution control	• Expand municipal wastewater collection and treatment capacity
	• Encourage use of non-engineering wastewater treatment methods
	• Reduce industrial discharges by tightening sector regulations on industrial emissions and improving monitoring and enforcement
	• Establish national quality parameters for drinking water resources
	• Involve farmers and other stakeholders in watershed management programs
Drainage and flood control	• Increase investment in extending, repairing, and maintaining draining networks
	• Encourage non-engineering approaches to flood management
	• Improve flood forecasting and early warning systems
	• In areas already experiencing seawater intrusion, increase investment in hydrological barriers

Source: Adapted from Jensen 2013.

low-regret options available. Yet low-regret measures will not always substitute for higher-stakes options that carry the possibility of large sunk costs such as flood protection infrastructure (Ranger and Garbett-Shiels 2012).

Decision makers have traditionally relied on cost-benefit analysis (CBA) to weigh potentially large costs and choose policies and investments that maximize net economic benefits. CBA may account for uncertainty by testing how optimal, benefit-maximizing solutions perform if the assumptions and parameters of the cost-benefit function are varied (Arrow et al. 1996, cited in Hallegatte et al. 2012). An example of CBA being used in the realm of climate risk management comes from New Orleans. In rebuilding after Hurricane Katrina, the U.S. Congress considered the costs and benefits of raising the city's flood barriers to protect against storm surges from the strongest hurricanes. The costs of raising New Orleans's flood defenses to the highest standard (that is, to protect against a Category 5 hurricane) was estimated at $32 billion, while the net present value (NPV) of benefits from improved flood protection was estimated to be only $1.5 billion to $6 billion. These figures would suggest, in Stefan Hallegatte's (2006, 4) words, "that it is more rational from an economic point-of-view to live the Katrina nightmare again in a more or less remote future" than to spend more money now to rebuild to higher standards. Yet as Hallegatte showed, varying the assumptions of the CBA could effectively increase the benefits of higher flood walls to $35 billion and reverse the apparently rational decision (see figure 5).

Figure 5: The Decision Maker's Dilemma—Considering the Costs of Building Higher Flood Walls in New Orleans after Hurricane Katrina



Source: Analysis by Hallegatte 2006.

As the example from New Orleans attests, policy decisions that are sensitive to deep uncertainties are not easily amenable to traditional CBA. CBA supposes that (1) risks are known and can be described with a single joint probability distribution function; and (2) there is agreement among decision makers as to objectives and key assumptions (see Ranger et al. 2010; Hallegatte et al. 2012). The balance of costs and benefits in the New Orleans example is influenced to a great extent by the range of climate change projections. The example assumes for the sake of illustration that Category 5 hurricanes will occur three to four times more frequently by the end of the century than they do today. Yet even if the most powerful hurricanes occur only two times more frequently—as opposed to three or four—the difference in the NPV of avoided damages is enough to sway the decision against raising flood protection standards. The decision also hangs on a number of thorny ethical questions, such as how much a human life is worth (in monetizing avoided damages) or how the welfare of future generations should be weighted (in setting a discount rate), which can easily swing the outcome one way or the other.

Robust options are those that "perform reasonably well compared to the alternatives across a wide range of plausible scenarios evaluated using the many value systems held by different parties" (Lempert, Popper, and Bankes, 2003, xiv). Aiming for robustness is appropriate in situations similar to that of New Orleans. In that example, policy makers were faced with making a choice on a very long-lived investment with the possibility of large sunk costs and lock-in effects, highly uncertain scientific assumptions, and differing views on questions of basic values.

As a method for evaluating policy options, **robust decision making (RDM)** starts with identifying a candidate set of policies or investment options. The decision maker or analyst tests the vulnerabilities of each option by looking at how the options perform under a wide variety of uncertain conditions. This may involve the exploratory use of climate model projections or statistical techniques to create hundreds or thousands of different future scenarios. New or modified strategies are proposed to address vulnerabilities, and then the scenarios are run again to evaluate if performance improves, with a focus on those scenarios for which the original option performed the worst. Looking at many different scenarios enables the decision maker or analyst to isolate what the greatest uncertainties are and weigh the trade-offs for reducing these uncertainties by pursuing other options (for example, in terms of higher costs). The process may be repeated until a viable strategy or set of measures is identified (Lempert et al. 2003; Groves et al. 2008; Lempert and Groves 2010; Lempert and Kalra 2011). RDM has been applied by water agencies in the American West to evaluate the climate robustness of their long-term water supply plans (Lempert and Groves 2010; see box 9) and is currently being employed in Ho Chi Minh City to improve the city's flood management strategy (Hallegatte et al. 2012).

One way of measuring robustness is to compare varying levels of regret associated with pursuing different strategies. The regret associated with pursuing a strategy is defined following Savage (1950) as the difference between the performance of that strategy (given some function of strategic, economic, or social value) and the performance of the "best" strategy under a given scenario (cited

Box 9: Robust Decision Making by Water Utilities Planning for Climate Change

Water utilities tasked with developing long-term water supply plans are familiar with the challenges of decision making under uncertainty. In the past, utilities have typically accounted for uncertainty by considering year-to-year variability in rainfall and stream flows and projecting what future water needs will be by considering present-day trends. Climate change is challenging this practice of water resources planning, as knowledge of past conditions is becoming less and less useful as a guide for what the future climate will be like.

Confronting this dilemma, in 2007 the Inland Empire Utilities Agency (IEUA) in Southern California invited the RAND Corporation to evaluate the vulnerability of the agency's water resources plan to climate change. Researchers worked with IEUA planners to identify key uncertain factors that could affect the ability of the agency to meet its water supply obligations under the current plan. Using the outputs from a GCM, researchers created a large ensemble of projections for temperature and precipitation to reflect the potential for warmer and drier weather as well as cooler and wetter weather (within the bounds of what IEUA staff believed was plausible). Because the population of the IEUA region is expected to grow 50 percent by 2025 as the region's farms are replaced with suburbs, researchers also considered the uncertainties involved with how much water new housing developments would need and how altering the local landscape with new construction could affect the natural replenishment of groundwater.

Using statistical techniques, 450 different scenarios were created to represent different combinations of the uncertain factors identified. The scenarios revealed that among the uncertain factors, changes in the regional climate presented a significant risk to the agency. Water supply costs exceeded what the IEUA could reasonably afford in 60 percent of the future scenarios involving warmer and drier weather. To explore how the vulnerability of the current water resources plan could be reduced, researchers and agency staff introduced eight alternative management strategies to increase local supplies and reduce dependence on costly imports of water from other basins. Strategies included capturing storm water to recharge groundwater supplies, recycling grey water from households, and investing in efficiency programs. The analysis found that the IEUA could reap the greatest benefits from these strategies by practicing flexibility and allowing the agency's supply plan to be adjusted over time in response to changing conditions down the road. By practicing adaptive management, high supply costs could be avoided in over 80 percent of the scenarios considered. The results of the analysis increased the confidence of IEUA planners that the agency's water resources plan could be effectively adapted to account for climate change.

Source: Lempert and Groves 2010.

in Lempert, Popper, and Bankes 2003). What it means to minimize regret depends on the appetite of the decision maker for risk. A highly risk-averse decision maker might opt for the strategy with the minimum amount of maximum regret across the entire gamut of scenarios being considered (that is, the least-worst worst-case scenario). Risk-neutral decision makers, on the other hand, might choose the strategy that comes with the lowest average level of regret across the range of scenarios. Tolerance for risk can be powerful in shaping decisions. Hughes (2011), for example, has shown that from the standpoint of a cautious leader, raising the design standards for water supply and sewer infrastructure in China would be a good economic decision even in today's climate—that is, without additional climate change. A risk-neutral leader, however, would delay raising standards until after the 2030s.

Robustness often goes hand in hand with **flexibility**. Flexibility is achieved by putting a mechanism in place for plans to be updated or modified as knowledge of the changing climate improves (see WRI et al. 2011). The Thames Estuary 2100 project is a good example of a flexible, climate-robust plan for infrastructure investment (box 10).

Box 10: Thames Estuary 2100 Project

The Thames Estuary 2100 project provides a real-world example of building resilience into long-lived, high-cost infrastructure assets in order to cope with future climate conditions and avoid inflexible design decisions at an early stage.

The Thames barrier protects Central London against at least a one-in-1,000-year return period storm surge. Opened in 1980, it was constructed to provide protection until 2030. Given that climate change is expected to increase the frequency and intensity of storm surges, the question arose whether the system needed to be modified in the interim and whether to design a forward plan to 2100.

A route-map decision analysis method was used to devise an adaptation plan that would build robustness even when dealing with long-lived decisions with high sunk costs (up to £9 billion) and deep uncertainty over future climate risks (extreme water levels in the estuary). The protection measures were designed to be built in a series of sequential steps, where each step represents a package of adaptation measures that provide protection against the current "most probable" estimates of storm surges (so there is no "overconstruction" at any stage). Series of packages are designed to span the plausible range of increases in water levels in the Thames by 2100 (the high end of the range is estimated at 4.2 m). Initial packages are typically "no-regret" measures that allow for the option of implementing other, possibly more irreversible measures (such as building a new barrage as opposed to upgrading the existing one) in the future as the risk is better understood. Construction on each package is to be triggered when observed extreme water levels cross a predetermined threshold, allowing for lead time needed for implementation. Such flexibility, however, can come at higher costs, and therefore economic analysis (net present value of investments and environmental impact) will be applied at each decision mode to choose the most cost-effective measure.

Source: Urvashi Narain, World Bank, summarizing Reeder and Ranger (2011)

Real options analysis (ROA) allows decision makers to explicitly account for the value of added flexibility in climate adaptation plans. A real option "is an alternative or choice that becomes available through an investment opportunity or action" (HM Treasury and Defra 2009, 11–12).[27] Leaving options open can create real economic value if plans can be adjusted to better fit changing circumstances as knowledge of those circumstances improves. ROA has been used in China to appraise investments in coal bed methane (Fan, Mo, and Zhu 2013), carbon capture and storage (Zhu and Fan 2011), and wind farms (Yang et al. 2010). It has also been suggested as a way of valuing biodiversity (Boyd 2010). To illustrate the use of ROA for climate adaptation, Gersonius, Ashley, and Pathirana (2013) assess the value of a flexible strategy for upgrading the urban drainage network of a city in England. The strategy allows for headroom allowances to be adjusted by building new storage facilities, replacing sewers, and taking other measures depending on changing patterns in the intensity of rainfall. The study finds that building in the possibility of adjusting the network can reduce costs by 20 percent over the lifetime of the infrastructure. Evidence of the cost-effectiveness of flexibility can be found elsewhere, too. Linquiti and Vonortas (2012) evaluate the social benefits of raising seawalls to protect two coastal cities, Dhaka, Bangladesh, and Dar-es-Salaam, Tanzania. The authors find that raising the height of the seawalls incrementally to respond to

[27] In the guidance note on accounting for climate change by the treasury office and environmental agency of the United Kingdom, the use of ROA is recommended for evaluating "policies, programmes or projects which have three core features: uncertainty, flexibility, and learning potential" (HM Treasury and Defra 2009, 11–12).

observed rates of global sea-level rise yields greater NPV benefits than designing the walls to protect against a one-in-100-year storm surge event at the beginning of the century and not making any adjustments. [28]

Apart from robustness, decision makers are also likely concerned with **cost-effectiveness**. Cost-effective adaptation measures are defined as those that reduce climate risks to a tolerable level while maximizing the resources available to decision makers to pursue other goals. Cost-effectiveness may serve as a secondary metric for choosing among options that satisfy a predetermined level of robustness. For example, a decision maker might pose a question like this: among those strategies that perform reasonably well in at least 80 percent of the scenarios being considered, which is least costly, taking into consideration capital costs and the net present value of future operations and maintenance costs?

The most robust and flexible options may not be the most cost-effective, and there are trade-offs to consider. Often, the most robust option is not the one that yields the highest returns in any single scenario, but rather the one that is "less brittle to surprise" and minimizes regret if predictions about the future end up being wrong (Lempert and Kalra 2011, 4; see also Lempert and Colllins 2007). For this reason, a common critique of RDM is that it is overly pessimistic and too geared toward the worst-case scenario (World Bank 2012b).

Ultimately, prioritizing robustness is a "normative" choice. The choice to plan for worst-case scenarios implies within it the values of the decision maker—about how much risk is tolerable, what objectives are most important, and what trade-offs are worth making (Lempert, Popper, and Bankes 2003). In some cases, the trade-offs associated with pursuing more robust options may be judged as too expensive. Far from dictating that people should always choose the course of action that offers the highest degree of robustness or flexibility, the point of RDM is rather to help people make risk-informed decisions that duly acknowledge the existence of deep uncertainties.

Step 4: Identify Challenges to Implementation and Plan to Monitor and Evaluate

Barriers. The "best" adaptation options chosen from the previous step (that is, those that are robust and reasonably cost-effective) need to be screened for institutional feasibility to determine the barriers to implementing them (see Brooks and Adger 2004). While climate risk assessments and option analysis are important, leaders may be unwilling or unable to act if risk management is not a priority, or if the institutional infrastructure needed to implement adaptation measures is not in place (Ranger and Garbett-Shiels 2012). The concept of risk management as an approach to coping with deep uncertainties in making climate adaptation policies is still relatively new in China. And China is not alone. A

[28] The only exception is in the scenario for Dar-es-Salaam where a 7 percent discount rate is applied to measure the NPV of future benefits instead of a lower social discount rate. In this scenario, doing nothing (that is, not building seawalls) is apparently the most economically rational strategy. The reason for this result likely has to do with the high up-front costs of building the walls, the low levels of development in the city (hence, low values of assets to be protected), and the significant discounting of future welfare benefits from pursuing an adaptive coastal flood protection strategy. If a 3 percent discount rate is used, then the adaptive strategy is the most economical (Linquiti and Vonortas 2012).

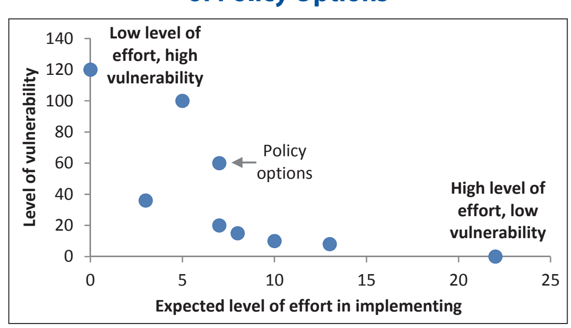
global review by the IPCC found "limited evidence" that countries are "explicitly integrating knowledge of and uncertainties in projected changes in exposure, vulnerability and climate extremes" in their DRM systems and policies (Lal et al. 2012, 342).

In China, two of the main institutional barriers to risk-based climate adaptation are weak cross-sector policy coordination and lack of incentives for implementation. These barriers to implementation are not unique to climate adaptation. Rather, they affect a wide range of environmental and social policies (see Ran 2013; Mei 2009; Lieberthal 1997). The incentives of officials are often aligned toward policies and projects that deliver immediate, visible benefits and political value.[29] By contrast, the benefits of risk management, climate adaptation, and resilient development tend to be longer term and more difficult to measure directly because they reflect a process and not a single outcome.

One practical way of weighing the robustness or cost-effectiveness of a measure with institutional feasibility is to map its benefits against the "level of effort" involved in implementing it, as Lempert and Groves (2010) do in comparing adaptation options for the IEUA's water resources plan (see box 9 above; figure 6 below). Under this approach, challenges for implementing each policy option are listed; then each policy option is assigned a score to reflect the expected difficulty in implementing it. The implementation difficulty score is then compared to a measure of policy performance, which in figure 6 reflects the number of future scenarios in the RDM analysis where water supply costs exceed a threshold value (a higher "vulnerability" score means a lower level of robustness).

Monitoring and evaluation. Monitoring and evaluation (M&E) aims to promote learning and ensure accountability. The uncertainty of climate change underscores the need for ongoing learning as part of climate change adaptation. Learning is facilitated by regularly reviewing progress and reassessing policies and plans as knowledge of the climate improves and unforeseen events unfold (see UKCIP 2011; Spearman and McGray 2011). Practically speaking, reviewing progress and demonstrating results are also fundamental to building confidence in the benefits of adaptation and attracting additional financing (Sanahuja 2011). The Climate Policy Initiative estimated that public and private financing for climate adaptation worldwide totaled $14 billion in 2012 (Buchner et al. 2012).

Figure 6: Mapping Barriers: Institutional Level of Effort Compared to Robustness of Policy Options



Source: Based on Lempert and Groves 2010.

Note: The x-axis represents an index score of difficulty assigned by decision makers and analysts; the y-axis represents the number of future scenarios in the RDM analysis where water supply costs exceed a threshold value for acceptability.

[29] This is due in large part to (1) the rotation of cadres to different posts and locales every few years; and (2) the weighting of criteria for GDP growth on official performance appraisals that are tied to career advancement (Ran 2013; Mei 2009).

Plans to monitor and evaluate the effectiveness of reducing vulnerability should be put in place during the design phase. Framework guidelines and tools for adapting M&E have been put forward by UNDP (2007), GIZ (Spearman and McGray 2011), and UKCIP (2011) among others. Previous reviews of adaptation M&E have found that “very few” evaluations of adaptation policies and projects have been done (Hedger et al. 2008; Villanueva 2011) and that new frameworks tested in the lab have yet to really be rolled out in the field (SEA Change 2013). Challenges to monitoring and evaluating climate adaptation cited in previous studies (Sanahuja 2011; Spearman and McGray 2011; Brooks et al. 2011) include the following:

- **Target setting.** Adaptation policies tend to lack measurable, clearly defined targets and outcomes. Careful framing of the decision, as recommended in step 1, can help address this problem.
- **Moving baselines.** Even in the absence of climate change, baseline social and economic development will strongly influence exposure and vulnerability. At the same time, M&E must also account for how changes in the weather or climate influenced policy and project outcomes.
- **Complexity.** Because adaptation represents a complex social process that occurs at multiple scales, the framework for M&E will usually focus on a single scale or process.
- **Indicators.** There is no standard set of metrics for judging success, though this problem can be resolved through careful dialogue between decision makers, analysts, and stakeholders in steps 1 and 3 to determine what priorities are and how possible options should be evaluated.
- **Attribution.** Due to moving baselines and the complex, multisector nature of the process, establishing direct cause and effect can be difficult. It can also be difficult to create a counterfactual situation to measure what would have happened in the absence of the policy or project (for example, what damages from flooding would have been).
- **Time frames.** The adaptation process extends beyond the cycle of an individual project or policy. The full economic benefits of improved flood protection, for example, may not be realized until decades in the future when a severe flood actually occurs. Thus in addition to satisfying a long-term goal, the adaptation process is often expected as a practical matter to demonstrate some short-term results and show that action is producing benefits or that progress is being made.
- **Maladaptation.** While measuring success is important, it is also important to understand failure when it happens. Part of M&E of climate adaptation should be to scan for unintended consequences and side-effects.
- **Learning.** Learning does not just happen. A specific mechanism (that is, performance review and policy reassessment at regular intervals as part of the FYP process) is needed to ensure that lessons are translated into action and adjustments are made.

4. Conclusion

The purpose of this paper was to outline the basic elements of risk-based adaptation planning. The process described by the paper is intended to be scalable. A full-blown assessment of climate risks, involving the development of sophisticated modeling tools and quantitative scenario analysis, may require up to a year and a budget of $100,000 to $500,000.[30] This level of analysis may be warranted for sectors with long investment time scales and decisions involving high sunk costs, possibly irreversible consequences, and constraints on future options. In cases where the stakes are much lower and the decision is less sensitive to climate change uncertainties, a light-touch screening of climate risks and adaptation options may be more appropriate. This kind of screening can be done within a few months and at much lower cost.

Rather than prescribing a single methodology, the aim of the process is to make risk-informed decisions that take fuller account of uncertainties. Uncertainty is at the heart of every long-term policy problem and is not unique to climate change. Policy makers and investors confront uncertainty when dealing with future commodity prices, exchange rates, and R&D outcomes. As a principle, risk management emphasizes the need to cope with and manage uncertainty and to not be disarmed by it.

Risk management is as much art as science and requires an up-front conversation on priorities in determining what is an acceptable level of risk and how trade-offs should be balanced. Consultation with stakeholders and a clear statement of public policy objectives are key elements of priority setting.

With risk management, the process is just as important as the outcomes. How the process is structured matters (Jones and Preston 2011). This is particularly true with managing the use of information. Traditionally, adaptation has been dominated by prediction-led approaches that put the climate science out in front of the decision. The risk management process is policy led, so the emphasis is much more on framing the decision first and then engaging with scientists and other experts to generate fit-for-purpose information about the exposure and vulnerability of the sector to present-day and future risks.

Risk management as an approach to climate adaptation planning is still relatively new in China, but it is beginning to gain traction. The adoption of risk management in public policy can be seen in recently introduced regulations for the prevention and reduction of risks from weather disasters and in efforts to develop risk assessment guidelines and systems for floods, droughts, and extreme weather by the CMA and National Committee on Disaster Reduction (NDRC 2012a).

[30] Time and financial cost estimates are for illustrative purposes only and are based on reported costs for RDM in Hallegatte et al. (2012)

One of the challenges to the uptake of risk management processes and principles in planning for climate change will be closing the gap between the climate adaptation and DRM communities. Elevating the rank of the National Committee on Disaster Reduction and linking the committee more closely with the National Leading Group on Climate Change can help address this challenge. Integrating the disaster response offices and leading groups on climate change in the provincial, municipal, and county governments will help, too. As with other areas of policy for sustainable development, China's central leaders will also need to strengthen incentives for local governments to pursue actions that yield longer-term benefits and to signal clearly that managing risks is a priority.[31] Risk management is in line with China's larger development goals and can help the country achieve those goals even in the face of deep uncertainty about the future climate.

[31] Statements by President Xi Jinping at a May 2013 study session of the Politburo reflect a step in this direction. President Xi stressed the need to include criteria for natural resource use and environmental health in official appraisals of economic performance. Xi also warned of "lifetime accountability" (career-long responsibility) for officials who fail to properly manage environmental risks by making policies or approving projects that result in severe environmental pollution or degradation (Xinhua 2013).

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