Volume 1:
Guidelines for Economic Analysis of Power Sector Projects

Version 1: Renewable Energy Projects

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PREFACE

These guidelines are directed to the economic analysis of power sector policy analysis and the appraisal of power sector investment projects. The general guidance is complemented by an Annex Volume that contains relevant technical notes, a glossary, and an extended Bibliography.

In this first edition, to be circulated in draft form, the focus of the technical notes is on grid-connected renewable energy projects. In FY16 the scope of the technical notes will be extended to cover transmission & distribution, rural electrification, off-grid, energy efficiency, and thermal projects.

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ABBREVIATIONS

ADB	Asian Development Bank
BTU	British Thermal Unit
CAPEX	Capital investment expenditure
CBA	Cost/benefit analysis
CCGT	Combined cycle gas turbine
CCS	carbon capture and storage
CEB	Ceylon Electricity Board (Sri Lanka)
CGE	computable general equilibrium (model)
CRESP	China Renewable Energy Scale-up Program
CSP	Concentrated solar power
CTF	Clean Technology Fund
CV	Compensating variation
DMU	Decision-making under uncertainty
DPC	Development Policy Credit
DPL	Development Policy Loan
DSCR	Debt service cover ratio
DSM	Demand side management
EMP	Environmental Management Plan
EOCK	economic opportunity cost of capital
EPRI	Electric Power Research Institute (US)
ERAV	Electricity Regulatory Authority of Vietnam
ERR	Economic rate of return
EU	European Union
EU ETS	European Union Emissions Trading System
FGD	Flue gas desulphurisation
FIRR	Financial internal rate of return
FIT	feed-in tariff
FS	feasibility study
GDP	gross domestic product
GHG	Greenhouse gas
GWh	gigawatt-hour
HHV	Higher heating value (see Glossary)
HSD	high speed diesel
HVDC	High voltage direct current (transmission)
IEA	International Energy Agency
IEG	Independent Evaluation Group (of the World Bank)
IFI	International Financial Institution
IPP	Independent power producer
ISO	International Standards Organisation
IWGSCC	Interagency Working Group on the Social Cost of Carbon (US)
LCA	Life cycle assessment
LCOE	Levelised cost of electricity
LHV	Lower heating value (see Glossary)
LNG	Liquefied natural gas
MAC	Marginal abatement cost
MADA	Multi-attribute decision analysis
MASEN	Moroccan Agency for Solar Energy
MATA	Multi-attribute trade-off analysis
mbd	million barrels per day
MENA	Middle East and North Africa (Region), World Bank
MFO	marine fuel oil
MIT	Massachusetts Institute of Technology
mmBTU	million British Thermal Units
mtpy	million tons per year
MUV	Manufacture Unit Value (index)
NEA	Nepal Electricity Authority
NPV	Net present value
NREL	National Renewable Energy Laboratory (US)
OCC	Opportunity cost of capital
ONE	Morocco State Power Company
OPEX	Operating cost expenditure
OPSPQ	Operations Policy and Quality Department (World Bank)
PAD	Project Appraisal Document (World Bank)
PAF	Project affected person
PCN	Project Concept Note
PLN	Indonesian Electricity Company
PMU	Project Management Unit
PPA	Power purchase agreement
PPP	Public-Private-Partnership
PSIA	Poverty and Social Impact Assessment
PV	Photovoltaic
RDM	Robust decision-making
RE	Renewable energy
SCF	Standard correction factor
SER	Shadow exchange rate
SMP	social mitigation plan
SPR	Strategic Petroleum Reserve (of the US)
SPV	special purpose vehicle
SVC	Social value of carbon
SRTP	Social rate of time preference (see Glossary)
T&D	transmission and distribution
TTL	Task Team Leader (World Bank)
UAHP	Upper Arun Hydro Project (Nepal)
US	United States
USAID	United States Agency for International Development
USEIA	United States Energy Information Administration
VND	Vietnamese Dong
VOLL	Value of lost load
VRE	variable renewable energy
VSL	Value of statistical life
WDI	World Development Indicators (World Bank database)
WACC	weighted average cost of capital
WEO	World Energy Outlook (IEA)
WTP	willingness-to-pay

1. INTRODUCTION

1. In June 2013 the Bank issued new guidelines for the economic analysis of projects.[1] These guidelines explain the revised approach to economic analysis introduced in the April 2013 version of BP10.00: *Investment Project Financing*. These require three questions be answered of all projects:

1. ***What is the project's development impact?*** This is the traditional question underlying the Bank's approach to cost-benefit analysis. It requires careful consideration of the expected stream of project benefits and costs, grounded in an explicit causal framework linking project activities to targeted outcomes.
2. ***Is public sector provision or financing the appropriate vehicle?*** This question probes the rationale for public involvement with respect to financing and/or implementation and should explicitly consider alternative modes of provision.
3. ***What is the World Bank's value added?*** This question examines the World Bank's contribution to the project. It seeks to determine the benefit from Bank staff involvement and whether the proposed project maximizes the development impact of staff effort.

2. Moreover, the new guidelines stress the importance of deciding already at the PCN stage on the form and content of the economic analysis that the team will undertake during preparation, necessitating advance thinking about economic analysis prior to the Project Concept Note (PCN) meeting. Economic analysis, and economic reasoning, should assist in the choice and design of projects, rather than simply serving as a final quality check at the late stages of Project Appraisal Document preparation.

3. The OPSPQ guidelines apply to the analysis of *all* investment projects financed by the World Bank, and are necessarily general. They set out in some detail the rationale for the new approach, and how economic analysis should be used to help the design of a project. The guidelines provide general advice in setting out the form and content of an economic analysis as listed in Table 1.1: for each point we note the relevant issues for the typical energy project – a more detailed discussion of which is provided in Section 2.

Table 1.1: The OPSPQ Economic Analysis Guidelines

OPSPQ	Relevance to power sector projects [References to the Technical Notes][2]
(1) Make a comprehensive list of anticipated costs and benefits with and without the project, including social costs and benefits, setting out what the team would likely need if it was to measure the expected NPV or expected ERR arising as a result of project activities.	This raises few problems for energy sector projects, except insofar as some externalities may arise in distant locations (e.g. a power project on the Mekong river in Laos has potential impacts on fisheries downstream in Vietnam, several 100 km distant).
(2) To the extent possible, **delineate and describe anticipated investment and non-recurring costs, operation and maintenance** as well as recurring costs (where appropriate) and their likely timing, and other opportunity costs to economy generated during the life of the project. (Opportunity costs reflect the value of the next best alternative use of the resources in question.) All of these costs need to be assessed relative to	For most power sector projects, establishing direct project costs is relatively straight forward: the main issue is uncertainty in capital investment costs (for example, renewable energy projects are relatively capital intensive compared to most thermal generation alternatives, and costs are highly specific to local conditions).

[1] Operations Policy and Quality Department (OPSPQ). *Investment Project Financing: Economic Analysis Guidance Note*, April 9, 2013. This document is hereinafter cited simply as OPSPQ.

[2] References to Technical Notes are shown in boldface: for example **C4** refers to Technical Note **C4** (Approaches to Decision-making).

OPSPQ	Relevance to power sector projects [References to the Technical Notes][2]
the postulated baseline.	
(3) To the extent possible, **delineate and describe anticipated project benefits, both direct and indirect, and their likely timing**. Note that for projects whose objectives are reducing environmental or other sorts of negative externalities, it is this reduction in spillover costs that needs to be quantified and monetized as benefit. A similar observation applies in the case of investment projects whose goals are to foster positive externalities (for example, investment in technology innovation and diffusion).	Many power sector projects have as a significant benefit the avoidance of environmental externalities associated with fossil fuel generation. Several of the technical notes discuss how such externalities can be quantified and monetized (**M4, M5**), and how energy security and learning curve benefits should be evaluated (**C7,T3**).
(4)List the set of variables required to perform a financial analysis, if needed.	With many power sector projects involving private sector participation, financial analysis is always needed (and is in any event required for an adequate distributional analysis).
(5) **Identify which of the listed costs and benefits can be quantitatively measured with existing knowledge** and which may likely be quantitatively measured cost-effectively with information gained during project preparation.	The Technical Notes discuss what can and what can not be readily quantified and monetized. In some cases the Bank has already issued special guidance notes (such as the guidance note on valuation of GHG emissions).
(6) Identify any possible externalities resulting from project outcomes, both positive and negative (for example, environmental impacts). Note which externalities might be quantitatively measured before or during project preparation. Those that can be quantified and monetized should be treated as part of the overall set of project costs or benefits as outlined above.	See **M4** and **M5** for damage cost estimates from fossil fuel combustion.
(7) **Assess the degree of risk and uncertainty relating to anticipated project** impact/effectiveness as well as degree of uncertainty in valuations delineated above, using the risk template as the basis. Delineate key parameters needed for economic analysis that are subject to significant variation (including indirect and external effects), the source of the variance, and an idea of the extent of variation. Take into consideration the range of possible variations and the extent of uncertainty attached to the outcomes.	It is often argued that the cost of renewable energy is largely locked in at construction, and therefore less subject to future variation than its fossil fueled alternatives subject to increasing price volatility. However, renewable technologies are also subject to significant variation during operation due to natural resource variability. Energy efficiency, loss reduction, and rehabilitation projects tend to be more robust with respect to many exogenous risk factors than greenfield generation projects.
(8) **Assess the feasibility of analytic activities during preparation**, given the time and resources available, that could fill in key data gaps. What analysis can be done within the required timeframe? Determine whether the analysis can be completed given the allocated resources?	
(9) **Delineate estimated costs and benefits identified that cannot be measured or valued given the current state of knowledge** (determined after a thorough review of existing knowledge) and explain why they cannot be measured or valued now or through information obtained during project preparation.	In the case of power sector projects, many externalities can be quantified but not easily monetized (or where monetization is highly controversial). However, such variables that reflect other goals can still be usefully incorporated using the techniques of multi-attribute decision analysis (**M6**).
(10) **Determine whether a distributional analysis is relevant to the careful consideration of social costs and benefits**. Delineate to the extent possible who benefits (or is harmed) from	For power sector projects a distributional analysis is always needed. Renewable energy projects in particular may involve incremental financial costs that must be recovered from some stakeholders

OPSPQ	Relevance to power sector projects [References to the Technical Notes][2]
the project activities and to what degree. This would include the identification of stakeholders affected by the project and the degree of impact such as a determination of access to project benefits and the distribution of benefit incidence. Determine appropriate approaches to the distributional analysis (quantitative versus qualitative).	(and whose willingness to accept may determine the financial sustainability of a project). The realization of the economic benefits of most power sector projects necessarily depends upon financial sustainability, and hence economic and financial analyses go together. Technical Note **C6** shows how a distributional analysis can best be prepared for the typical renewable energy project: such a quantitative approach is appropriate for all power projects.

4. In short, the OPSPQ guidelines describe ***what*** is to be done in an economic analysis for a bank-funded project, and ***why*** it should be done: the guidelines for economic analysis set out here focus on ***how*** it is to be done in the specific case of power sector projects.

Related Guidance Documents

5. Three other World Bank guidance documents are relevant to the economic analysis of power sector projects, which need to be consulted to guide certain aspects of CBA for power sector projects and policy analysis:

- *The Social Value of Carbon in Project Appraisal*, Guidance Note to the World Bank Group Staff, September 2014. This document provides the monetary values to be given to carbon emissions: for renewable energy projects these constitute a benefit associated with the avoidance of thermal emissions.
- *Guidance Note: Greenhouse Gas Accounting for Energy Investment Operations: Transmission & Distribution projects, Power Generation Projects and Energy Efficiency Projects*, Version 2, January 2015. World Bank Sustainable Energy Department. The approach is now mandatory for all power sector projects.
- *Interim Technical Note for Greenhouse Gases from Reservoirs Caused by Biochemical Processes,* Water Paper, April 2013. (Relevant to hydro projects).

6. In addition, the following documents should be on the shelves of all economists evaluating power sector policy and projects:

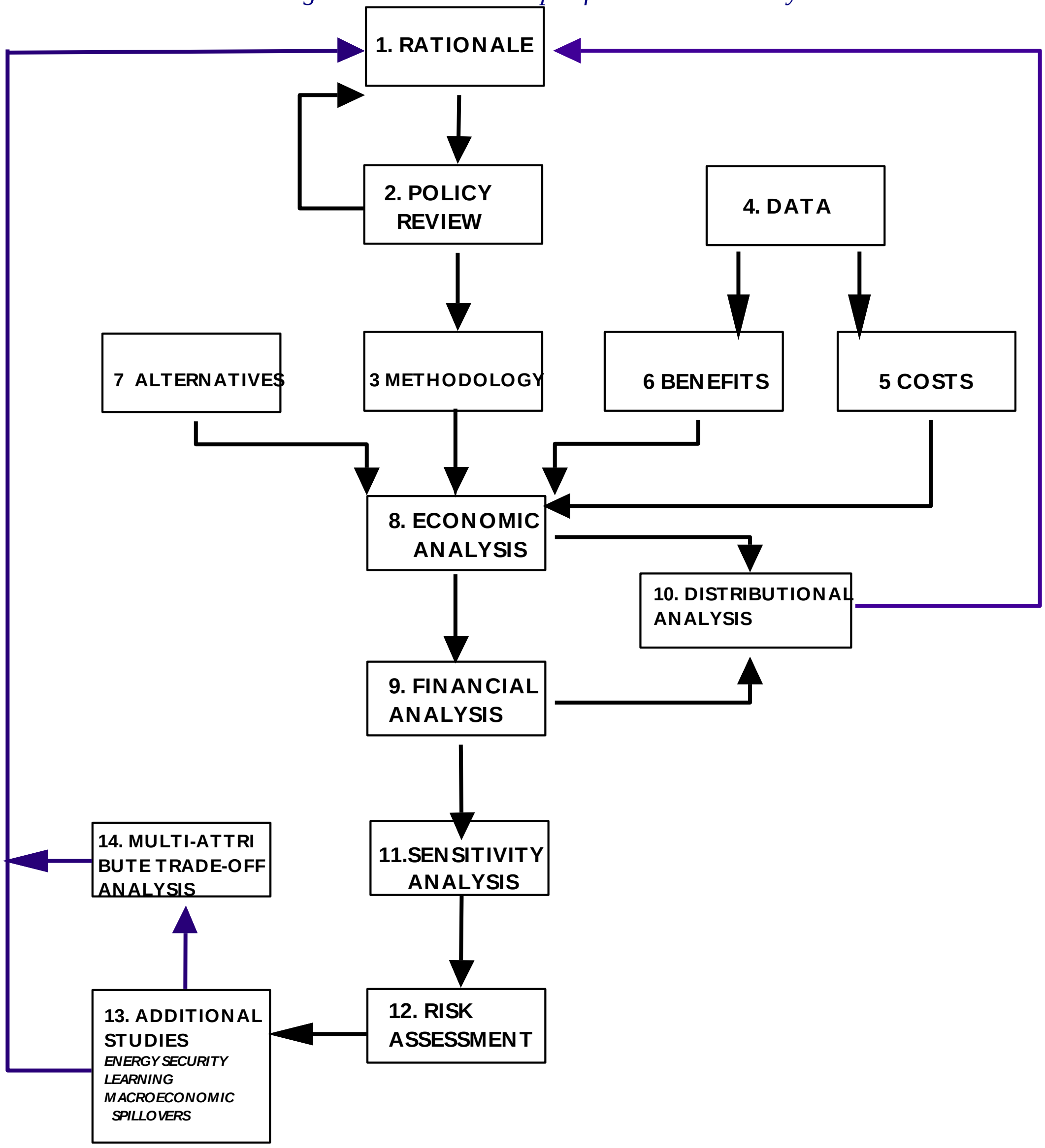
- *Cost Benefit Analysis in World Bank Projects*. Independent Evaluation Group (IEG), World Bank, 2010.
- *Handbook on Economic Analysis of Investment Operations*, by P. Belli, J. Anderson, H, Barnum, J. Dixon and J. Tan, World Bank, Operations Policy Department, World Bank, 1997.
- *The Economics of Project Analysis: A Practitioner's Guide*, by Ward, W. and B. Deren, Economic Development Institute of the World Bank, 1991.

Each Technical Note sets out additional recommended reading, supplemented by the general bibliography (Annex **A1**).

2. THE ANALYTICAL PROCESS

7. Figure 2.1 summarises the key steps in the economic analysis of power sector projects. Each of these steps is described in more detail in Section 3.

Figure 2.1: The main steps of an economic Analysis



Scope and Form of the Analysis

8. The scope and form of an economic & financial analysis should be adjusted to the main categories of project:

- **Large greenfield projects**, often \$500 million and more, often involving other major IFIs, with typically large project preparation budgets, and often with comprehensive feasibility studies completed: most large generation and high voltage transmission projects fall into this category.[3] The sheer scale of such projects generally warrant application of the full set of economic analysis tools described in these Guidelines..

[3] Among renewable energy projects, typical examples in this category include the Morocco CSP Project (World Bank Report-4663-MA) and the Tarbela Hydro extension project (Bank Report 60963-PK).

- **Portfolio projects** often involving client country financial intermediaries, that may enable a wide range of renewable energy or energy efficiency technologies and projects implemented by the private sector, sometimes with many subprojects, each of which may be individually quite small. At the time of project appraisal, the economic analysis is necessarily limited to the evaluation of a sample of potential sub-projects (or subprojects identified in the pipeline for implementation in the first year of the project). Typical examples include the Turkey Private Sector Renewable Energy and Energy Efficiency Project; the Vietnam Renewable Energy Development Project or the Uganda Energy for Rural Transformation project. Many of the Bank's transmission and distribution projects also involve large number of subprojects only some of which are in the project pipeline at time of project preparation. Part of the economist's role during project preparation is to set out the scope and form of economic analysis required during project implementation, typically implemented by project management units (PMUs).
- **Smaller projects and rehabilitation projects:** while these may well require a more limited analysis, one should avoid the presumption that the economic analysis of small projects requires little serious attention. It is always difficult to set minimum thresholds for satisfactory analysis, but the spreadsheet snapshots provided in the Annex Volume provide guidance on what is minimally required for smaller projects.
- **Policy analysis:** The Bank is increasingly involved in assisting its clients with power sector policy reforms, which invariably requires economic reasoning to ensure rational results. Many of the tools and techniques provided in the technical notes provide support for this kind of project, which often requires illustrative examples of the impact of reforms on the various stakeholders and of the financial and macroeconomic consequences (particularly in the demonstration of the economic costs and targeting performance of fuel subsidies, and the economic costs of non-technical and revenue collection losses in T&D projects).
- **Small projects in small countries,** in many cases associated with emergency projects requiring immediate implementation.[4] For such projects the economic and financial analysis can be limited in scope, for the economic benefits of restoring power supply are so large that much detailed study may be deemed superfluous. But that does *not* mean a basic economic risk assessment is unnecessary: there are a number of examples of emergency power projects that have ended up as white elephants,[5] which might have been avoided had there been even a simple risk assessment-based scenario analysis.

9. Just as economic analysis as set out in the new OPSPQ guidelines reflects an iterative role in the project definition and project preparation cycle, so is the analytical process an iterative one. An economic analysis is rarely conducted as a one-time pass through a set of proscribed steps, *seriatim*. Typically the economic analysis starts with a quick first pass through all the steps in Figure 2.1, using whatever data as may be conveniently at hand, mainly as a way of identifying data gaps: placeholders based on the experience of the analyst are often indispensable. As noted by the OPSPQ guidelines, a first estimate of the economic returns should already be prepared even before the PCN stage.

10. Often such a first pass will reveal economic returns that are too good to be true, or so low that their acceptance implies abandonment of the project as proposed. In the first case the economist's role is to bring realism to the table, in the second case it is to force attention to revised project designs or consideration of alternatives better suited to achieving the project objectives. There are many examples of seemingly good renewable energy projects (say a wind project to replace diesel generation on a very windy island) but which on closer examination of the realisable economic benefits prove to be at best marginal because the load is insufficient; or because the load curve is such that night-time wind production cannot be absorbed (even with

4 Such as the Afghanistan Emergency Power Project (that included rehabilitation of the Naghlu hydro project) and the Burundi Emergency Power Project that included small hydro development (World Bank Report 56454-BI)

5 For example, the 110 MW diesel power station constructed in 2008 by USAID on an emergency basis at Tarakhil, outside Kabul has almost *never* been used – in part because of problems of reliable supply of diesel fuel, in part because diesel fuel has been prohibitively expensive, and in part because relatively abundant imports of surplus power for Uzbekistan have been available at low cost. Such outcomes could easily have been anticipated in 2007/2008.

time-of-day tariffs to encourage night time use such as for ice-making for fishermen); or because of the part-load inefficiency of diesels.

11. As the preparation of the economic analysis Annex to the Project Appraisal Document (PAD) proceeds, it may be useful to evaluate its content against the Checklist of Table 2.1. Many of the questions apply to all projects: others are specific to particular types of projects. One may note that the answer to all of these questions is not necessarily "yes" – but whenever the answer is "no", then there should be a plausible answer as to why not.

12. The Technical Notes are organised in three sections:

- **Basic Concepts**: applicable to all power sector projects (**C1** to **C8**)
- **Technology related issues**: In this first version of the guidelines, these relate just to renewable energy projects (**T1** to **T5**). Subsequent versions will add additional notes on other types of power sector investment and policy projects.
- **Methodologies and techniques**: providing guidance on specific techniques useful for economic analysis of power projects (such as Monte Carlo simulation, estimating demand curves, and mean-variance portfolio analysis). (**M1** to **M9**).

Each technical note provides a subject oriented reading list, supplemented by a Master Bibliography in Annex **A1**.

Table 2.1: Checklist of questions (with reference to relevant Technical Notes)

	Task	All power sector projects
1	Rationale	• What is the main rationale for the project? • What is the main alternative to the project?
2.	Policy review	• What is the rationale for public sector and World Bank involvement? • Are the supporting policies adequate to ensure a sustainable project?
3.	Methodology	• Does CBA provide a sufficient justification for the project?
		• Is there a need for additional analysis using RDM (**C4**) or MATA (**M6**) to reflect other objectives?
4.	Data	• Are the sources of data credible, and adequately described and cited?
5.	Project Costs	• Are project costs estimated in the past brought to a consistent price level? (**C1**) • Are all relevant negative externalities identified? (**C3, M4**) • Is the presentation of economic and financial costs clear? (**C1**) • Have important inputs (e.g. water) been shadow-priced? (**C1**)
6.	Project benefits	• Is the basis for benefit valuation (incremental, substitution) adequately justified? (**M2**) • Are all likely benefits considered? (see checklist in **C2**) • If energy security benefits are claimed, is their presentation consistent with the best practice recommendations? (**C7**)
		• If incremental benefits are based on estimates of willingness-to-pay, is the methodology credible? (**M2**)
		• In the case of substitution benefits, are the economic values properly adjusted for subsidies and taxes? (**C1**)
		• Are all positive externalities identified? (**C3**) • re the costs of fossil fuels properly valued as *economic* prices? (**C1**) • Is the valuation of avoided GHG emissions consistent with the Guidance Note on the value of the social cost of carbon?(**M5**)
7.	Define the alternatives to the project	• Are the alternatives to the proposed project adequately justified? – for example, in the case of a generation project, are T&D and energy efficiency options really mutually exclusive substitutes, or are they complements?(i.e. they should also be implemented, regardless of the proposed project)(**C2**).
8.	Baseline calculations, economic returns	• Are the macroeconomic assumptions (GDP growth, inflation, international fuel prices) clearly stated? (**M1**) • Has the choice of numeraire ($US or local currency) been explained? (**C1**) • Is the presentation of the economic flows and the calculations consistent with the recommended format (illustrated in Annex **A4**)? • Is the choice of baseline discount rate consistent with the recommendation of **C8**
9	Financial	• Is the economic analysis accompanied by a financial analysis with a consistent

	Task	All power sector projects
	analysis	set of assumptions?
10.	Distributional analysis	• Is a distributional analysis presented, and the stakeholders identified? (**C6**) • Are the impacts of the project on the poor identified? • Are any unusual or counter-intuitive results of the distributional analysis properly explained?
11.	Sensitivity analysis	• Have the switching values been calculated for all important variables? (compare to checklist in **M1**) • Is a sensitivity analysis to discount rate presented? (see example in **T4**) • Where switching values indicate a significant risk to the realisation of economic returns, are mitigating measures discussed in other sections of the PAD?
12.	Risk Assessment	• Are all the main risks identified in the PAD risk matrix included in the economic analysis risk assessment? (**C5**) • Are the probability distributions proposed for key input assumptions credible? (**M7**) • Is the probability of *not* meeting the hurdle rate provided? (**M7**)
13.	Scenario and trade-off analysis	• Is the sensitivity analysis (one variable at a time) accompanied by a scenario analysis that identifies plausible worst cases (many variables at unfavourable outcomes)? (**C5**)
14.	Need for additional studies	• If employment creation is noted, do these show *net* employment (i.e., offset by job losses associated with thermal fuel generation, say in coal mining?) (**C8**) • If macroeconomic impacts are included in the analysis, are the arguments for the establishment of local manufacturing, and the assignments of economic benefit, plausible for the project under appraisal (**C8**)

POLICY ANALYSIS AND PROJECT APPRAISAL

13. Although the emphasis of this Guidance is directed at the appraisal of investment projects, the principles of economic reasoning apply to other types of projects encountered in the Energy & Extractives Global Practice. The Bank is increasingly being asked to provide assistance to client Governments in formulating an improved policy environment to enable private investment in the sector, and to provide development policy credits and loans expressly tied to power sector reform. Moreover, the sustainability of investment projects is often largely determined by the policy environment, and therefore the policy review (Step 2 of Figure 2.1) must necessarily encompass a much broader canvas than just the details of a particular proposed project. For this reason the Technical Notes include exposition of tools relevant as much to policy evaluation as to project appraisal.[6] Table 2.2 summarises the main applications.

Table 2.2: Applications of economic analysis

Activity	
Investment Project Appraisal	The main steps of which are outlined in Figure 2.1. A review of the policy background must necessarily precede consideration of a specific project.
Development Policy Credit/Loan	These are typically tied to power sector reforms, and premised on a set of prior actions and policy reforms, whose economic and environmental impacts must be evaluated in the PAD. The analysis and evaluation of these prior actions rests largely on the same techniques as those presented in these Guidelines.
Technical Assistance for improving the policy environment	Typical projects include assistance in drafting renewable energy tariffs (as in Vietnam), or in improving regulation and reducing subsidies (such as the introduction of performance based regulation to PLN in Indonesia), which provide the necessary enabling environment for larger investment projects in the sector. See Annex I (Additional Guidance for Renewable Energy Projects, Step 2) for a summary of the policy issues germane to renewable energy.

6 For example, Technical Note **M3** on Supply Curves informs the process of setting renewable energy targets and the design renewable energy support tariffs based on benefits.

3. THE STEPS OF A PROJECT ECONOMIC ANALYSIS

1. THE RATIONALE

14. The OPSPQ economic analysis guidelines call for the early involvement of the project economist, whose first task is a quick reality check with whatever cost and benefit data as may be at hand. How likely is the project to meet the required hurdle rate? What are the main data gaps that need immediate clarification? And, especially important in the case of renewable energy projects, what are the seasonal and daily patterns of the renewable energy resource in question, for this will be one of the key determinants of potential benefits.

15. A presentation of the energy sector background is required of all PADs, which generally develops the rationale for the proposed investment project or policy intervention. However, clarity of objectives – that will largely determine the shape, form, and content of an economic analysis – is not always assured. For example, some recent proposed T&D projects have included a component to introduce smart meters – but upon closer inspection, some of the benefits demonstrated in developed countries (replace expensive manual meter reading) or even in some developing countries (reduce very high non-technical and commercial losses - i.e. pilferage - such as in India and Pakistan) do not really apply to other countries (for instance in Vietnam, where both pilferage rates and labour costs are low).[7] In the case of grid connected renewable energy projects with high incremental costs, the importance of a clearly defined rationale is paramount.

16. "Least cost" deserves careful definition. Many utilities claim to use least cost planning models which upon close inspection means least *financial* cost to the *utility*. The term as used in these Guidelines means least economic cost including all local externalities, *from the perspective of the country*. Global externalities (principally the damage costs of GHG emissions) should always be considered separately in a CBA, because their impact is critically dependent upon the valuation of the social cost of carbon, and because many of the Bank's low and middle income client Governments disagree that this should influence their investment decisions - particularly when the valuation as proposed by the new World Bank guidance document on the social cost of carbon is much higher than the developed countries' own willingness-to-pay for carbon reductions (as evidenced by the current value in global carbon markets such as the EU ETS).

17. The view taken in these Guidelines is that whatever carbon reduction targets as may be set by Governments as a matter of policy, the task of the economic analysis is to ensure that this target is achieved at least *economic* (social) cost. For example, the decision of the Government of Indonesia to include in the evaluation of benefits of geothermal energy at \$30/ton CO_2 valuation for GHG emissions was essentially a political decision:[8] the task of the economist is to insist that this value applies equally to all renewable energy technologies (and their support tariffs, and indeed to all power sector projects), and that the relevant question is how to meet carbon reductions at least economic cost – which may well mean that energy efficiency or thermal generation or distribution system rehabilitation should be preferred over some high cost renewable energy projects. The extent to which so-called learning curve benefits accrue to the countries now embarking on high cost renewable projects (as in the case of the CSP projects in Morocco) is particularly contentious (and is discussed in Technical Note **T3**).

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7 See M. Madrigal and R. Uluski, *Practical Guidance for Defining a Smart Grid Modernization Strategy: the Case of Distribution*. World Bank Study, 2015.

8 It could be argued that this is not a political decision at all, but that \$30/ton (or more) simply reflects the reality of global damage costs. But that ignores the other reality that it is the rich countries that are largely responsible for the GHG emissions problem, who became wealthy as a consequence of abundant low cost fossil energy, and that it is profoundly unfair to burden poor countries (and their consumers) with the cost of mitigation (particularly at a time when the carbon markets of the rich countries value carbon at \$10/ton CO_2).

2. POLICY REVIEW

18. Both OPSPQ and the Energy Directions Paper[9] stress the importance of the policy framework that will ultimately determine the sustainability of a proposed project. The main policy questions to be resolved for a project appraisal are as follows: is the policy (and tariff) environment

- **Transparent**: Bankability of project PPAs depends on the principles and calculation methodology of tariffs being understood by the various stakeholders. In the case of renewable energy projects, is there clarity about how the incremental costs are recovered?
- **Equitable**: Many subsidies on electricity and fuels are poorly targeted, with a disproportionate share captured by the better off income groups (i.e., they are poorly targeted).[10]
- **Sustainable**: Projects that rely upon tariff subsidies, or on thermal fuel subsidies, may not be sustainable, because the burdens of subsidies may themselves be unsustainable (and subject to rapid change). Renewable energy projects that depend on recovery of incremental costs from some "Fund" will be at risk if the funding of that "Fund" cannot be assured.
- **Efficient**: Access to feed-in tariffs for renewable energy under first-come first served arrangements does not assure economic efficiency: unless transaction costs outweigh the benefits (which may be the case for small projects), competitive mechanisms should be sought. Consumer tariffs should reflect the economic cost of supply (and are ideally based on the long term marginal costs of supply at each voltage level of consumption).

3. METHODOLOGY

19. With the rationale defined, one then identifies the main data requirements and the methodology to be used. What are the main sources of information (e.g. utility capacity expansion plan, a detailed feasibility study?) What is the approach for setting the counter-factual? What externalities will be considered? What can be valued? What discount rate (or range of discount rates) should be used and why? What subjects are worthy of separate detailed assessment?

20. OPSPQ mandates the use of CBA as the principal tool of economic analysis for project appraisal, though with some latitude to use cost-effectiveness analysis – in which one may not be able to monetize all anticipated benefits or the alternatives considered,[11] and simply makes comparisons of costs of alternatives to deliver "roughly similar bundles of outcomes and benefits." But where indeed there are project objectives beyond economic efficiency, so-called multi-attribute decision analysis is a useful tool to illuminate the trade-offs among conflicting objectives (Technical Note **M6**).

Beyond CBA

21. The performance of long-term energy infrastructure projects is sensitive to future changes in energy prices, energy demand, technological innovation and climate change. Making these projects resilient to long-term changes is challenged by the irreducible uncertainty that surrounds future climate change and socio-economic developments. This has resulted in an increasing demand for new methodologies that take this uncertainty into account during the economic analysis of projects, and which places more emphasis on robustness than on claimed optimality.

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9 World Bank, 2013. *Toward a Sustainable Energy Future for All: Directions for the World Bank Group's Energy Sector*

10 See, e.g., K.Komives, V.Foster, J. Halpern and Q. Wodon, *Water, Electricity and the Poor: Who Benefits from Utility Subsidies*?, World Bank, Directions in Development, 2005; and M. Kojima, R. Bacon, and C. Trimble, 2014. *Political Economy of Power Sector Subsidies: A Review with Reference to Sub-Saharan Africa*. World Bank.

11 See OPSPQ, ¶23.

22. The traditional approach to power systems modelling (and the related preparation of so-called "Masterplans"), and the conventional approach to CBA, fall under a decision-making paradigm often described as "predict then act". The presumption is that given some set of assumptions about the future (load forecasts, international energy prices) one can identify an "optimal" investment plan to meet the objective, with optimality defined as least economic cost (or in the case of a project appraisal, choose that alternative with the highest NPV >0). In a deterministic world, or one where most assumptions about the future were judged reasonably certain (as they were in the years immediately following WW II when CBA evolved, i.e. before the first oil crisis in 1973), this approach performed well.

23. But with the increasing levels of uncertainty that characterise the modern world, traditional CBA – even when accompanied by the ensemble of ancillary tools of sensitivity analysis and Monte Carlo Risk assessment - has run into difficulties. First, there may be disagreement about forecasts of the future, or the discount rate used to trade-off current and future consumption and saving, so decisions may be stalled because of lack of consensus. Second, if the predicted future does not materialize, then what was thought to be optimal ("least-cost") proves in reality to have been distinctly *non*-optimal. Moreover, many variables are very difficult to forecast in probability terms (for example, how does one assign probabilities to trajectories of future oil prices?)

24. Several methodologies to address these problems are being proposed, referred to collectively as Decision Making under Uncertainty (DMU). These start with a different approach, namely to ask "Which investment option best meets our goals given that we cannot know what the future will bring?"[12] Such methods seek to identify robust decisions that satisfy decision makers' objectives in many plausible futures, rather than being optimal in any single best estimate of the future.[13]

25. These various approaches are discussed further in Technical Note **C4,** and include:

- **Robust decision-making:** developed at the RAND corporation to inform policy choices under deep uncertainty and complexity (such as predicting the vulnerability of a project to future climate change impacts when there may even be disagreement about the validity of models that link outcomes to current actions).[14] In the Bank literature, a good general introduction to RDM is Hallegatte and others. [15] RDM is being applied to several ongoing World Bank projects including power sector planning in Afghanistan, and hydropower investments in Nepal.[16]
- **Real options:** long used in the private sector to assess resource exploration, marketing and investment decisions under uncertainties that may require additional time or money to resolve (discussed further in Step 12,below).
- **Probabilistic Scenario Analysis**: which derives the economic consequences of making non-optimal decisions, and highlights the relationship between the degree of risk-aversion of the decision-maker and the consequences of non-optimal choices (Technical Note **C4** includes an example of setting targets for renewable energy).

[12] N. Kalra, , S. Hallegatte, R. Lempert, C. Brown, A. Fozzard, G. Stuart, and A. Shah. 2014. *Agreeing on Robust Decisions: New Processes for Decision Making under Deep Uncertainty*. World Bank Policy Research Working Paper No. 6906

[13] R. Lempert and others, 2013. *Making Good Decisions Without Predictions* (No. RB-9701), Research Brief. RAND Corporation

[14] See Bonzanigo, L, and R. N Kalra. 2014. *Making Informed Investment Decisions in an Uncertain World: A Short Demonstration.*. World Bank Policy Research Working Paper No. 6765.

[15] Hallegatte, S, A. Shah, R. Lempert, C. Brown and S. Gill, 2012. *Investment Decision Making Under Deep Uncertainty: Application to Climate Change*, World Bank Policy Research Working Paper 6193

[16] These studies will be published later in 2015.

4. DATA

26. In most cases, the main problem for the economist is not so much the technical and cost details of the proposed project, but that of the counterfactual. For the proposed project, detailed technical feasibility studies are often available, that present costs and performance data in some detail – and, depending on the quality of the FS, also provide the rationale for the particular project design alternatives considered (for example in a hydro project the dam axis, reservoir size, powerhouse configuration, determination of turbine sizes). Rather, the problem lies in the specification of the counter-factual, for which much less information is generally available (often because the alternative has not been of great interest to the project proponent).

27. One might have assumed that the Bank's unique and wide experience with power sector projects (surely many hundreds over the past decade) would have led to a database repository of power project data across generation types, geography, equipment source, with costs and technical performance. Unfortunately, this has not been the case thus far (though with the introduction of the global practice on energy and extractives, one may hope this be done at some point in the future). But for the time being, the project economist is generally left to his own devices to assemble cost and performance data for the set of technologies of interest. The main sources can be summarised as follows:

- ***Fossil fuel generation costs***: NREL is a source of good information not just on renewable energy, but also on the thermal generation alternatives as well. The Bank's META tool contains data for a wide range of representative thermal technologies. The US Energy Information Administration (USEIA) website also provides good data of cost and performance of generation projects, but such generic estimates need care for application to developing countries (and often do not reflect the much lower costs of Chinese suppliers). Sadly, the EPRI Technical Assessment Guide that was for many years the standard reference in the US is no longer maintained.
- ***Renewable energy***: the various reports by the International Renewable Energy Agency (IRENA) provide useful references for technology cost and performance trends The US National Renewable Energy Laboratory (NREL) is another rich source of technical information. Some computer tools such as RETSCREEN and HOMER also include databases of valuable cost and technology information.

The main difficulty here is that especially in the case of renewable energy projects, costs are highly site-specific (as in the case of large hydro costs), which generic estimates issued by international agencies often do not reflect well. Technical Note **C1** discusses data issues in more detail: Table **C1**.7 presents an annotated list of sources that have proven useful.

5. IDENTIFYING PROJECT COSTS

28. Estimating the capital and O&M costs of power sector projects is generally straightforward (albeit subject to the usual uncertainties of cost escalation and delay). However, several topics require special attention:

The transparency of cost estimates

29. The reconciliation of economic and financial costs needs to be transparent, clearly identifying such financial costs as are excluded from the economic flows, and with a careful breakdown of foreign and domestic costs, and what elements of costs are transfer costs to be excluded from the economic flows. This is also an essential prerequisite for the distributional analysis. A recommended format for the presentation of economic and financial costs is presented in Table **C1**.12.

The opportunity cost of consumptive water use.

30. Most CBAs encountered in PADs simply assume the equivalence of opportunity cost of water with its financial cost (which only rarely reflects the true cost, particularly in arid countries). Indeed in many cases, consumptive water use is not separated out from general

O&M costs. The Medupi coal-fired generatoin project in South Africa illustrates the importance of the need for a careful water balance. Even though the project uses dry cooling (requiring relatively little make-up water compared to evaporative cooling), the FGD units to be added later on are based on a wet process, requiring 11 million cubic metres of water per year. Whether the financial price to ESKOM reflects the actual opportunity cost of water in an arid part of the country is controversial: good practice demands that in all arid countries, consumptive water use and its economic cost be separately identified in the table of economic flows.

31. Consumptive water use is also required for some renewable energy projects (such as the CSP project in Morocco). Any consumptive water use associated with the displaced thermal generation should also be accounted for (and whose avoidance constitutes an additional benefit of renewable energy generation).

32. To establish a credible value for the economic cost of water may be difficult in the absence of relevant detailed studies of the cost of developing municipal water supply or irrigation. Whether such studies would need to be commissioned to support a CBA would depend on a first round of sensitivity analysis – if an order of magnitude increase of the financial water price (which generally *is* known) has a negligible impact on the economic returns, more detailed study may not be necessary.

Shadow pricing of other inputs[17]

33. A review of current World Bank practice shows that relatively few power sector project appraisals have shadow-priced domestic (non-traded) inputs and outputs. However, in ADB practice labour inputs are frequently shadow priced.[18] Whether this is really worth doing depends on whether the adjustments are reasonably well grounded (there are few reliable studies of the labour composition of renewable energy project construction work force), and what proportion of the capital cost is imported equipment. With the exception of hydro (where significant construction labour for civil works are required), for most energy projects the labour inputs in both construction and operation are relatively small. Technical Note **M1** discusses the need for adjustments to the exchange rate (using either the standard correction factor, SCF or the shadow exchange rate, SER).

Externalities

34. What externalities will be considered? As noted, in the case of GHG emissions, the Bank's new Guidance Notes on both carbon accounting and the valuation of carbon are now in place.[19] But for local air emission damage costs, impacts on downstream fisheries, or valuation of lost forestry, there is much scope for judgement. What non-use values should be included, and how should they be quantified? Technical Note **C3** includes a checklist of externalities (both positive and negative) that generally apply to different kinds of power sector projects, and provides examples of their assessment and monetisation.

6. IDENTIFYING PROJECT BENEFITS

Valuation of fossil fuels

35. Correct valuation of fossil fuels is fundamental to almost every type of power sector project

- *Generation projects*: the cost of fossil fuel is often the largest single cost item (in NPV terms).

17 The best non-technical explanation of shadow pricing is still that in Chapter 12 of R. Turvey and Dennis Anderson, *Electricity Economics: Essays and Case Studies*, Johns Hopkins for the World Bank, 1977 ("A Layman's Guide to Shadow Pricing").

18 In all of the ADB projects reviewed, unskilled labor inputs are adjusted by a shadow wage rate factor of 85%, but the source of this adjustment is unclear.

19 World Bank, 2015. *Guidance Note: Greenhouse Gas Accounting for Energy Investment Operations: Transmission & Distribution Projects, Power Generation Projects and Energy Efficiency Projects*, Version 2, January 2015.

- *T&D projects*: technical loss reduction is often an important component of benefits, which translates to avoided consumption of thermal fuels.
- *Renewable energy projects*: the *avoided cost* of fossil fuel is the principal economic benefit of a RE project.
- *Energy Efficiency*: whether these displace oil and coal, or electricity that (at the margin) will indirectly displace thermal fuels, correct valuation is again critical.
- *Rural electrification*: access to the grid may increase thermal generation in the grid, but will be offset by lower use of kerosene for lighting and diesel for self-generation: both are often subsidised, so these displaced fuels should be valued at their economic price, not their financial price (with the necessary reconciliation of economic and financial costs presented in the distributional analysis).

36. Where fossil fuels are imported there are few issues, the relevant economic cost being the border price at the point of import (on a cif basis).[20] More difficult is the appropriate valuation in the case of countries that produce their own thermal fuels (or are even fuel exporting countries).

37. In some countries the price regime for domestic fuel has been aligned to international price levels (such as coal pricing to the Indonesian power company PLN). But in others, domestic fuel prices for power generation still remain subsidised (gas in Egypt, coal in Vietnam and South Africa). The problem of valuation is also complex in cases where high quality coal is exported (at a well documented price), but the domestic market uses low quality coal which has no export market – in which case the opportunity cost of coal used for domestic power generation is much lower than the international price. And even where a fuel is exported (such as gas exports from Egypt to Jordan), the negotiated price often reflects other foreign policy objectives, so the stated border price may not necessarily reflect the *real* opportunity cost of the resource in question.

38. Technical Note **C1** offers guidance for the proper valuation of the opportunity costs of thermal fuels, and shows examples of appropriate netback calculations to establish import parity prices. Even where a least cost planning model is in place, it is sometimes run by the utility using financial prices, so the input assumptions need careful review by the economist.

7. ALTERNATIVES

39. The Bank's guidelines require the consideration of a "no project" alternative. The idea of "no project" is sometimes derided as unrealistic, because in face of increasing electricity demands associated with economic development, not building *any* additional generation projects is simply not plausible. Yet the fact remains that many countries are indeed facing severe power shortages because insufficient capacity has been added. And it is also true that many countries have very high T&D losses, mitigation of which may well have higher returns than building new supply. These issues are often discussed at some length in the project justification and sector context sections of a PAD, but the question remains on whether and how these issues should also be treated in the *economic* analysis.

40. For most projects there exists a hierarchy of alternatives, illustrated for a hydro project as follows:

- Alternatives to supply side expansion (DSM, T&D loss reduction)?
- Alternatives for peaking power additions (why hydro and not CCGT? or coal+pumped storage?)
- Other renewable energy alternatives (why hydro and not wind or geothermal?)
- Alternative hydro projects - given a set of candidate hydro projects, why this *particular* project?

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[20] These may need to be adjusted for transportation differentials to derive the so-called import parity price (explained in Technical Note **C1**).

- For the specific project proposed, alternative sites, reservoir sizes, dam axes, and installed capacity alternatives.

41. For large projects with a detailed Feasibility Study (FS) already in place or underway, some of this analysis would often already have been done by the time Government requests assistance from the Bank, and upon which the economic analysis can draw. But for many smaller projects such questions will often remain to be assessed, and will fall on the project economist to answer during preparation of the PAD.

42. Comparisons of levelised cost of energy (LCOR) should be used with caution: geothermal and coal, both delivering base load power, can be validly compared in a simple LCOE analysis; but coal and wind, or coal and gas-fired combustion turbines can not (see Technical Note **C1**).

The counter-factual

43. The best-counterfactual for a grid-connected power generation project is developed with the assistance of a generation expansion planning model – which should be run with and without the proposed project. This is a practical approach only where a country's utility already has the capacity to have run such models for some years. But not all countries have a WASP model (or equivalent) in place, and some that do may yet require help to run the model for the particular purpose of a project CBA. Moreover it is not always clear whether such models have the ability to properly account for renewable energy variability (whether over very short time intervals, seasonal, or even inter-annual variations).[21] Furthermore, the sequence of large hydro projects is often forced exogenously into such models according to the state of readiness, rather than in order of economic merit.

44. The main challenge is how to construct a credible counter-factual when such a model is not available. This is crucial where avoided carbon emissions of the thermal alternative are to be considered: it matters greatly whether it is coal, oil or gas – or indeed some mix of all of them – are displaced. Technical Note **T4** discusses further the problems of selecting an appropriate counter-factual for renewable energy technologies.

45. The most difficult counter-factual is for generation rehabilitation projects. Predicting alternative futures for an existing plant in serious decline is subject to high uncertainty (for example, how much can conditions degrade before the plant would be abandoned completely; or in the case of a hydro project, how soon would the active storage be degraded by sediment in the absence of proper sediment management practice?). Setting up the "no project" alternative requires detailed consultation with the relevant engineering experts.

8. THE ECONOMIC ANALYSIS

46. Just as the financial analysis included in PADs follows a standard format (following the conventions of financial accountancy), the economic analysis should follow a standard form for the summary presentation of the baseline economic analysis which should be included in the main text of the PAD in the *appraisal summary* section. This may usefully follow the format presented in the PAD of the Noor CSP project (Table 3.1): here the choice of discount rate was one of the main issues - in other projects the columns may represent a different set of important alternative parameters for the calculation of economic returns. This format displays the major components of costs and benefits, and the calculations of ERR and NPV are presented

- without externalities
- with avoided local externalities
- with avoided local + global externalities

21 For example, many countries have experienced significant inter-annual variations in annual average wind speeds (in both China and India, as well in Northwestern Europe, significant decreases in annual wind speeds have been observed - and their cause or whether these are part of some natural long-term cycle still remains a matter of research).

Table 3.1: Summary of economic analysis for a CSP project (from the Noor II&III PAD) [22]

			Govt. opportunity Cost	ONE
	Discount rate		5%	10%
1	**Levelised economic cost of energy**			
2	CSP: the proposed project	USc/kWh	16.9	24.5
3	CCGT: the thermal counter-factual	USc/kWh	10.7	11.3
4	**Economic rate of return**			
5	ERR	[ ]	-0.07%	-0.07%
6	ERR+local externalities	[ ]	0.18%	0.18%
7	ERR+local+GHG@30$/t (3)	[ ]	1.72%	1.72%
8	Switching value, avoided GHG emissions	[$/ton]	92	225
9	**Composition of NPV**			
10	*Costs [CSP]*			
11	capital cost	$USm	-1,873	-1,749
12	O&M	$USm	-511	-300
13	*Benefits[avoided thermal generation]*			
14	Avoided gas cost	$USm	988	504
15	Capacity credit	$USm	249	198
16	Avoided cost of oil&coal	$USm	414	342
17	NPV (before environmental benefits)	$USm	-733	-1,005
18	local environmental benefits	$USm	25	13
19	NPV (incl. Local environmental benefits)	$USm	-708	-992
20	GHG emissions @$30/ton	$USm	191	110
21	NPV (including environment)	$USm	-517	-883
22	Lifetime GHG emissions, undiscounted	Mtons CO_2	12.8	12.8
23	Marginal abatement cost MAC (1)	$/ton	57	79

(1) Required for CTF justification (see ***Technical Note M5***)
(2) ONE=Morocco State Power Company (a 10% discount rate was used in the WASP model)

Minimum requirements

47. Particularly in the case of small projects, the question of what constitutes an acceptable analysis arises frequently. To this end we provide in the Annex Volume a set of tables that describe what is minimally acceptable. We note that the Bank's new carbon accounting guidelines apply to all projects, which necessarily requires all power sector projects enumerate the types of thermal energy that is generated or saved. The following tables should be provided in all economic analysis of power projects, each showing annual values over the expected economic lifetime.

- **Macroeconomic assumptions**, including forecasts of future border prices for thermal generation fuels, inflation, exchange rates, GDP growth (relevant for health damage cost assessment)
- **Electricity Balances**, that display the flow of energy through all of the affected parts of the system, and account for own-use, T&D losses and the type of thermal generation that is avoided or added. In the case of T&D projects, these balances need to be prepared with and without the proposed intervention for a reliable calculation of the net impacts.
- **Calculation of economic returns,** with an enumeration of each of the major economic flows, in sufficient detail to permit preparation of the summary table shown in Table 3.1.
- **Carbon accounting table:** with sufficient detail to achieve a reliable calculation of lifetime *and* yearly emissions from each of the different types and sources of fossil fuels avoided/added.
- **Calculation of economic returns including externalities:** estimates of economic returns using the Bank's guidelines for the social cost of carbon is now required for all energy sector projects. Any project involving coal generation (including renewable energy projects that *displace* coal) should also include an estimate of local environmental damage costs (added or avoided).

22 In this example, the calculation of the Government's opportunity cost of capital was based on the interest rates of recent Euro and US$ bond issuances: of course not all countries have such a track record of successful bond sales as guidance.

Capacity credit

48. The question of capacity benefits arise in a wide variety of power sector projects. That a T&D loss reduction or energy efficiency project avoids energy losses is uncontroversial, but the extent to which it also avoids capacity costs is more difficult to answer. For example, an energy efficiency project may install waste heat recovery for power generation to meet power needs previously supplied by the grid. At the margin, the grid supplier will avoid the variable generation costs of the most expensive units. But whether the supplier avoids capacity costs will depend on the way in which the unit is operated (and avoided generation capacity may not necessarily also avoid transmission capacity costs).

49. Among renewable energy projects, if provided with thermal storage CSP is among the renewable energy technologies that command a significant capacity credit (in the case shown in Table 3.1, the capacity credit accounts for some 20% of the total benefit). The same is true of geothermal projects that have typical load factors of 90%, and often displace baseload coal generation.[23] But for other renewable energy technologies, the claim of capacity credit is more controversial and requires careful consideration, particularly in light of much greater seasonal variation of wind speeds than is experienced in the US and Europe (see Technical Note **T1**).

Discount rates

50. The choice of discount rate in the calculation of economic returns is critical, but has become increasingly controversial in connection with the climate change debate and the estimation of the damage costs of GHG emissions. For some time, in the absence of country-specific studies on the economic opportunity cost of capital (EOCK), or a Government directive to use some specific rate, the Bank has been using 10-12% as a default. Most countries that run power sector capacity expansion models use similar discount rates. This default has been criticised on two grounds; first, that it discriminates against projects that have long and even inter-generational benefits, and secondly that in fact the real cost of capital is much lower today (and in the foreseeable future) than was the case in the 1980s and 1990s. The Bank has now taken up this problem, and plans to issue new bank-wide guidance on discount rates in the very near future. [24]

Decision-criteria

51. Many decision criteria have been proposed for CBA:

- The economic rate of return (ERR) (project is economic if ERR>economic opportunity cost of capital, EOCK)
- Net present value (NPV) (project is economic if NPV at EOCK >0)
- Benefit-cost ratio (project is economic if >1)
- Payback period

The first three of these are often taken as equivalent and particularly so for NPV and ERR. But they are not in fact so.

52. The rate of return is defective as a measure of the relative merit of mutually exclusive projects: a higher rate of return does not necessarily indicate a superior alternative as measured by the size of the surplus when costs and benefits are discounted at the shadow rate of interest. For this reason, World Bank practice is to use NPV as the main decision criterion. An additional issue that when there is more than one reversal of sign in the net annual flows, the ERR calculation may have multiple solutions.[25] Nevertheless, the (internal) rate of economic

[23] Among renewable energy technologies, some daily-peaking small hydro and some biomass projects can also credibly claim a capacity credit.

[24] Once this bank-wide discount rate guidance note has been issued, the planned Technical Note C8 on discount rates for power sector projects will be issued.

[25] Normally there is just one sign reversal – negative flows in the early years reflecting investment, positive once the project is in operation. But some projects may require large additional expenditures during the operating period (e.g., in the case of a hydro project, turbine runner replacement) that may cause a negative net economic flow in some years.

return is a widely understood concept and serves as a compact summary measure of economic merit. Consequently the World Bank PADs report both ERR and NPV.[26]

53. ERR should be especially avoided in any ranking exercise – say for an on-lending operation to support multiple small hydro projects. In such cases the choice should be made on the basis of maximizing the total NPV given the capital constraint, which rarely provides the same subproject selection as given by choosing the first ***n*** projects from a list ranked by ERR. Benefit cost ratios are similarly misleading, as are traditional business indicators such as payback period: both are incorrect indicators of *economic* profitability.[27]

9. FINANCIAL ANALYSIS

54. Traditional World Bank practice has been for the project economic analysis to be accompanied by a so-called "project" financial analysis, with the calculation of a project FIRR. Taxes and duties and other transfer payments excluded to derive economic costs are added back in, and the resulting financial return compared to the weighted average cost of capital (WACC). If FIRR>WACC, a project is deemed financially feasible. Both the FIRR and the WACC were calculated at constant prices.

55. This may have been useful when almost all power sector projects were in the hands of a vertically integrated, state-owned utility, and where, in effect, financing was on the balance sheet of this entity, and for which a utility-wide WACC calculation was relevant. It has also been argued that this avoids setting out the details of financing which may not be fully known at the time of project appraisal. Thus much of the emphasis in financial analysis of traditional power sector projects was on the financial condition of the *borrower:* in reality the project FIRR at constant prices commanded little attention.

56. This approach has diminishing relevance today. Many power sector projects are implemented as Private-Public Partnerships (PPPs), whose financing is essentially on a *project finance* basis, and whose financial acceptability to private investors is based on actual expected and nominal cash flows. The financial structure of such projects is integral to the special purpose vehicles (SPVs) that are created to develop and implement projects. In any event, the WACC calculation does not take into account loan tenors which is central to the determination of cash flows, and to the debt service cover ratio (DSCR).

57. In the absence of an explicit understanding of the impact of project financing on cash flows, it is very difficult to see how the OPSPQ requirement that the economic analysis assess the financial sustainability of a project can be reliably provided by the traditional approach. Indeed, the project financial return at constant prices provides no useful information about actual likely project cash flows, and the crucial relationship between tariffs (and their adjustments) and debt service cash requirements. Moreover, in portfolio projects involving on-lending to commercial banks (or even to subproject borrowers), credible assessment of FOREX risks (especially on concessionary loans with very long tenors) is impossible in the framework of the traditional project FIRR approach.

58. A good economic analysis provides a reconciliation of economic and financial flows, which is a prerequisite for a distributional analysis that identifies the impacts on the main stakeholders. Thus a good economic analysis model will be linked to a financial model: since many assumptions are common to both, it greatly eases a transparent reconciliation of economic and financial flows. Nowhere is such a reconciliation and consistency more important than in rural electrification and off-grid renewable projects, where the economic benefits of household electrification are derived from the financial prices experienced by consumers: the kerosene that is replaced by grid electricity is often subsidised, so a substantial

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26 ADB practice is different. Many of the renewable energy project appraisals reviewed report *only* the ERR.

27 L. Squire and H. van der Tak, 1975. *Economic Analysis of Projects*. Johns Hopkins University Press for the World Bank, Washington DC

economic impact derives from the avoidance of deadweight losses associated with the elimination of such subsidies.

10. DISTRIBUTIONAL ANALYSIS

59. The point of a distributional analysis is to quantify the impact of a project on the stakeholders, among which there will be winners *and* losers. This is a particularly important question for high cost renewable energy projects: who bears the incremental *financial* costs is the central question. With many renewable energy projects involving highly concessionary finance (such as CTF) and on-lending operations, identification of exactly who benefits from such financing, and by how much, is critical to long-term sustainability: the risk is always that at some point, Government decides it can no longer afford the subsidy to a high-cost project. Technical Note **C6** offers suggestions on how the distributional analysis can be presented, and how to cross the bridge between the baseline economic analysis at constant prices, and a financial analysis that is at nominal prices.

60. One of the reasons for the lack of good distributional analysis is that economic and financial analyses are often conducted as separate studies, and often by different individuals: a financial analyst prepares the project financials, and an economist prepares the assessment of economic returns. Yet distributional analysis requires the reconciliation of economic and financial flows because the stakeholders perceive the impact as financial. In a power sector often riddled with subsidies, there also arise deadweight losses, which constitute economic costs no less than consumer surplus constitutes an economic benefit. A plausible counter-factual is another essential prerequisite for a good distributional analysis: what matters is the *net* impact of the project on the stakeholders, relative to the counterfactual.

61. The transparent recovery of incremental costs lies at the heart of whether a support tariff for renewable energy can be successful. There are many examples of countries setting up "renewable energy funds" that do not have a credible source of long term funding ("Funds without funds"), or renewable energy tariffs that are either excessively generous or set at a level so low as not to enable any projects. The special problems of the financial sustainability of renewable energy projects are discussed in Annex I.

CBA and poverty alleviation.

62. The question of the extent to which traditional analytical practice in CBA reflects equity concerns is not new: already the 1975 World Bank's classic textbook on project economic analysis proposed the use of distribution weights in CBA to reflect equity concerns. [28]

63. Many large power sector projects (and hydro projects in particular) are located in relatively remote rural areas, and the directly affected families who may require resettlement, or whose livelihoods are affected, are often among a country's poorest inhabitants. Estimating the costs of R&R as provided by the Bank's safeguards policies is generally straightforward, and easily incorporated as a line item in the table of economic flows. Under the presumption that project affected persons (PAFs) are completely compensated by the project, the net impact on PAFs would be zero. However, some social mitigation plans seek not just to compensate PAFs, but *improve* their standard of living: even if described as "benefit sharing," such additional improvements constitute a transfer payment and should not be treated as a project (economic) cost.[29]

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[28] L. Squire, and H. van der Tak, 1975, *op.cit.*

[29] The 4,600 MW Dasu hydro project in Pakistan (on the Indus River, above the Tarbela project) is a case in point. Some 4,000 persons are planned to be relocated, but the budget cost estimate for the Social Mitigation Plan (SMP) is $470 million (or more than $100,000 per person!) How much of this survives the final project implementation remains to be seen, but the Dasu SMP stresses the commitment not just to compensation, but to achieving an improvement of the socio-economic well-being of those affected by the project.

64. Recently, CGE models are coming into use for Poverty and Social Impact Assessment (PSIA) to assess the welfare impacts of larger energy projects (including Development Policy Loans tied to power sector reform).[30] The economist charged with the CBA should consult with the PSIA economist to ensure consistency of assumptions, and to ensure that any significant welfare impacts on households are captured in the distributional analysis.

Table 3.2: Power sector projects and poverty alleviation

Project type	Issues
Grid-connected renewable energy	In most cases consumers will experience little change in tariff from even expensive renewable energy projects at the penetration levels expected in the early years of increased renewable energy generation: such projects can hardly make a credible claim to benefit low income groups (or any particular set of consumers). However, there may arise significant equity considerations in the *recovery* of incremental costs. In Malaysia, the incremental costs of the renewable energy FIT are recovered by a 1% levy on all electricity customers who consume more than 300kWh/month, or whose bills exceed 37 Ringgit/month ($10.60), thereby shielding lower income consumers.[31] Who bears such incremental costs is best assessed in the distributional analysis.
Rural electrification& off-grid renewable energy	Invariably such projects disproportionately benefit lower income consumers that predominate in rural areas. How such benefits of electrification are evaluated raises many issues, addressed in Technical Note **M2**.
Generation projects	If a new generation project is deemed to have incremental benefits, then (as in off-grid projects), the power benefits accrue to the extant mix of consumers. The extent to which these include the poorer sections of society would need a case by case evaluation. In the Tarbela T4 hydro project, which was designed primarily to alleviate summer power shortages, the main benefits would accrue to agricultural users (who would switch from diesel pump-sets to grid power). However, pump sets tend to be owned by the better-off farmers rather than the rural poor.

11. SENSITIVITY ANALYSIS

65. Notwithstanding the guidance of the existing *Handbook on Economic Analysis* that calls for calculation and discussion of switching values, in many economic analyses sensitivity analysis is limited to recalculations of ERR/NPV for a few input variables by some fixed percentage. Such an approach is unacceptable. Calculation of switching values is required for *all* projects. Technical Note **M1** describes the recommended approach for the presentation of an adequate sensitivity analysis.

66. As noted above, one of the main issues for project appraisal is the extent to which the risks of a project should be considered in the investment decision. Even if measures are taken to mitigate some of the enumerated risks (and their costs of mitigation included as project costs), substantial uncertainty over factors beyond the control of implementing agencies and EPC contractors will remain. Some are related to natural resource variability (such as wind and hydrology); others are related to the state of the global economy and world energy markets. Some of these uncertainties about the future are best handled in a scenario analysis; others are best illuminated by an explicit assessment of the trade-off between risk and returns – as discussed in Technical Note **C5**.

67. The discussion of consumptive water use (in Step 5) illustrates the role of sensitivity analysis in identifying how the resources available for economic analysis are best spent, and in

30 See, e.g., World Bank, *Pakistan: Second Power Sector Reform Development Policy Credit*, Project Appraisal Document, April 2015.

31 By contrast, in Germany until very recently it has been the largest industrial consumers who have been exempt from the surcharge to recover the costs of the FIT. In 2012, German residential customers paid $0.25/kWh for electricity, of which the surcharge for the feed-in tariff levy accounted for $0.039/kWh, or 13.9% of the average bill. This surcharge rose to $0.0528/kWh in 2013. (K. Neuhoff and others, 2013. *Distributional Effects of Energy Transition: Impacts of Renewable Electricity Support in Germany*. Economics of Energy & Environmental Policy, Volume 2,No.1, March).

identifying the need for more detailed study to firm up key costs and benefits. As noted there, the need for detailed study of the opportunity cost of water in an arid country will depend on the sensitivity of the economic returns to the value of that assumption. If the switching value indicates that hurdle rate would not be met if the economic cost of water were 100 times the financial cost, then further study is not required: if it is twice the financial cost then further investigation *would* be required, For thermal generation projects that may lead to a decision to use dry cooling rather than evaporative cooling - and illustrates the role of economic analysis in project design just as the OPSPQ guideline suggests.

12. Risk assessment

68. In recent years, project risks have been summarised in a PAD risk matrix. But few PADs have made much effort to coordinate the economic analysis with the risks and their mitigation as enumerated in this matrix. The converse is also true: it is rare for the PAD risk matrix to refer to the results of the economic analysis risk assessment.

69. For example, the risk of delay and cost overruns is often identified in the risk matrix, but nevertheless the economic analysis is silent on the subject. Not all risks can be quantified and monetised, but those that can – and delay and construction cost overruns are certainly among these – always deserve examination in the economic analysis.

70. Indeed, one of the practical reasons that the OPSPQ guidelines call for the involvement of the project economist already at the PCN stage is to make sure that the design of the project benefits from the results of at least a preliminary economic analysis. The main point of the economic analysis risk assessment is to prioritise and focus risk mitigation measures to ensure the robustness of the economic returns. A well structured project preparation effort requires the TTL (generally responsible for the preparation of the PAD risk matrix) and the project economist to inform each other.

71. In its assessment of CBA at the Bank, IEG argues that "*variability of a project's expected NPV around its mean should not carry weight in decisions*". This view goes back to the Bank's traditional public sector lending to governments, who are assumed to wish to maximize the expected NPV of their *portfolio* of projects (i.e., they are presumed to be risk neutral).[32] IEG takes the view that risk assessment is relevant mainly for the identification of mitigation strategies. However, to use an illustrative example, suppose the best ranked alternative **A** has an expected NPV (net benefits) of $500m, with variance $150m (say as revealed by a Monte Carlo simulation of the probability distribution of NPV/ERR), but the second ranked option **B** has an expected value of NPV of $490 million with a variance of $50million. Risk neutrality would dictate that **A** be chosen, rather than **B** that has a lower NPV but which is more robust with respect to exogenous uncertainties.[33]

72. The presumption of risk neutrality may well apply in some instances, and may be appropriate for Bank projects considering portfolios of small to medium sized sub-projects (often encountered in on-lending operations). But in the case of large power projects this may *not* be the case. Indeed, with the World Bank increasingly involved in public-private partnerships (PPP), and particularly so for larger hydro and renewable energy projects, the private sector's evaluation of project risks is rarely risk neutral. International private power developers may well have a portfolio of projects under development in different countries, and may well be primarily concerned with the performance of their total portfolio. However individual projects are still subjected to intense scrutiny and requirements to ensure equity returns appropriate to risks at each stage of project development. Technical Note **C5** (risk

[32] The full discussion is to be found on p.98 of the *Handbook*.

[33] Exogenous uncertainties are those which are outside the control of the Government and not amenable to mitigation at the project level – such as the future world oil price or the extent of climate change (that will largely be determined by the world's big carbon emitters, not the typical small developing country that account for most of the Bank's clients).

analysis) discusses further the treatment of risk in project appraisal, and the use of tools derived from financial portfolio management to assist in both policy analysis and project evaluation (Technical Note **M8**).

Real options[34]

73. One approach to deal with uncertainty and its resolution is the application of so-called real options (developed originally for financial markets). A real option is the right, but not the obligation, to invest in a future project of unknown benefit at a known cost today. Just like buying a plot of land gives you the right (but not obligation) to erect a building in the future, a real option implies at least two time steps – a decision to be made today, followed by a decision to be made tomorrow. [35]

74. There are several necessary conditions for the real option value approach to be suitable: uncertainty, learning and flexibility – which we can illustrate in the case of a hydro project for which the commissioning of a detailed feasibility study (FS) is an example:[36]

- **Uncertainty: w**ithout which there is no need to consider the possibility of deferring an investment decision: if the future is already known the best decision under certainty can be made now. But one does not start dam construction before the major geotechnical , hydrology and environmental uncertainties have been resolved.
- **Learning**: information regarding uncertainty must change over time. The FS represents that learning. If it is unlikely that uncertainties will be resolved over time, then one might as well make a decision today.[37]
- **Flexibility**: if the FS shows that the hydro project will be uneconomic (or technically infeasible), one must be prepared *not* to proceed, or to delay a the investment pending resolution or narrowing of uncertainty over time.

75. Technical Note **C4** provides a more detailed discussion of these alternative decision-making frameworks.[38] In the past decade a number of transmission planning and investment problems in the developed countries have been cast as real options.[39]

76. At this point in the analysis it should become clear under what circumstances the economic returns of a proposed energy project meet the hurdle rate. Under the current guidelines this means that when all relevant externalities have been quantified and monetized, including GHG emissions (or their avoidance) at the values now set for project appraisal, the hurdle rate is achieved.

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34 There are many good texts. T. Copeland and V. Antikarov, *Real Options: A Practitioner's Guide*, Texere, New York, 2001 is one of them.

35 Hallegatte, S., A. Shah, R. Lempert, C.Brown and S. Gill, 2012. *Investment Decision-making Under Deep Uncertainty: Application to Climate Change*, World Bank Policy Research Working Paper 6193.

36 One may note that a FS for a large hydro project runs into the millions of dollars. That means that even before one embarks on a FS, one should ask what the FS would need to say about capital costs for the hydro project to be competitive with other thermal peaking options. If a hydro project would have to cost less than $1,000/kW to be competitive with gas or imports, why spend $5million for an outcome that seems most improbable?

37 Even with the benefits of a FS, however, not all geotechnical problems can be resolved – there are several examples of dam axes being changed once construction started, and foundation and geological fault conditions verified. Similarly, notwithstanding that commercial lenders often insist they take no tunneling risk (which means that the costs of unexpected conditions must be covered by equity), depending on terrain it may be judged uneconomic to confirm by drilling at the FS stage the actual rock conditions deep underground. A FS can never eliminate *all* uncertainty.

38 A. Dixit and R Pindyck, *Investment Under Uncertainty*, Princeton University Press, 1994 is the classic text.

39 For example, A. Borison, G.Hamm, P. Narodick and A. Whitfield, 2011. *A Practical Application of Real Options Under the Regulatory Investment Test for Transmission*. Report by NERA Economic Consulting to Grid Australia.

Scenario analysis

77. As an adjunct to a Monte Carlo simulation one may conduct a scenario analysis which compares plausible worst cases – in which *all* the input assumptions take on pessimistic values together - against the baseline. This addresses the concerns of the IEG CBA evaluation that analysts are prone to selecting what are judged to be the most likely values for all input variables, presuming a future that is rarely realised, with the result that economic returns are often over-estimated.[40]

78. Such a scenario analysis may need several iterations with inputs from the team (and from the client) to develop plausible worst cases. It is also useful to examine the plausible *best* case scenario, and to then proceed to a formal decision-analysis that takes into account the risk preferences of decision-makers, and the economic consequences of having to make decisions under highly uncertain assumptions - as well illustrated by the potential consequences of the current decline in oil prices were they to persist for several years (see example in Technical Note **C4**). Several recent hydro project appraisals have used scenario analysis to test the robustness of economic returns to worst case conditions and serious accidents (which in case of hydro projects is powerhouse flooding attributable to extreme weather events or equipment failures: the costs of such events being not just the cost of repair, but also the cost of lost generation[41]).

13. ADDITIONAL STUDIES

79. As recognised in the OPSPQ guidelines, not all the information necessary to assess the full set of expected project consequences may be available at the PCN stage. In setting the analytical form and scope of the analysis, the OPSPQ guidelines require that the economist:[42]

> Delineate the causal framework that links the project activity to ultimate outcomes of interest. List the major assumptions utilized by the causal chain framework. Define a clear link between project activity, intermediate outcomes/objectives, and ultimate outcomes/outputs (program development objectives) within the result chain framework:
>
> (i) Determine whether this is a project where the results chain is well established and documented. Determine how to effectively utilize this prior knowledge.
>
> (ii) Determine whether it would be appropriate for supplementary studies to be supported by, or conducted in conjunction with, project activities in order to improve knowledge around project impacts and important mitigating factors. These studies may run the gamut from small-scale observational exercises to a full-blown prospective impact evaluation, depending on the informational needs and timeframe of the project.

80. In addition, the OPSPQ guidelines recognise that [43]

> . . . . In many projects in today's portfolio it may not be possible to arrive at a comprehensive monetary value of benefits, or else prohibitively costly to do so, once more making it difficult to provide a numerical estimate of the rate the return

81. In the case of some high cost renewable energy projects, it is often argued that several positive project outcomes provide additional justification, but which are excluded from the customary quantification of economic flows: the usual economic rate of return therefore provides only a partial picture of potential benefits. These benefits relate to

- Energy security
- Macroeconomic impacts (including beneficial employment impacts)
- Learning curve benefits (whose benefits to society can only be realised in the future if projects in the early phase of the learning curve for new technology are financed today)

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40 World Bank, 2010. *Cost Benefit Analysis in World Bank Projects*. Independent Evaluation Group (IEG).

41 see, e.g., the Project Appraisals for the Tarbela T4 Hydro Project and the Kali Gandaki Hydro Rehabilitation Project.

42 OPSPQ, op.cit., ¶25

43 OPSPQ, *op.cit.*, ¶3

Energy Security

82. Energy security has rarely been clearly defined, which makes it hard to measure and therefore difficult to balance against other policy objectives. Indeed, discussion of energy security requires much caution and scepticism: as noted by the eminent MIT economist Paul Joskow, "*There is one thing that has not changed since the early 1970s. If you cannot think of a reasoned rationale for some policy based on standard economic reasoning, then argue that the policy is necessary to promote "energy security*."[44]

83. A large and growing literature discusses energy security, but very little of this is relevant to the specific question of whether energy security benefits can be quantified in a form useful to CBA: that is, framed as a line item in the tabulation of economic flows. Policy-makers in many countries assert that energy security is of great concern, but often they do little to use the already available tools to improve the financial and physical dimensions of energy security (fossil fuel price hedging, increasing tank farm storage, etc.) Nor do many place much emphasis on energy efficiency and efficient pricing policy, both of which reduce the vulnerability of an energy system to all of the risks and uncertainties associated with energy supply.

84. Thus one of the pitfalls is to claim benefits against imaginary concerns. It is claimed, for example, that RE will improve energy security because a country will be less vulnerable to supply disruptions and price volatility of imported fossil fuels. But were that indeed a concern, then the question would be how the incremental costs of a RE project compares to other alternatives to address the same concern as may be proposed by Government even in the *absence* of any renewable energy projects – for example, by mandating increased physical storage (say an extra 30 days coal supply to be stockpiled at coal projects, or the establishment of a strategic petroleum reserve).[45]

85. The large literature on the macroeconomic consequences of fossil fuel price shocks concludes that the impacts are not symmetrical – the loss of GDP following the price shock is not regained once the price decreases again. Consequently any policy that reduces exposure to price shock by reducing dependence on imported fossil fuels would be of economic benefit.

86. But translating these effects into an oil price volatility risk premium that can be included in the ERR calculations is difficult, and rarely attempted. A recent study for Latin America by the Inter-American Development Bank suggests this risk premium to be very small, (0.01 USc/kWh), an order of magnitude lower than the damage costs from local air pollution of thermal generation.[46] A study to develop an avoided cost tariff for Indonesian geothermal development estimates the volatility premium at 0.07 USc/kWh (estimated as the cost to Ministry of Finance of short-term financing of unexpected increased subsidy to PLN in wake of forecasting errors of PLN's fuel costs attributable to unforeseen price volatility).[47] Another study for the EU shows the cost of the "oil security externality" to be less than 0.01 Eurocent/kWh.[48]

87. One approach is to define energy security as an attribute in a broader evaluation of the tradeoffs between economic returns and risk using mean-variance portfolio theory, which

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[44] P. Joskow, 2009. *The US Energy Sector, Progress and Challenges, 1972-2009*, Dialogue, Journal of the US Association of Energy Economics, 17(2) August.

[45] An ongoing ESMAP study for Afghanistan proposes a methodology for evaluating energy environmental-energy-security trade-offs in situations of high uncertainty (a situation that Afghanistan shares with a number of post-conflict World Bank client countries). The study will be completed later in 2015.

[46] Vergara, W., *et al.*, *Societal Benefits from Renewable Energy in Latin America and the Caribbean*, IDB Technical Note, January 2014

[47] World Bank and ADB, 2015. *Unlocking Indonesia's Geothermal Potential*, May 2015.

[48] S. Arnold and others, *Electricity Supply Externalities: Energy Security*, in A. Markandya, A. Bigano and R. Porchio, Eds., The Social Cost of Electricity: Scenarios and Policy Implications, Edward Elgar, Northampton MA. USA, 2010.

examines the trade-off between expected economic returns (say measured as the levelised cost of energy) against risk (standard deviation of returns).[49] Nevertheless, the central question for any energy security argument for renewable energy – in essence an argument for less exposure to fossil fuel price volatility risk – is whether the incremental cost of renewable is a more cost-effective hedge than relevant alternatives, and how much a decision-maker is prepared to pay for that lower risk. These questions about the ability to quantify energy security benefits, and the extent to which they can be incorporated in the table of economic flows, are discussed further in Technical Note **C7.**

Macroeconomic benefits

88. A general discussion of energy-macroeconomic linkages lies outside the scope of this paper. We take as given that provision of electricity is fundamental to economic development, and that severe and prolonged power shortages impede the rate of economic growth. The welfare benefits of electrification are well established (and are confirmed by the IEG study of this topic).[50] Equally well-established are the macroeconomic penalties associated with excessive (and often poorly targeted) subsidies on electricity and the fuels used to generate it. With rare exceptions (for very large projects in small countries),[51] few power sector projects need to run CGE and input/output models to evaluate macro-economic consequences as part of project appraisals. In most cases the presumption is that a project is too small to affect labour markets. However, as noted earlier, recently CGE modelling has been used in the PSIA of a large power sector reform DPC project where significant price changes are anticipated as a result of subsidy and efficiency reforms, with significant potential for negative impacts on poor households.

Learning curve benefits

89. So called learning curve benefits are often raised as a justification for Bank finance of projects that cannot be justified at *today*'s technology and GHG damage costs, but which deserve support at the early stages of the learning curve – for in the absence of early stage projects, potential technology cost reductions would never be achieved. The dramatic falls in the cost of solar PV are often held up as an example. Potential learning curve benefits are not restricted to renewable energy: carbon capture and storage (CCS), and new nuclear technology will be subject to similar cost reductions as the technology matures. However, such technologies involving large mechanical and thermal components (including CSP, CCS and advanced nuclear reactors) cannot be expected to have the same rates of learning as PV.

90. Learning curve benefits are of two types: those whose benefits can validly be included in the project economic flows, and those whose benefits cannot be assigned to the project under appraisal, but accrue to other projects in the future.

91. The first makes assumptions about the reductions in average cost of technology achievable during a second phase of a project – for example, in the economic analysis of the Egypt Wind Project it was assumed that the cost of wind energy will decrease from 8 to 5 USc/kWh as a consequence of "increasing technical efficiency". However, no further justification was offered, presumably reflecting the view that these cost decreases are self-evident. Such unsupported assumptions should be avoided - or at the very least subjected to a switching value analysis to display the impact on economic returns.

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49 As proposed by Auerbuch and others who argue that the role of renewables in a portfolio of generating assets is the same as the role of relatively risk fee treasuries in a financial portfolio (see, e.g., S. Auerbuch, 2000. *Getting it Right: the Real Cost Impacts of a Renewables Portfolio Standard*, Public Utilities Fortnightly, February 15)

50 Independent Evaluation Group (IEG), *The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits*. World Bank, 2008.

51 The Mahaweli Ganga Scheme (irrigation and power) in Sri Lanka would be one of these exceptions – a project so large as to have consumed a major share of national capital expenditure and labor inputs (crowding out investment in other sectors), and changed to such large extent agricultural productivity that significant changes in the structure of the economy resulted: see, e.g., World Bank, 2012. *Sri Lanka: Mahaweli Ganga Development,* Independent Evaluation Group.

92. The Bank's literature reveals just two serious attempts at quantifying the learning curve benefits of the second type – for wind power as part of the project preparation for the China Renewable Energy Scale-up Project (CRESP), and for the Morocco Noor II&III CSP projects. In both cases a benefit cost analysis was prepared that takes the form of defining as costs the subsidies required to build projects at present costs today, to be balanced against the future benefits that are expressed as the difference between the lower (future) cost of the technology against the fossil fuelled alternative. Technical Note **T3** summarises these two studies, but too little work is currently available to make a best practice recommendation on this subject.

93. Learning curve benefits do not change the economic flows of the project being financed at today's capital costs. Nor do they answer the question of who bears the incremental costs of a high-cost renewable energy project in the short term. It is only relevant as additional justification for the World Bank to *finance* such projects – and therefore informs the second of the three main questions for economic analysis required by the new OPSPQ guidelines.

94. Another way of thinking about learning curve benefits is as a real option. Investment in a CSP today will (likely) have a negative NPV. But in 20 years time, in the absence of such CSP projects today the option to use CSP to stave off catastrophic climate change would not be available (or only at prohibitive cost in the absence of prior learning). So an investment in CSP today is desirable because it will create the option of rapid (and low cost) decarbonisation in the future, not because of its own return in the short run.[52]

14. MULTI-ATTRIBUTE TRADE-OFF ANALYSIS (MATA)

95. Cost-benefit analysis is the standard tool for evaluating projects in Bank Practice. The presumption is that provided all of the relevant externalities can be included in the economic flows, the correct investment decision follows from choosing that alternative with the highest NPV. But as recognised by OPSPQ, this is not always possible.

96. Multi-attribute decision analysis is one approach to go beyond the single objective cost-benefit analysis as a basis for making decisions. This offers some practical help in coming to better decisions in face of multiple objectives where not all variables of interest can be monetised; by providing better insights into the problems by forcing clarity about goals and risks; by facilitating understanding (if not agreement) among diverse stakeholders; and by assisting decision-makers in making trade-offs.

97. In the assessment of renewable energy technologies, GHG emissions are often treated as a separate attribute precisely because their valuation is controversial, and invite distracting debate about discount rates. Undiscounted lifetime GHG emissions is thus an often-encountered attribute (and is also used by the CTF calculation of marginal abatement cost). MATA is discussed in detail in Technical Note **M6**.

[52] See e.g., Ha-Duong, M., 1998. *Quasi-option Value and Climate Policy Choices*. Energy Economics 20, 599–620

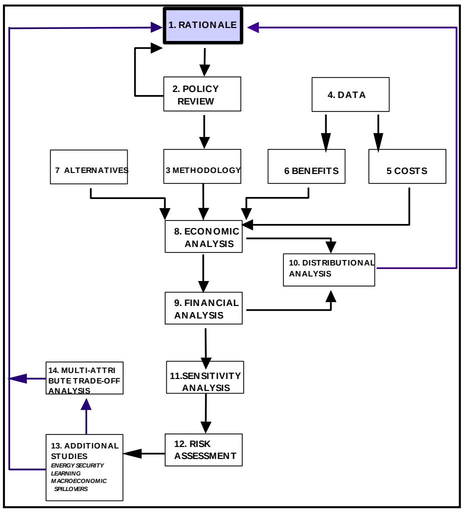
Annex I: Additional Guidance for Renewable Energy Projects

This Annex summarises some of the special issues faced in the economic analysis of renewable energy projects. The following Technical Notes – to be found in the Annex Volume - provide more detailed discussion:

T1 Renewable energy variability
T2 Incremental transmission costs for renewables
T3 Learning curve benefits for renewable energy
T4 Renewable energy counterfactuals
T5 Macroeconomic impacts of renewable energy

An important resource for renewable energy projects is the ESMAP Renewable Energy Toolkit website, that includes many examples of good practice (www.ESMAP.org)

RATIONALE [STEP 1]



98. Renewable energy projects may be proposed for four main reasons:

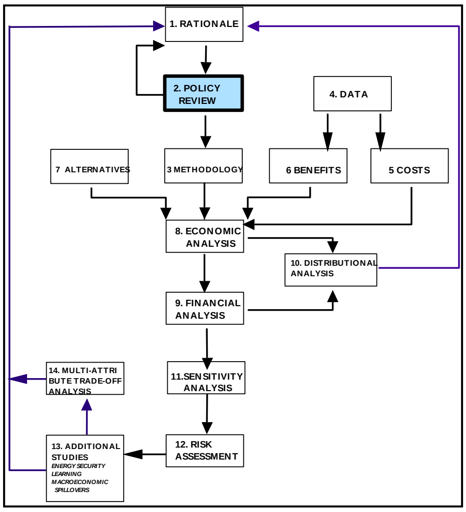
- **Because a project is in the least cost expansion plan of the utility**, that just happens to be renewable, (typical of most large hydro projects, hydro rehabilitation and pumped storage projects). These projects will likely be justified on the basis of conventional cost-benefit analysis, and supported by least cost capacity expansion planning models run by the utility. The principal challenge in this kind of project will be a demonstration that the predicted economic returns have included consideration of all relevant externalities (in addition to the usual concerns of construction cost escalation and delays). Note that traditional least-cost planning models chose capacity based on firm capacity available at the time of the system peak, to which wind and solar generally contribute very little.[53]
- **Because a project is the least cost way of achieving carbon emission reductions**. The Indonesia geothermal project is an excellent example: the capacity expansion plan shows coal to be the least-cost option for meeting base load requirements. But the Government is committed to power sector carbon emission reductions, and among the available renewable energy options, geothermal is the least-cost way of achieving such reductions. The principal challenge in this kind of project is a demonstration that economic returns are assured when the relevant externalities and uncertainties are properly valued. In the case of variable renewables (such as wind and run-of-river hydro) there is the additional problem of properly recognising the costs of intermittency, seasonal, and inter-annual variation.
- **Because a project is the least cost way of reducing local air pollution**: This has been one of the main drivers of renewable energy projects in China, and to a lesser extent in India as well. However, the "least cost" rationale needs careful justification, and a RE project needs to be compared to other interventions as well (for example, the Bank's

53 However, as noted in Technical Note **T1**, portfolios of renewable energy projects of different types and in different locations may provide system wide capacity benefits that may well not apply to a single project.

Shandong project showed that to improve urban air quality, retrofitting FGD was more cost-effective than new renewable energy projects.[54]

- **Because a project contributes to the renewable energy learning curve** that will make the technology in question the least-cost way of achieving carbon emission reductions in the future. These are projects where even if all relevant externalities (and particularly carbon emission reductions) are monetised and included in the economic flows, economic returns are still below the hurdle rate at present technology costs, and at present valuations of greenhouse gas (GHG) damage costs. Concentrated solar power (CSP) and PV are the main examples here. The challenge for economic analysis is to show that such projects contribute to the global learning curve necessary to bring about cost reductions in the long run; and to demonstrate a credible case for additional macroeconomic benefits that derive from local manufacture of project components.

THE MAIN ISSUES OF RENEWABLE ENERGY POLICY [STEP 2]



99. There are several discussions of renewable energy policy that are grounded in economic reasoning. Suggested reading includes:

- Azuela, G. and L. Barroso, 2011. *Design and Performance of Policy Instruments to Promote the Development of Renewable Energy in Selected Developing Countries*, Energy and Mining Sector Board Discussion Paper 22.
- Meier, P., M. Vagliasindi, and M. Imran, 2015. *Design and Sustainability of Renewable Energy Incentives: An Economic Analysis*, World Bank, Directions in Development.

100. Many of the World Bank's more successful renewable energy projects (China CRESP; Sri Lanka, Vietnam, Indonesia) benefited from detailed economic assessments of the support policy framework as part of the project preparation work. Even though the recommendations of economic reasoning regarding support mechanisms have not always been accepted by Governments, bringing these matters to active discussion have demonstrated the importance of the questions raised, which in turn led to successful renewable energy projects. Nowhere is this more important than in the transparent recovery of incremental costs that will determine the sustainability of tariff support instruments. There are several issues that deserve attention in such a policy review:

- ***Targets***: RE projects are often proposed on grounds that they are required to meet Government targets. The main question is whether such targets have been derived on the basis of standard economic reasoning (intersection of the RE supply curve with the full social cost of thermal generation, including their environmental damage costs), or are they merely an aspirational goal (see Technical Note **M3**, Supply Curves). The credibility and longevity of targets has come under increasing question in many countries, yet credible commitments to introduce a new technology are vital to attracting local investment into manufacture of components.
- ***Energy sector context***: power sector options need examination in a broader context of energy policy and low-carbon development. A good example is biomass utilisation for power generation, which may in fact ***increase*** national GHG emissions. For example in Vietnam, rice husk is extensively used in rural industry (brick making, ceramics) where it displaces oil and coal. But if used for power generation then it will displace the most expensive thermal generation, which (in Vietnam) is gas CCGT (whose gas price is linked to Singapore fuel oil prices). A feed-in tariff high enough to enable biomass power generation will drive up rice husk prices (as occurred in Thailand), pushing

[54] World Bank, *Project Appraisal Document, Shandong Power Plant FGD Project*, June 2007, Report 38067.

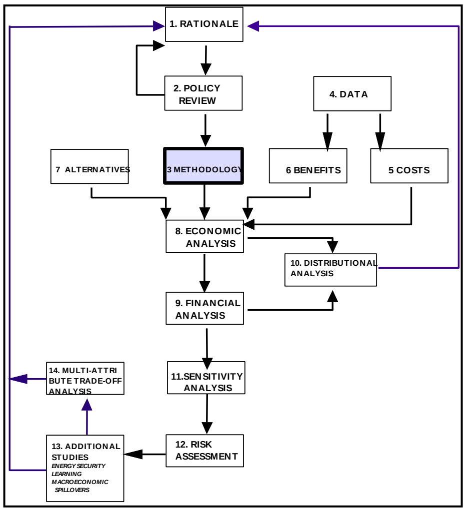
rural industry back to oil and coal, whose GHG emissions are higher than those from the gas power projects displaced by biomass electricity generation.

- ***Policy instruments***: a wide range of policy instruments are in use, but often their design is not economically rational. In mandatory green purchase requirements imposed on distribution companies, penalties for non-compliance are often completely arbitrary (made worse by arbitrary targets and quota sizes).
- ***Incremental costs***: Where targets are aspirational, they are often set without any effort to estimate the incremental costs. In the CRESP project, the Government acted in full knowledge of the incremental costs of large scale wind power development when setting the tariff support mechanism; by contrast, the 2012 Indonesian feed-in tariff and the various targets set by the Government for geothermal projects, were issued without any analysis of the incremental cost and the impact on MoF that was to provide the necessary subsidy (see Technical Note **C6**, distributional analysis). The extent to which buyers - whether provincial distribution companies, or large vertically integrated utilities - can treat RE power purchases as pass-throughs is a frequent question (and often determines the extent of opposition of such buyers to renewable energy).
- ***Willingness to pay for mitigation of global and local externalities.*** The question of whether a relatively poor country should value carbon at levels far in excess of the value in the world's carbon markets arises frequently (\$30/ton CO_2 according to the World Bank's current Guideline, as against the present \$10/ton CO_2 price the EU carbon trading scheme).
- ***Rationality of support tariffs:*** Economic reasoning holds that tariffs should reflect the economic costs of supply. When setting an avoided cost tariff its build-up (of the various benefits) should reflect the same line items as used in the table of economic flows used in CBA. In competitive systems, benefit-based tariff ceilings (whether published or not) serve to ensure that winning bids do not exceed benefits.[55] Such economic reasoning conflicts with the widespread use of feed-in tariffs based on the estimated production costs of the IPP which are preferred by developers (but whose principal interest is adequate revenue, not economic efficiency).
- ***Competition:*** Competitive tendering of IPPs is generally the preferred approach, but this again conflicts with fixed feed-in tariffs – which forces developer selection into one of several inferior options (first come-first served or beauty contests, neither of which ensure economic efficiency in project selection). On the other hand, transaction costs dictate that small projects be exempted from competition – so the question becomes one of setting an appropriate threshold.
- ***PPA:*** Many Bank renewable energy projects involve on-lending through local banks in support of portfolios of qualified renewable energy subprojects. The worldwide experience is that a standardised PPA is always preferable to *ad hoc* project by project negotiation. And even where IPPs are selected by competitive tender (e.g., Indonesia geothermal), the tariff schedules of the PPA should be fixed at time of tender (to avoid interminable post-award negotiations on escalation and indexation).
- ***Institutional Issues***: A range of issues need assessment, including the human resource issues associated with staffing and leadership of RE units in Ministries; how to define the role of the state (for example in countries with geothermal resources, defining the role of the State in up-front exploration); the extent to which resource data should be in the public domain; and the need for enabling legislation, among others. While these are not directly matters of economic analysis in project appraisal, they will determine the extent to which economic reasoning can be brought to bear on decision-making.
- ***Procedures for support tariff implementation***: A rational tariff-setting process – involving regular review, stakeholder consultation, and a published methodology – is vital for a successful RE program, particularly from the perspective of lender-confidence in cash-flow forecasts. Even where independent electricity regulators (or Public Utility Commissions) are not part of the institutional framework, entities housed within Ministries of Energy can provide leadership for tariff reform, and promote a

55 Such an approach is now in place (since June 2014) in Indonesia for competitive tenders to select geothermal developers (and which replaced the fixed feed-in tariff of 2012).

rational mechanism for the promulgation and regular review and adjustment of renewable energy support tariffs (For example, in Vietnam, the Electricity Regulatory Authority of Vietnam (ERAV), a unit of the Ministry of Industry and Trade, has been very effective as a driver of reform).

RENEWABLE ENERGY VARIABILITY [STEP 3]



101. Variability is an issue for several renewable energy technologies, but notably for wind, PV and run-of-river hydro. In the past, many renewable energy CBAs have simply ignored the issue: others do acknowledge the limited capacity contribution of wind but make no corrections in the CBA itself; and yet others provide a good assessment of the costs of variable renewable energy (VRE), in many cases concluding that the integration costs are quite small at low levels of penetration.

102. The development of wind- and solar-generating capacity is growing rapidly around the world, driven mainly by strong government support of various policy goals in support of environmental sustainability and energy diversity. But integrating variable wind and solar generation into grid operations is challenging: since wind and solar generation only occur when wind and solar resources are available, their output is not controllable. Grid operators are accustomed to dealing with variability, but primarily on the load side. The challenge is that higher levels of wind and solar generation add both variability and uncertainty.

103. Several countries—notably Denmark, Germany, Portugal, and Spain—are providing real-world experience in integrating high levels of variable generation, primarily wind power. In addition, several integration studies have modeled and simulated the addition of large amounts of wind, and to a lesser extent, solar generation to the grid. Such studies provide valuable information on the expected impacts of high levels of variable energy generation and potential strategies for successfully integrating variable energy generation into the system. These studies look at the technical operational impacts of integrating these resources into the systems and the potential technical and economic implications to system operations, notably short-term, reserve-related costs. Globally, variable renewable generation sources still represent mainly an energy rather than a capacity resource. While their contributions to capacity or “firm” power and associated costs are different from those of conventional power sources, variable renewable generation technologies can contribute to long-term system adequacy and security. Several lessons learned can be gleaned from both operating experiences and integration studies. The best summary of this experience is Madrigal & Porter.[56]

104. Where a good capacity expansion planning model is available, the capacity credit can be assessed by examining the capacity expansion plan with and without the project – the model will determine how much other capacity is actually displaced – some units will be delayed, some eliminated completely – though even here the user has to input the firm capacity of a RE project at the time of peak demand (which for many RE technologies may be quite small). But where such a model is not available, the best approach is to treat energy benefits and capacity benefits separately, rather than just compare on the basis of levelised cost of energy (against the counterfactual) - and then calculate the switching value for the extent of capacity credit required to reach the hurdle rate (see example in Technical Note T4).

105. Wind projects in particular impose a range of system integration costs that arise as a consequence of the highly variable output. These costs will be a function of the scale of wind penetration: the greater the fraction of penetration, the greater the potential difficulty in

[56] M. Madrigal and K. Porter, 2013. *Operating and Planning Electricity Grids with Variable Renewable Generation Review of Emerging Lessons from Selected Operational Experiences and Desktop Studies*. World Bank.

accommodating the variability. A 100 MW wind project connected to the 30,000 MW Java-Bali grid in Indonesia can be accommodated with little difficulty; but a 10 MW wind project on a small eastern island heretofore served by a 20 MW of diesel may impose a range of additional system costs that need to be reflected in a CBA. An excellent starting point for understanding the integration of wind in small diesel systems is Garrad Hassan. [57]

106. The impact of wind power depends not just on the wind power penetration level,[58] but also on the power system size, the seasonal and daily variation patterns, transmission network topology, generation capacity mix (particularly the proportion of storage and pumped storage hydro), the degree of interconnection to neighbouring systems, and load variations. In short, the problem is complex, and therefore plausible quantification of network integration costs generally goes beyond the competence of the (average) project economist. For non-engineers, Romero[59] is an excellent introduction.

107. The costs imposed on the buyer of intermittent energy include the following[60]:

- Cost of additional firm capacity needed to counter the seasonal and inter-annual variability.
- Increased O&M costs at existing thermal units called upon to ramp output levels over a broader range and more often and with shorter notice.
- The heat rate penalties (and related fuel costs) associated with such increased ramping
- Regulation costs (that arise from the intra-hour variability of wind resources that requires additional fast response capacity be available).
- Systems operations cost (that arise from less than optimal operation of the system as a consequence of the uncertain nature of wind energy production).
- Gas storage costs (that arise from inaccuracies in the amount of gas nominated each day, which may require the need to inject or withdraw gas from storage at short notice).
- Large-scale grid-connected battery storage which still remains very expensive and is not currently available at a commercial scale (though these costs are expected to decline in the future, possibly quite rapidly).

Technical Note **T1** discusses and summarises the order of magnitude of incremental system integration costs as reported in the literature.

108. Power utilities will often raise a long list of technical problems associated with network stability that are difficult for an economist to assess, and the technical engineering experts brought in by the TTL will often be reluctant to give precise estimates in light of uncertainties, especially where detailed system studies have yet to be performed: this is frequently the case at the time when support tariffs are being discussed by Government, and the utility has no prior experience with wind projects. Often the main question (and the focus of the buying utility's main objection to wind power) is how the incremental transmission connection costs are to be financed (see Technical Note **T2**). The project economist's role is to insist that plausible integration costs are developed: even so, very often the only recourse is to include a generic estimate of costs from the informed literature, and treat this as one of the variables in the sensitivity analysis and risk assessment of economic returns.

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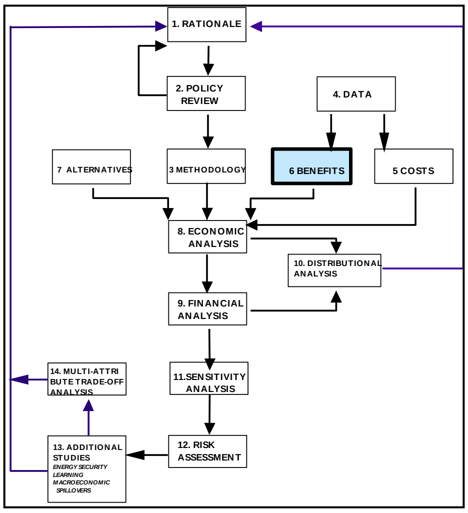
57 Garrad Hassan, 1997. *Network Power Quality and Power System Operation with High Wind Energy Penetration*. Report to the World Bank.

58 Normally defined as the installed capacity of the wind project divided by the maximum peak load. In some cases that is less of a constraint than during off-peak hours, when a large wind farm may account for a much larger share of the *minimum* load.

59 S. Romero, 2012. *Integration of Variable Renewable Technologies (VRE) into Power Systems: Review of Impacts and Solutions for Non-engineers*, ESMAP presentation.

60 Xcel Energy and EnerNex, 2011 *Wind Integration Cost Study for the Public Service Company of Colorado.*

RENEWABLE ENERGY BENEFITS [STEP 6]



109. Our review of past Bank practice for renewable energy project CBA shows that the basis for assessing benefits varies widely, in part because of lack of rigour in defining objectives, in part because the "no project" alternative that is required to be evaluated by the Bank's guidelines is often seen as implausible. In most cases, if the renewable energy project were not built, then it is highly unlikely that some other electricity generation project would *not* be built, and that electricity demand would continue to be unserved, or served by self generation and other grid-electricity substitutes (kerosene for lighting, dry cell batteries). In reality such benefits should be treated as non-incremental (i.e., they derive from substitution), and assessed as the avoided costs of (grid-connected) thermal generation that is the next best alternative to the project.

110. In the case of substitution benefits, the impact on electricity consumers derives from any change in tariff: other things equal, a renewable energy project with high incremental costs will result in an *increase* in tariff (and a loss of consumer surplus); a renewable energy project in the least cost plan (for example a hydro project that would displace a gas CCGT) will result in a *decrease* in tariff (and an increase in consumer surplus). Because many of the Bank's clients have electricity tariffs that are far from cost-reflective, the incremental costs of renewable energy are often absorbed by Governments through additional subsidy to utilities.

111. A geothermal project on a remote Indonesian island grid previously served (poorly) only by diesels for just a few hours a day may bring 24-hour power, and significant additional electricity consumption. The same is true of some hydropower projects whose main rationale is alleviation of power shortages in peak hours (as in the case of the Tarbela T4 extension project). In such cases the incremental benefits are assessed on the basis of willingness-to-pay (WTP) derived from demand curves based on household surveys. Technical Note **M2** discusses further the implications of the choices for valuation, and the problems of using survey-based willingness-to-pay (WTP) estimates.

The impact of renewable energy tariff design

112. Good tariff design can influence the technical design of renewable energy projects. Most flat rate feed-in tariffs (FITs) (based on estimates of production costs) provide little incentive to design projects that maximise peak hour generation and provide capacity benefit to the grid. For example in the case of small hydro, a tariff specified simply as USc/kWh gives no incentive for developers to propose high-head, daily peaking projects that require relatively little pondage to achieve this. However, the experience of Vietnam demonstrates that developers will respond to time-of-day and time-of-season generation tariffs to propose daily peaking projects that have much greater benefits than pure run-of-river projects. (The Vietnamese avoided cost tariff for small renewable energy producers offers a substantial premium for energy produced during the peak hours of the dry season).[61]

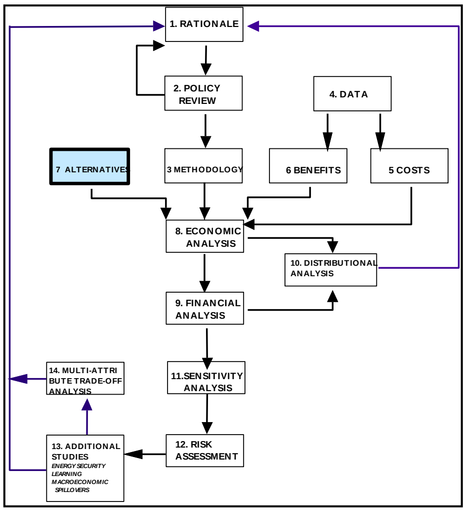
Portfolio diversification

113. It may well be true that a single small hydro project, or a single wind turbine, has no (or very little) capacity value. But a portfolio of small hydro projects spread across several catchments may provide a significant capacity benefit through spatial diversification. And there are many countries where a portfolio consisting of wind and small hydro can diversify the seasonal output (for example, as shown in the CRESP studies for Zhejiang, where a

[61] Electricity Regulatory Authority of Vietnam (ERAV) 2011. *Review of the Avoided Cost Tariff for Small Grid-connected Renewable Energy Generation Projects*, Hanoi.

portfolio of small hydro peaking in wet summers and wind peaking in winter matches well the annual load curve).[62] Such system benefits are often overlooked when appraising just a single project. Technical Note **T1** discusses this issue further.

ALTERNATIVES TO RENEWABLE ENERGY PROJECTS [STEP 7]

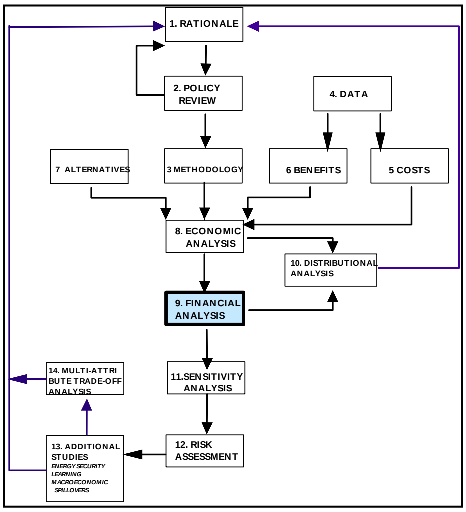


114. In many countries, renewable energy development is driven by developers and bilateral donors anxious to pursue their own development agendas, for example underpinned by the argument that since a country has wind resources these therefore warrant development (whatever may be the cost). Indeed, there are countless examples of renewable energy support tariffs being introduced in response to pressure from these stakeholders, often in the absence of any *economic* rationale, and in the absence of any evidence that a particular technology has any competitive advantage over other renewable energy alternatives. With a rich (and low cost) small hydro resource and a mediocre wind resource, does it really make sense to encourage (high cost) wind in Vietnam? With a rich (and low cost) geothermal resource, and a modest wind resource, does it make sense to encourage wind in Indonesia? And with an excellent wind resource in Egypt, does it really make sense to encourage high cost CSP? These are questions for the project economist to make sure are asked, and answered.

115. A useful demonstration of the plausibility of a renewable energy project is to examine the proposed project's position in the renewable energy supply curve. The construction of such supply curves, and how to avoid some of the pitfalls, are discussed in Technical Note **M3**.

116. Although one can generally recommend the use of capacity expansion planning models such as WASP and EGEAS to assist in the development of the counter-factual, the contribution of firm energy from intermittent renewables has to be determined exogenously by the user – so caution is required: the economist would be wise to consult with the Bank's power systems planning experts to assess the credibility of claims about the firm capacity contribution of VRE.

TRANSPARENT RECOVERY OF INCREMENTAL COSTS [STEP 9]



117. Economic benefits can be realized only if financial sustainability is assured (a point noted in the OPSPQ guidelines). In the case of high-cost renewable energy projects this requires clarity and transparency in the recovery of incremental costs. This is related not just to the distributional analysis (who pays), but also to the need for a sound framework for renewable energy policy. Feed-in tariffs may provide the illusion for security of cash flows for a financial analysis, but there are a number of examples of where renewable energy feed-in tariffs have failed because funding arrangements for covering the incremental costs are not in place (e.g. Sri Lanka), or because they have been set at unrealistic levels (as in Vietnam for the wind FIT).

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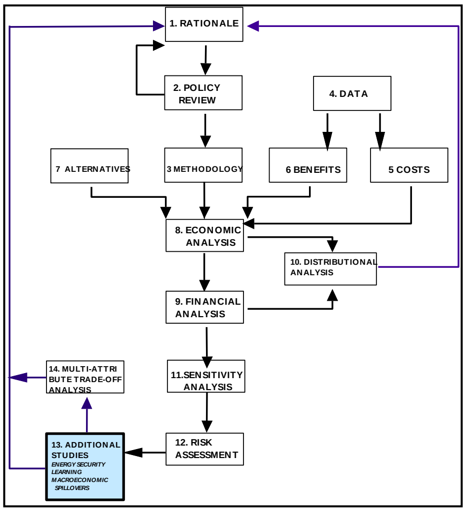
[62] World Bank, 2003. *Economic and Financial Analysis of the China Renewable Energy Scaleup Programme (CRESP)*. ESMAP Renewable Energy Toolkit Website. This example is discussed further in Technical Note **T1**

118. The rationality of renewable energy tariffs is thus of major importance to an economic analysis. Of necessity, many PADs discuss the arrangements for RE tariffs, but caution is needed in how that discussion is framed. From the perspective of economic efficiency, the optimum level of renewable energy is given by the intersection of the renewable energy supply curve with the social cost of thermal generation (i.e. including consideration of all local externalities), and with due consideration of adjusting supply curves for capacity penalties. The ideal tariff is therefore set at this level, and ideally the marketplace best decides what mix of technologies can achieve carbon emission reduction at least cost. Unfortunately this ideal is not always appreciated by the Bank's client countries.

119. Yet technology-specific and above all generous feed-in tariffs based on estimated production costs are popular around the world precisely because they have been demonstrated to achieve ambitious MW targets for wind and solar installed capacity. But for developing countries where the new Bank economic analysis guidelines now make clear that the prime focus should be the *development benefits* of a project, any feed-in tariff that lies above the avoided social cost of thermal generation needs careful justification, and a PAD should provide clear demonstration of why incremental costs above the optimal tariff are justified, and how they should be recovered.

120. This is no different to the general aspects of electricity tariff design, where deviations from the optimal electricity tariff require careful justification. Lifeline tariffs reflect a valid Government objective, and some degree of deviation from the economic optimum for sake of equity is a trade-off for Government to make. But the targeting performance (i.e. what proportion of the subsidy provided is captured by the intended beneficiary) always needs assessment.

MACROECONOMIC SPILLOVERS [STEP 13]



121. Macroeconomic spillovers have become a major issue in project appraisal of high cost renewable energy projects. This interest has arisen as a consequence of the high costs of many renewable energy projects, for which it is claimed that additional benefits beyond those captured in a conventional CBA provide additional benefits to offset the incremental costs of implementing the project. Employment creation ("green jobs")[63] and the establishment of new industries related to domestic RE component manufacture are the most commonly encountered arguments. A single wind project will admittedly have negligible macro-economic impact, but a large scale commitment to green energy (it is argued) would have significant (and presumably) beneficial impact. But at such scale, the incremental capital requirements (even if to some extent covered by concessional green financing) may well crowd out other investments and other job-creating expenditures.[64]

122. Such macroeconomic benefits as derive from domestic manufacture of RE equipment have been proposed for several CSP and wind projects. But we know of only one study that is of sufficient credibility to allow inclusion of macroeconomic benefits in the economic accounts

[63] See e.g., A. Bowen, *Green Growth, Green Jobs and Labor Markets*, World Bank Policy Research Working Paper 5990, March 2012.

[64] The South Africa Medupi coal project illustrates the problem. The economic analysis showed that even leaving aside any additional capacity costs to offset the lack of firm capacity of wind projects, to produce the same energy at the Medupi coal project would require an additional $20billion of investment capital, far in excess of the carbon finance (of around $1billion) actually available to South Africa (see Table M5.8, Technical Note **M5**).

of a major renewable energy project – that for Morocco, prepared under the auspices of the Bank's MENA CSP initiative.[65]

123. The main issue is that these macroeconomic benefits are almost always contingent on the assurance of a sufficiently large domestic market to justify the necessary private investment in domestic manufacturing facilities which will generate the macroeconomic benefits. That in turn translates into the credibility of Government commitments to supporting a particular RE technology. Few industrialists will be persuaded on the basis of aspirational renewable energy targets (by 2020, so many percent of power generation from renewable energy): what is needed are plausible and enforceable institutional and pricing reforms. In Morocco the Government has backed up its targets with the establishment of a strong agency (MASEN) to implement solar projects, and to provide credible financial backing: but elsewhere supporting policies are often weak. The practical question for the project economist would be whether project preparation funds are sufficient to include a high quality study of potential macroeconomic benefits for the country in question. Technical Note **T5** further discusses macroeconomic spillovers of renewable energy.

RENEWABLE ENERGY PROJECTS: CHECKLIST

Note: These questions are in addition to those that apply to all power sector projects (enumerated in the general Checklist of Table 2.1)

	Step	Issue
1	**Rationale**	• If not least-cost, then is the selected renewable energy project the least-cost option for GHG emission reduction compared to other RE options, or to EE and T&D loss reduction?
2.	**Policy review**	• Have all the relevant issues been assessed? (targets, incremental costs, rationality of tariffs, competition, PPAs, institutional capacity).
3.	**Methodology**	• Does the presentation in the appraisal summary section of the PAD conform to the format of Table 3.1?
4.	**Data**	• Have the resource data series (wind speed data, hydrology) been examined for long term trends? (**M7**)
5.	**Project Costs**	• Are the consequences of intermittency presented? (**T1**) • Have the system integration costs imposed on the buyer been quantified? (**T1**) • Are the incremental transmission costs described and included in the table of economic flows? (**T2**) • For hydro projects, are the calculations of GHG emissions from reservoirs consistent with the Water Practice Guidelines?
6.	**Project benefits**	• Have all the externalities associated with displaced thermal generation been assessed? (see Checklist, Table **C3**.1)
7.	**Define the alternatives to the project**	• If a system planning model is used to establish the impact of the RE project on the system dispatch and capacity expansion plan, are the input assumptions based on economic prices? (**C1**) • Where does the project lie on the supply curve for renewable energy? (**M3**)
8.	**Baseline calculations, economic returns**	• Is the rationale for a capacity credit credible? (**T1**) • In the case of VRE, are the capacity benefits clearly identified in the economic flows? (**T1**)
9	**Financial analysis**	• Are the renewable energy support tariffs adequate to assure financial sustainability? • What are the arrangements for the recovery of incremental costs, and are these credible and sustainable? (**C6**)

65 Kost, J. 2011, *Estimated Economic Benefits and Job Creation Potential of the Morocco Solar Plan*, Fraunhofer; and ESMAP, 2011 *Assessment of the Local Manufacturing Potential for Concentrated Solar Power (CSP) Projects*, World Bank.

	Step	Issue
10.	**Distributional analysis**	• Are the incremental costs of high-cost VRE identified, and does the analysis show who bears them (providers of concessionary finance, electricity consumers, or Government) (**C6**)
11.	**Sensitivity analysis**	• In the case of intermittent renewables, does the sensitivity analysis show the relationship between capacity credit and economic return? (**T1**)
12.	**Risk Assessment**	• Have the risks uniquely associated with natural resource variability (hydrology risk, wind speed variability, solar insolation variations) been adequately presented and characterised as probability distributions (**M7**)
13.	**Scenario and trade-off analysis**	• Are trade-offs between costs and environmental indicators to show win-win options and trade-offs considered (**M6**)
14.	**Need for additional studies**	• If energy security benefits are claimed, are plausible arguments presented that even in the absence of the renewable energy project, the Government is taking actions to enhance energy security by reducing the potential impact of physical interruption (increased fuel stocks, petroleum reserves) or by reducing the impact of fuel price volatility (reduce subsidies on fossil fuels, cost reflective tariffs)? (**C7**) • Are the claims for learning curve benefits presented in proper context (i.e., that they do not benefit the project under appraisal, but are mainly relevant to the rationale for Bank involvement in financing)? (**T3**)