CHAPTER 2

The Economic Rationale for Renewable Energy

Analytical Framework

The *economic* rationale for renewable energy (RE) is straightforward: the optimum amount of RE for grid-connected generation is given by the intersection of the RE supply curve with the avoided cost of thermal electricity generation (figure 2.1). Very little RE will be competitive with the avoided thermal cost if that cost is based on financial prices: in almost all Asian countries that have their own fossil-fuel resources, subsidized prices to power utilities are widespread. Only where the marginal thermal resource is imported (unsubsidized) oil is RE competitive (as was the case in Sri Lanka in the early 2000s); where the thermal generation price is based on coal, little if any RE is competitive.

If thermal energy is correctly valued at the border price P_{ECON} (which equals = $P_{FIN} + \alpha$, the subsidy), then the optimal quantity of RE increases, as depicted in figure 2.2.

These principles constitute the basis for the original avoided cost tariffs (ACTs) for RE in Sri Lanka, Indonesia, and Vietnam. In Sri Lanka, which has no domestic fossil resources, the marginal thermal production cost was set by imported diesel fuel, so the acceptance of an RE tariff set at this avoided cost was easily achieved in 1998. In Vietnam this was more difficult, since at the time of its introduction in 2009, the avoided financial cost of thermal generation to the state-owned utility (Electricity of Vietnam, EVN) was based on extensive subsidies to coal and domestic gas used for power generation. But as additional gas-fired combined-cycle-gas-turbine (CCGT) plants came online, with prices linked to international prices,[1] EVN accepted a tariff based on the cost of the marginal thermal project. This is discussed further in chapter 3.

But even if the cost of fossil energy is correctly valued at the border price, this needs to be further adjusted to reflect the local environmental damage costs of fossil energy—that is, the damage caused by local air pollutants (PM_{10},[2] SO_X,[3] NO_X[4]), or the environmental damage costs associated with coal mining (to the

Figure 2.1 Economic Rationale for Renewable Energy: Optimal Quantity (Q_{FIN}) at Financial Cost of Thermal Energy (P_{FIN})

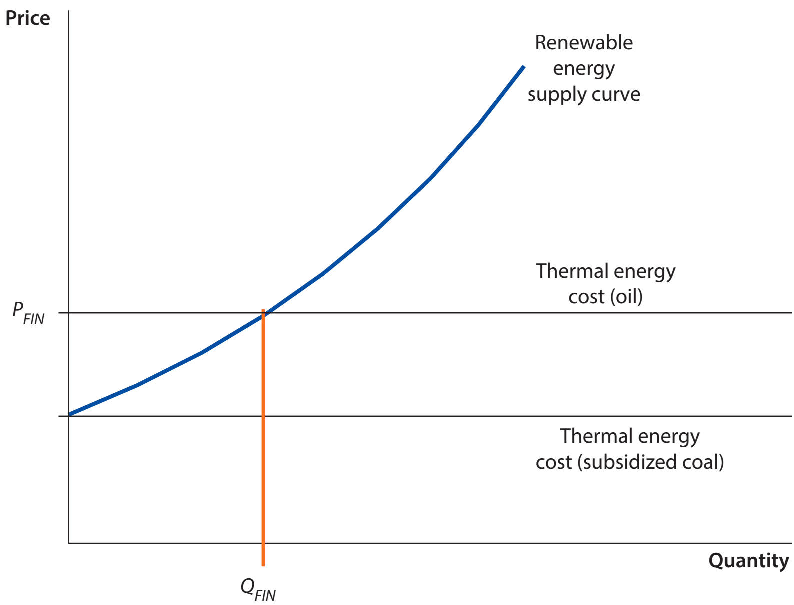


Figure 2.2 Optimal Quantity (Q_{ECON}) at the Economic Cost of Thermal Energy (P_{ECON})

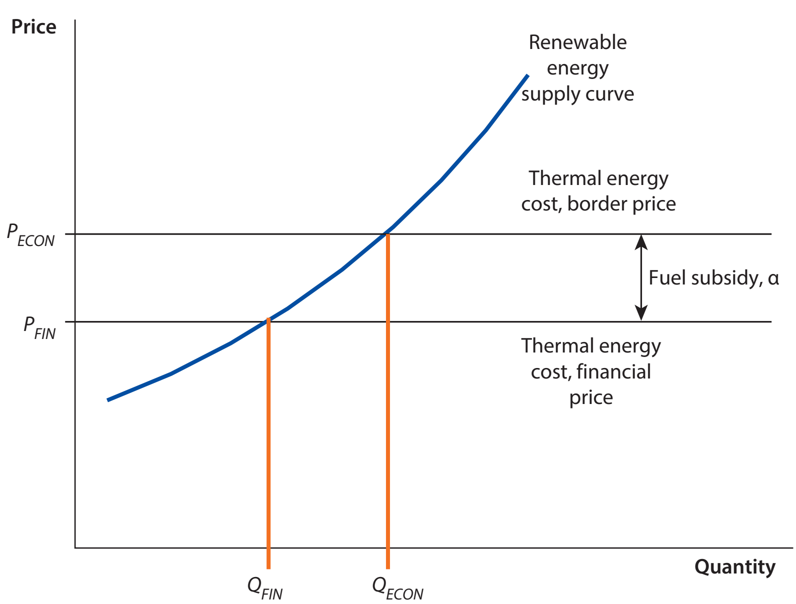


Table 2.1 Externality Costs of Coal Generation

	Rand cents/kWh	*US cents/kWh*
Positive externalities	18.00	2.40
Negative externalities		
Combustion air pollution	−1.35	−0.18
Biodiversity loss	−0.70	−0.09
Acid mine drainage	−2.10	−0.28
Fuel production health impacts (coal mining)	−0.36	−0.05
Total negative externalities	−4.51	−0.60
Net benefit	13.49	1.80

Source: Edkins and others 2010.
Note: kWh = kilowatt-hours.

extent these are not already reflected in the economic cost of coal supplied to a coal-burning project).

As shown in the example of South Africa, in the case of coal these externality costs may be substantial (table 2.1). Nevertheless, there are also positive externalities to be included, which as shown in this table exceed the negative externalities—these benefits derive mainly from the avoidance of the health effects from indoor air pollution associated with kerosene lighting and diesel self-generation. However, while these net benefits are relevant for evaluation of the no project alternative, when comparing coal with RE alternatives these same benefits also accrue to RE, so it is only the comparison of the *negative* externalities that matter.

Such environmental damage costs represent real economic costs to the national economy, and their avoidance should be reflected as a benefit in the economic analysis of RE. In effect, the real social cost of thermal generation is its economic price (that is, without subsidy) plus the per kilowatt-hour (kWh) local environmental damage cost. As shown in figure 2.3, at this cost (P_{ENV}) = $P_{ECON} + E$, the economic quantity of RE increases further, to Q_{ENV}.

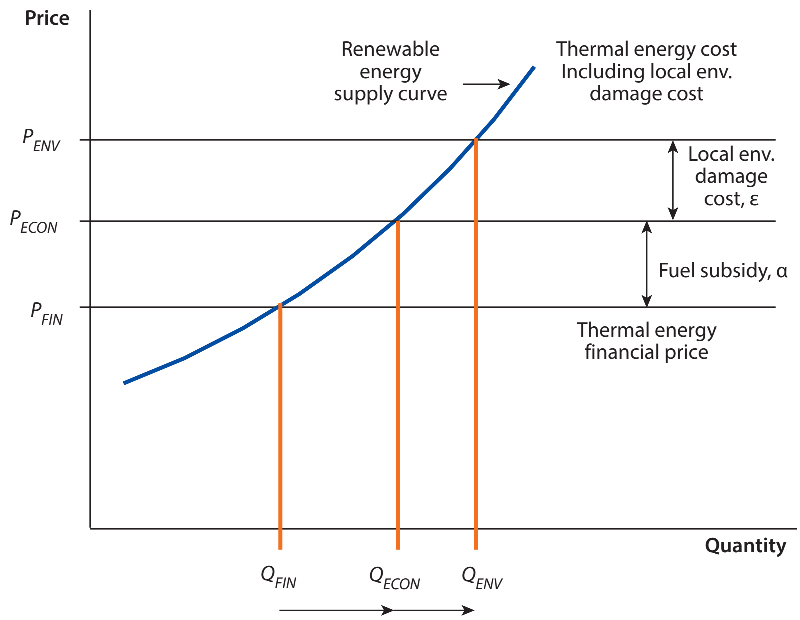
Just this framework was used to underpin the case for RE in China, as is summarized in figure 2.4. The quantity of additional RE increases from 79 terawatt-hours (TWh) to 89 TWh when the environmental damage cost of coal, estimated at 0.4 yuan/kWh (0.48 cents/kWh), is added to the economic cost of coal-fired generation.[5] Appendix C shows how such supply curves can be used in practice to illustrate and estimate incremental costs.

Local Environmental Damage Costs

Table 2.2 summarizes estimates of the environmental damage costs of thermal projects in several developing countries.

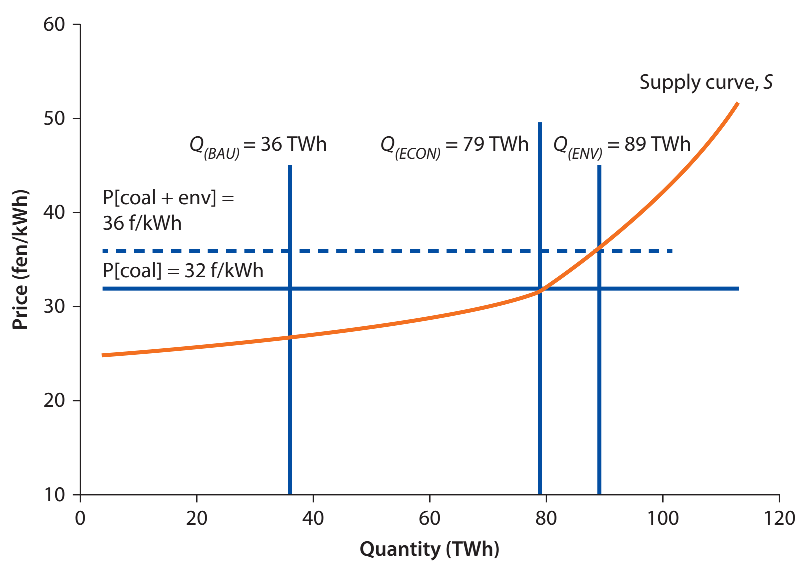
The difficulty with such aggregate damage cost estimates is that they are not transparent with respect to a whole range of important assumptions: the population affected, per capita income, the quality of the fuel (and the efficiency with

Figure 2.3 Optimal Quantity of Renewable Energy, Taking into Account the Environmental Damage Cost



Note: env. = environmental.

Figure 2.4 The Economic Rationale for Renewable Energy: China



Source: Spencer, Meier, and Berrah 2007.
Note: kWh = kilowatt-hours; TWh = terawatt-hours.

which it is burnt), the height of the stack at which the pollutant is emitted, and the pollution control technology in place. Therefore, application of such aggregate per kilowatt-hour emission factors to any specific project comparison, or policy evaluation, can be very misleading. Compounding the difficulty, a significant part of the damage cost from the air pollutant is related to the cost of mortality—how to value the cost of human life is the key question. This is recognized in the latest European Union (EU) studies, which show damage costs based on two main methodologies: the value of statistical life (VSL), and years of life lost (YOLL).[6] Thus, for example, the damage cost estimate per kilogram (kg) of PM-10 (particulate matter no greater than 10 microns in diameter) emissions in Germany varies from €28.9/kg using YOLL, to €81/kg using VSL (EEA 2011).

Perhaps it is not surprising that even using the same methodology across all countries (or across provinces in the large countries), the damage cost estimates for specific pollutants vary widely. In both Europe and China (figure 2.5) regional variations in damage costs span an order of magnitude.

EU and U.S. estimates of health damages are often scaled by per capita gross domestic product (GDP) figures, adjusted by purchase-power parity when transferred to developing countries (the so-called benefit-transfer method).

Table 2.2 Local Externality Damage Costs in Selected Countries

		Cent/kWh	*Date of estimate*	*Source*
India	Coal	1.21	2010	See box 2.1
South Africa	Coal	0.60	2010	See table 2.1
China	Coal	0.1–1.0	2006	World Bank (2005)
Indonesia	Coal	0.32	2010	(1)
	Gas	0.087	2010	(1)
	Heavy fuel oil	2.2	2010	(1)
Egypt, Arab Rep.	Gas CCGT	0.03	2013	NO_X only

Note: (1) see box 5.2 (in chapter 5 of this report) for details. CCGT = combined-cycle gas turbine; CRESP = China Renewable Energy Scale-Up Program; NO_X = nitrogen oxide.

Box 2.1 The Renewable Energy Supply Curve in India

A good example of an renewable energy (RE) supply curve is that prepared by a recent World Bank study for India (Sargsyan and others 2011). The production cost of coal is 5.65 cents/kWh (3.08 rupees [Rs]/kWh), to which is added the estimated local environmental damage cost of 1.21 cents/kWh, which intersects the RE supply curve at about 38 gigawatts (GW). The additional global environmental premium is 2.24 cents/kWh (based on a carbon valuation of $32/carbon dioxide, CO_2), which enables an additional 13 GW—to bring the total to 51 GW (see figure B2.1.1). This would constitute a rational basis for setting an all-India target for RE.

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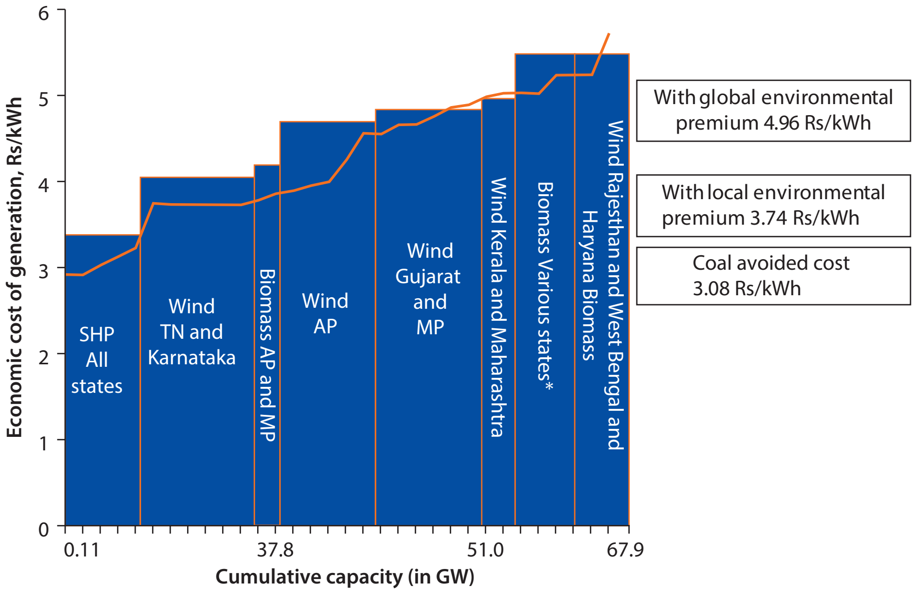
Box 2.1 The Renewable Energy Supply Curve in India *(continued)*

Figure B2.1.1 Renewable Energy Supply Curve in India, by States and Energy Source



Note: SHP = small hydro project; TN = Tamil Nadu; MP = Madhya Pradesh; AP = Andhra Pradesh. $1 = Rs. 54.5.

In the case studies presented in this report, some of the issues associated with such supply curves will be discussed in more detail. For example, India in particular suffers from low (and declining) average load factors in its wind projects, so gigawatt-hours rather than megawatts is the preferred unit of comparison. And different RE technologies also have very different capacity values, which require some adjustment to the RE cost if expressed simply as Rs($)/kWh. But whatever the difficulties, such an analysis is always a better basis for setting an RE target than mere political statement of aspirational goals.

Source: Sargsyan and others 2011.

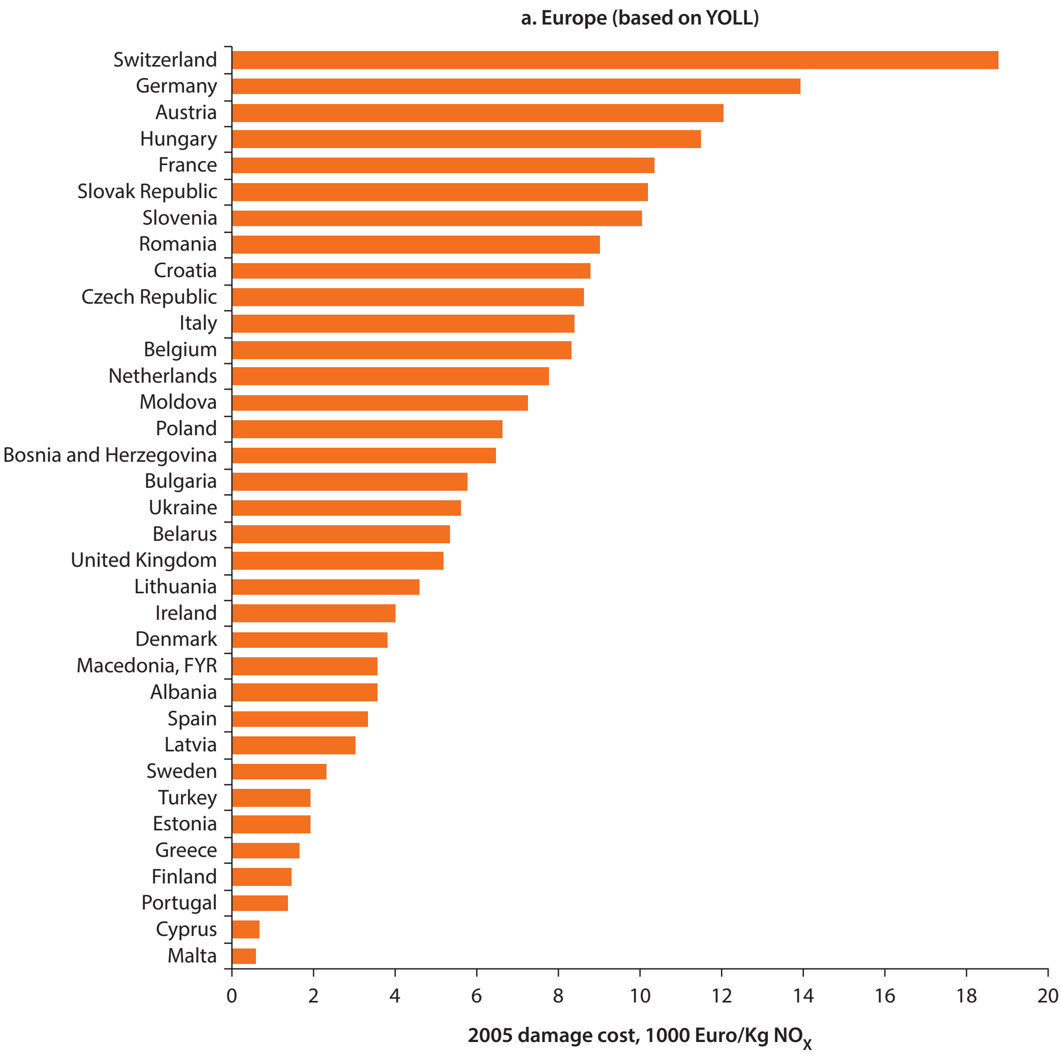
Table 2.3 shows such an exercise for NO_X emissions in the Arab Republic of Egypt, estimated at about 0.1 cent/kWh using the U.K. damage costs. Had the calculation been based on German damage costs, the estimate would be three times higher.[7]

The rationale for such adjustment is therefore doubtful. Figure 2.6 shows the relationship between damage cost estimates for NO_X (as €/kg) versus per capita GDP for European countries. There is little evidence of correlation. The practice of scaling by per capita GDP would certainly not work within Europe, so there is little reason to suppose it would work across developing countries.

These problems were recognized in a 2000 World Bank study that estimated health damage costs from air pollution across six major cities in developing countries. As shown in table 2.4, damage cost estimates varied by two orders of magnitude across (a) ground-level emissions, typical of self-generation, and (b) large-scale utility projects, which have high stacks and are typically located in areas remote from densely populated cities.

The damage cost estimates of table 2.3 are recalculated in table 2.5, using the average values for medium-stack-height emission factors (CCGTs rarely have the sort of high stacks used at coal projects). The damage cost per kilowatt-hour is one-tenth of the benefit transfer estimate listed in table 2.2.

Figure 2.5 Variation in Damage Cost Estimates



Source: EEA 2011.
Note: YOLL = years of life lost; kg = kilogram; NO_X = nitrogen oxide.

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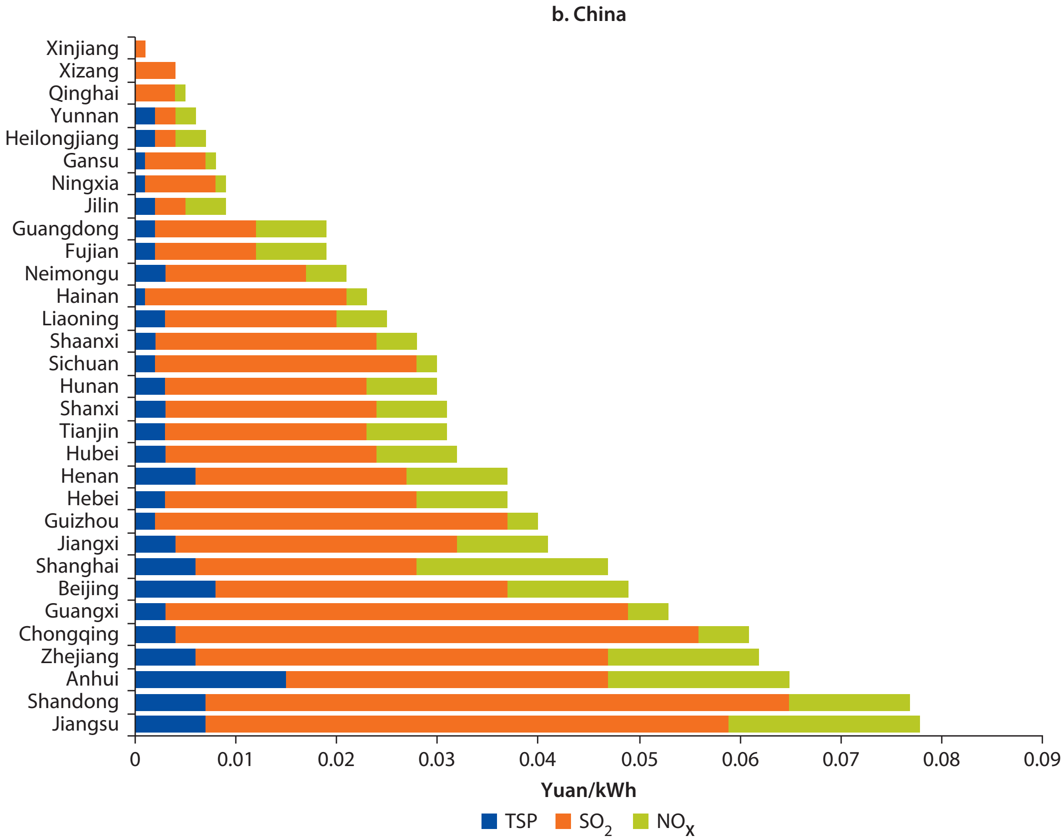
Figure 2.5 Variation in Damage Cost Estimates *(continued)*



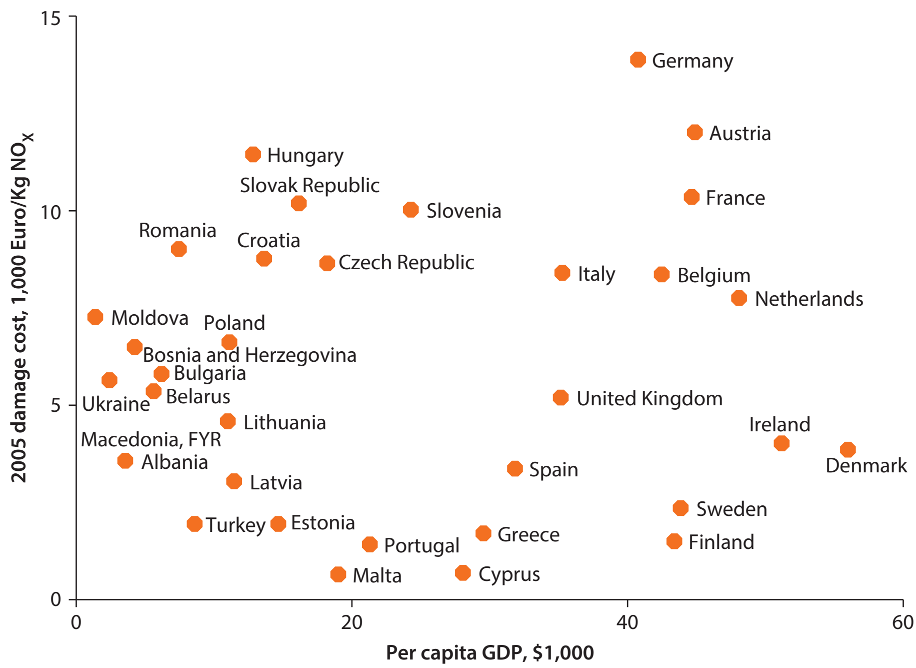
Source: World Bank 2005.
Note: (in 2005, $1 = 8.25 Yuan). The total damage cost in Shandong of around 0.08 Yuan would be (in 2005) 0.97 cent/kWh. In Yunnan the damage cost is one-tenth of this, about 0.1 cent/kWh. NO_X = nitrogen oxide; SO_2 = sulfur oxide; TSP = total suspended particulates.

Table 2.3 Damage Cost of NO_X Emissions from Combined-Cycle Gas Turbines in the Arab Republic of Egypt

		Unit	*CCGT*
1.	NO_X damage cost, utility emissions	2005 €/ton	5,181
2.	NO_X damage cost, utility emissions	$/ton	6,735
3.	Adjusted to 2013 prices	$/ton	8,206
4.	Emission factor	gms/kWh	0.71
5.	EU damage cost	cents/kWh	0.6
6.	PPP Euro zone, per capita GDP	$	35,657
7.	Country PPP	$	7,057
8.	Local damage cost	$/ton	1,333
9.	Egypt, Arab Rep., damage cost	cents/kWh	0.095

Source: World Bank 2013.
Note: CCGT = combined-cycle gas turbine; EU = European Union; GDP = gross domestic product; gms = grams; kWh = kilowatt-hours; NO_X = nitrogen oxide; PPP = purchasing power parity.

Figure 2.6 Damage Costs of NO_X Emissions vs. Per Capita GDP in Selected European Countries



Source: Data from EEA 2011.
Note: GDP = gross domestic product; kg = kilogram; NO_X = nitrogen oxide. Three outliers—Switzerland, Norway, and Luxembourg—have been removed, as their economic conditions are unique in Europe.

Table 2.4 Damage Cost Estimates ($/ton Emissions per Million People per $1,000 of Per Capita GDP Income)

	High stack (modern power plants)	*Medium stack (large industry)*	*Low stack (small boilers and vehicles)*
PM-10			
Range	20–54	63–348	736–6,435
Average	42	214	3,114
SO_2			
Range	3–8	10–56	121–1,037
Average	6	33	487
NO_X			
Range	1–3	3–13	29–236
Average	2	9	123

Source: Lvovsky and others 2000.
Note: GDP = gross domestic product; PM-10 = particulate matter (no greater than 10 microns in diameter); NO_X = nitrogen oxide; SO_2 = sulphur dioxide.

Table 2.5 Damage Costs of NO_X Emissions from Combined-Cycle Gas Turbines in the Arab Republic of Egypt

		NO_X
Damage cost	$/ton/million population/$1,000 GDP	9
GDP (PPP)	$1,000/capita	7.1
Population	Million	2
Cost per ton	$/ton	127.8
Emission factor, CCGT	gm/kWh	0.71
Damage cost	Cent/kWh	0.009

Source: World Bank 2013.
Note: CCGT = combined-cycle gas turbine; GDP = gross domestic product; gm = grams; kWh = kilowatt-hours; NO_X = nitrogen oxide; PPP = purchasing power parity.

The point is simply that there is high uncertainty in the cost estimates for local environmental externalities. This means that, in turn, targets for RE set on the basis of such estimates are also associated with similar uncertainties—though the impact in practice will also depend on the slope of the RE supply curve.

Discount Rate

Supply curves are based on a ranking of potential projects according to their levelized cost of energy, defined as:

$$LCOE = \frac{\sum_{i=1,..n} \frac{C_i}{(1+r)^i}}{\sum_{i=1,..n} \frac{E_i}{(1+r)^i}}$$

where

r = Discount rate
$LCOE$ = Levelized cost of energy
E_i = Net energy generation in year i
C_i = Economic cost incurred in year i
n = Economic life

The levelized cost is thus critically dependent upon the choice of the discount rate. RE is generally more capital intensive than fossil energy, for which a greater part of the cost (of fuel) lies in the future. Consequently, the lower the discount rate, the more favorable RE appears by comparison—which is quoted by some as a reason for using lower discount rates when evaluating RE alternatives.[8]

Discount rates across countries vary: as shown in table 2.6, discount rates in the Bank's RE project portfolio have varied from 8 percent to 15 percent. For example, in the Philippines the rationale for the high 15 percent discount rate (as used in the solar PV program) is that public sector projects ought not to crowd out private sector investment, and that therefore public sector hurdle rates (at least in the energy sector) should be *higher* than the typical weighted average cost

Table 2.6 Discount Rates in World Bank Renewable Energy Projects

Country	*Rate (%)*	*Renewable energy technologies evaluated*
Philippines	15	Solar homes (PV)
Peru	14	Small hydro, solar homes (PV) (Peru Rural Electrification Project)
India	12	Solar homes (PV), small hydro
China	12	Small hydro, wind, bagasse, landfill gas
Vietnam	10	Large and small hydro
South Africa	10	Landfill gas, small hydro, pulp and paper cogeneration: Renewable Energy Market Transformation Project (carbon finance for renewables)
Sri Lanka	10	Small hydro, wind, village (micro) hydro, solar homes
Cape Verde	10	Wind
Croatia	8	Biomass (combined heat and power), wind, small hydro

Note: PV = photovoltaic.

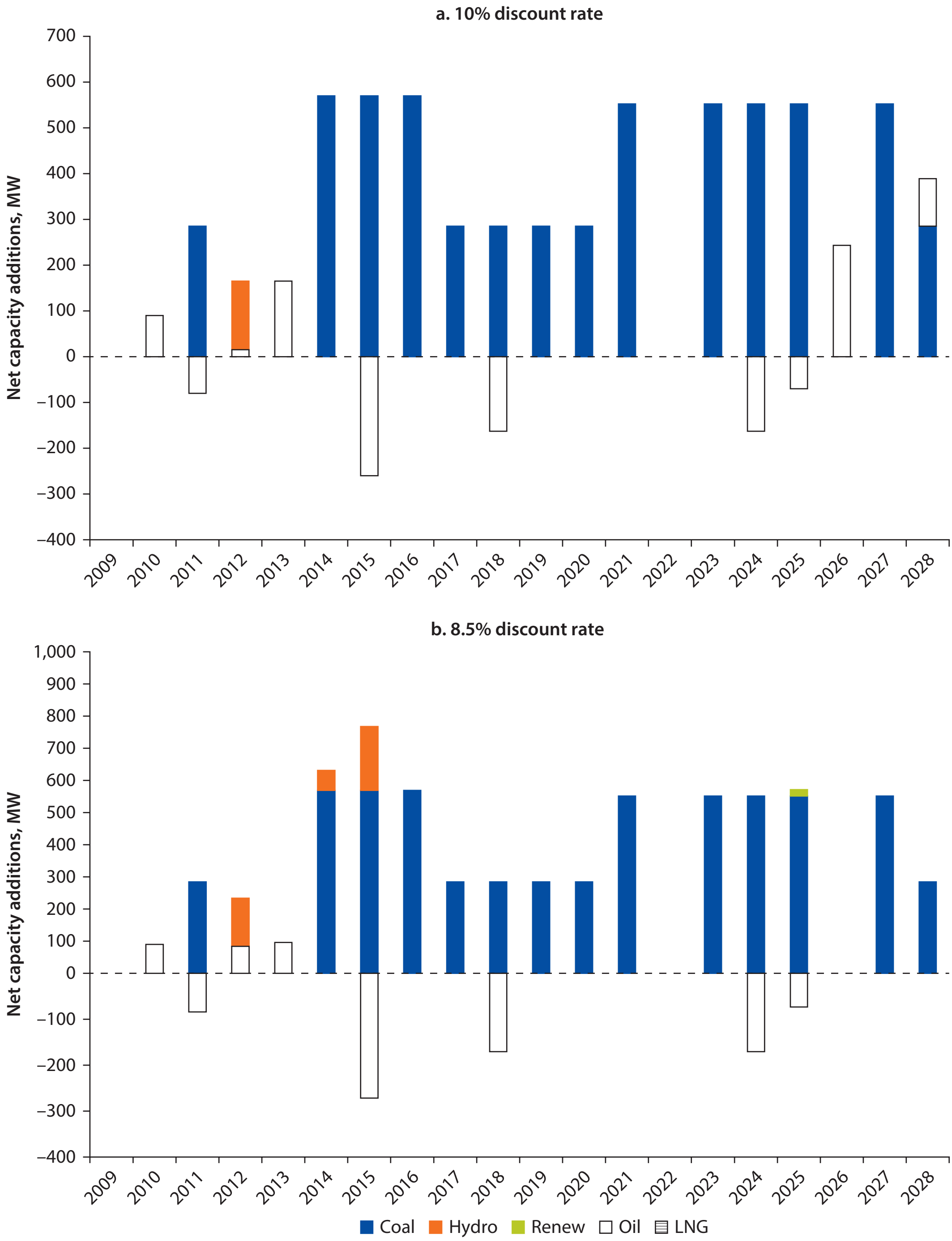
of capital (WACC) for private sector companies. If one argues that the optimal quantity of RE is given by the intersection of the RE supply curve with the avoided social cost of thermal generation (that is, including the cost of externalities), the same discount rate should be used for both sets of calculations. If the discount rate used in the least-cost expansion plan is 10 percent, one cannot justify a comparison with an RE option whose levelized costs are calculated on the basis of a 6 percent discount rate.

Low discount rates should be used with caution, and should not be used merely as a substitute for attempting quantification of environmental impacts. At the same time, they do need country-by-country scrutiny. For example, almost every country that uses formal capacity expansion planning models (such as WASP or EGEAS) use 10–12 percent as the discount rate. At least in theory, the discount rate used for power sector planning should reflect the Government's actual opportunity cost of capital (OCC)—which may or may not be 10–12 percent as is often assumed.

That such a rate is not always appropriate is illustrated by the recent example of the economic analysis for the proposed Noor II & III concentrated solar power (CSP) projects in Morocco (World Bank 2014), where the state-owned Morocco power utility ONEE has long used 10 percent (real) for its discount rate in its least-cost planning studies. One measure of the Government's actual OCC is the cost of recent bond issues in foreign currency,[9] for which a nominal rate of 6 percent would be reasonable.[10] Given an inflation assumption of 2 percent (for both Morocco inflation and trade-weighted FOREX), the corresponding real rate would be 4 percent. Now it might be argued that *additional* $2 billion bond issue earmarked expressly for CSP would require a somewhat higher coupon rate, a reasonable assumption for the real discount rate used for economic analysis would be 5 percent. That is significantly lower than the standard 10 percent assumption, and has a correspondingly large impact on the results. The main lesson here is simply that an economic analysis needs to examine a range of discount rates.

Figure 2.7 illustrates the impact of the discount rate on Sri Lanka's capacity expansion plan. Much as expected, at the lower discount rate of 8.5 percent, the

Figure 2.7 The Impact of a Discount Rate on an Optimal Capacity Expansion Plan: Sri Lanka



Source: World Bank 2010a.
Note: Negative numbers indicate retirements. LNG = liquefied natural gas; MW = megawatts.

planning model chooses to build additional medium-scale hydro projects in 2014 and 2015, reducing the need for additional combustion turbine capacity. In the later years of the planning horizon, the model builds additional coal capacity, rather than the combustion turbines built in the reference case using a 10 percent discount rate.

The Social Cost of Carbon

In economic analysis, the relevant global environmental premium is not the financial revenue that may be obtained from the sale of carbon credit on global carbon markets, but the global *social* cost of carbon (SCC) that reflects the actual damage costs of increasing atmospheric concentrations of greenhouse gases (GHGs).

The literature on the SCC is growing, with estimates ranging from a small net *benefit* to costs of several hundred dollars a ton. Thus almost any estimate would find some support. Tol's (2008) meta-analysis of peer-reviewed literature—which updated an earlier 2005 meta-analysis (Tol 2005)—cites 211 studies, and finds an average estimate of $120/ton carbon ($33/ton CO_2) for studies published in 1996–2001, and $88/ton carbon ($24/ton CO_2) for studies published since 2001. Tol concludes in the 2005 study that "it is unlikely that the marginal damage costs of emissions exceeds $50/ton carbon ($14/ ton CO_2) and are likely to be substantially lower than that."

Much of the economics literature on the subject is highly technical, particularly with respect to the choice of discount rate and assumptions about future global economic growth and income inequalities: in general one can say that the lower the discount rate, the higher the SCC (a value that may also change over time). The high valuation given in a report by Stern (2007) ("the current SCC might be around $85/ton CO_2") is largely a consequence of the use of a very low discount rate.[11] A 2007 Intergovernmental Panel on Climate Change (IPCC) report highlighted the wide range of SCC estimates, given in the literature as $4–$95/ton CO_2. In the United States, regulatory impact analysis requires consideration of the SCC[12] using a range of discount rates (from 2.5 percent to 5 percent), with carbon values that increase over time. For example, at a 5 percent discount rate the valuation is $12/ton in 2015, rising to $27/ton by 2050; at a 2.5 percent discount rate the valuation rises from $58/ton to 98$/ton by 2050. In the United Kingdom the Department of Environment recommended, in 2007, a value of £25/ton ($37/ton) CO_2[13]; this was subsequently updated to a time-dependent system ranging from £23/ton CO_2 in 2015 rising to £48/ton by 2025 ($36–$76/ton CO_2).

The World Bank—like other international financial institutions (IFIs), such as the Asian Development Bank (ADB) and African Development Bank AfDB)—does not publish an official estimate of the value of the SCC to be used in economic analysis. In the typical economic analysis of RE projects, recent practice has been to calculate the economic rate of return (ERR) with and without consideration of GHG emissions. The choice of valuation is left to the economist assigned the task of estimating the economic returns (table 2.7).

The approach taken in this study is not to choose any particular value for the SCC, but to calculate the *avoided cost of carbon* associated with a particular RE option. This is the value of CO_2 that makes the cost of an RE project exactly equal to the least-cost thermal alternative. What is particularly important about such calculations is that they *only* have meaning relative to the option against which the RE is being compared. For example, in South Africa, where concentrated solar power (CSP) would be compared to coal (which has a high GHG emission factor), the avoided cost of carbon for CSP is much lower than in Egypt, where the comparison is with natural gas, whose emission factor per net kilowatt-hour (in a highly efficient CCGT) is just one-third that of coal (table 2.8).

In this report the calculations presented for the avoided cost of GHG emissions are based on discounted GHG emissions (using the same rate as costs and benefits are discounted): in this definition, the avoided cost, in $/ton, is defined as the value that must be given to a ton of avoided GHG emissions (i.e., a benefit)

Table 2.7 Carbon Valuations in World Bank Studies and Project Appraisals

Country	*$/ton CO_2*		*Reference*
India	32		Sargsyan and others 2011
Indonesia	30	Geothermal project appraisal	PAD
Vietnam	30	Trung Son hydro project	PAD
Egypt, Arab Rep.	5–50	Wind Power Development Project	PAD
South Africa	29	Medupi coal project	PAD
Morocco	30	Ourzazate I CSP	PAD
Central Asia	13–43	CASA-1,000 transmission project	PAD
EEA	44		
IPCC	4–95		

Note: EEA = European Environment Agency; ton CO_2 = ton of carbon dioxide; PAD = Project Appraisal Document (of the World Bank); CASA-1000 = HVDC transmission project to export summer hydro surplus from the Kyrgyz Republic and Tajikistan to Afghanistan and Pakistan.

Table 2.8 The Avoided Cost of Carbon for Concentrated Solar Power

Country	*Technology*	*Production cost, cents/kWh*	*Carbon shadow price, $/ton CO_2*
South Africa	Medupi coal = least cost	5.8	0
	CSP no storage, 25% LF	14.8	115
	CSP storage, 40% LF	17.0	143
	CSP storage Eskom estimate	17.9	155
Egypt, Arab Rep.	Kom Ombo (1) (against Gas CCGT)	—	267

Source: South Africa: World Bank 2010b, 2013.
Note: CSP = concentrated solar power; CCGT = combined-cycle gas turbine; CO_2 = carbon dioxide; Eskom = Electricity Supply Commission of South Africa; kWh = kilowatt-hours; LF = load factor; ton CO_2 = ton of carbon dioxide; — = not available.
(1) see chapter 8 for a detailed discussion of the Kom Ombo project.

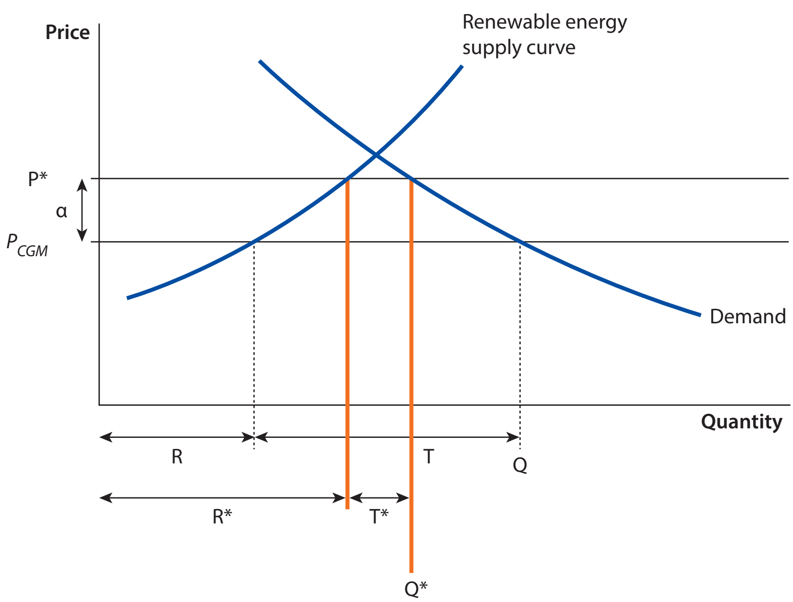
to bring the incremental costs of a RE option to the hurdle rate. It could also be termed the *switching value* as used in sensitivity analysis and risk assessment. Note that this differs to the term "marginal abatement cost" of GHG as used by the CTF and GEF, in which the net present value of costs and benefits (at the discount rate used) is divided by the undiscounted lifetime GHG emissions (i.e., assuming a zero discount rate). In general one should avoid arithmetic operations on quantities based on different discount rates. The calculation based on undiscounted emissions will typically be 50–60 percent lower than in the switching value definition.[14]

Fossil-Fuel Price Subsidies

The impact of fuel subsidies is readily illustrated. Consider figure 2.8, which shows the demand for electricity, the RE supply curve, and the price of thermal energy in a competitive generation market, P_{CGM}, assuming that the coal price is subsidized in the amount α. The quantity consumed at this price, Q, is given by the intersection of the demand curve with P_{CGM}. The quantity of renewables will be R (namely that quantity whose production cost is less than P_{CGM}), and the balance will be fossil generation, T ($R + T =$ Q).

Now suppose that the subsidy on domestic coal is removed, which increases the price to P^*. At this higher price, the demand curve intersects at Q*. More RE will be economic at the higher price P^*, and the quantity of fossil energy reduces to T^* ($R^* + T^* =$ Q*).

Figure 2.8 Impact of Coal Price Subsidies



Thus there are three important consequences of reducing the subsidy on coal:

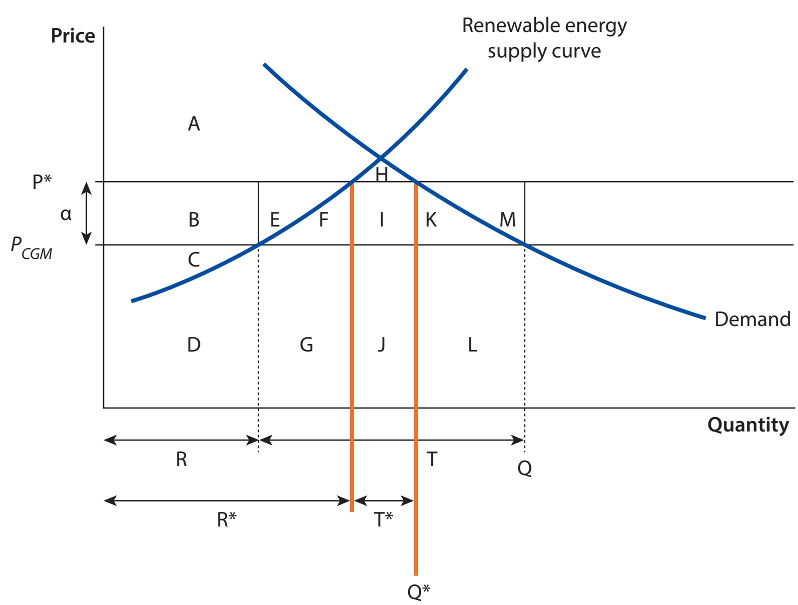
- Less electricity is consumed.
- The amount of fossil energy, and hence GHG emissions, is reduced.
- The amount of RE increases.

It is easily shown (in box 2.2) that both social and global welfare increases as a result of the elimination of the subsidy: the reduction in fossil-fuel subsidies is a win-win.

The International Energy Agency (IEA 2012) Energy Outlook[15] estimates subsidies on energy consumption in the largest countries outside the Organisation for Economic Co-operation and Development (OECD) at $523 billion in 2011—almost $110 billion higher than in 2010, based on the IEA's price-gap methodology (figure 2.9). This applies to several of this report's case study countries (Egypt, Vietnam, Indonesia, South Africa, and Brazil). Most countries

Box 2.2 The Welfare Impacts of Fuel Subsidies

The cost of a fuel subsidy to a government is ***Tα***, equal to the area ***E + F + I + K + M***. At the subsidized level of consumption ***Q***, consumers enjoy a net benefit equal to the area under the supply curve less their cost, the so-called consumer surplus, equal to the area ***A + B + E + F + I + H + K***. RE producers enjoy the producer surplus **C**. And GHG emissions are ***Tα*** where ***α*** is the relevant emission factor.



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Box 2.2 The Welfare Impacts of Fuel Subsidies *(continued)*

Once the subsidy is eliminated, the government benefits by the amount of that subsidy. The consumer surplus shrinks to ***A* + *H***, but RE producers increase their surplus to ***C* + *B* + *E***. So the balance of costs and benefits can be shown as in table B2.2.1.

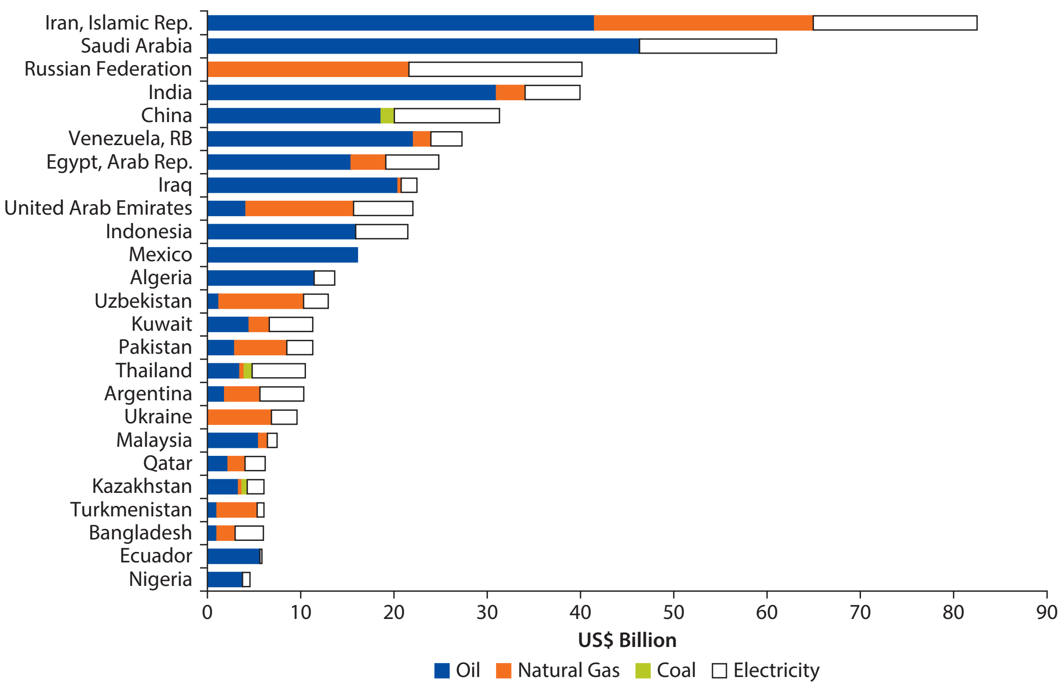
In other words, society gains (because the cost of the subsidy *exceeds* the increase in consumer surplus enjoyed under the subsidy), *and* the global environment gains (because there is less fossil generation).

Table B2.2.1 The Welfare Impact of Subsidy Removal

	With subsidy	*No subsidy*	*Net impact*
Government (subsidy cost)	−E − F − I − K − M	0	+E + F + I + K + M
Consumers	+A + B+ E + F + H + I + K	A + H	−B − E − F − I − K
RE producers	+C	C + B + E	+B + E
Society	A + B + C + H − M	A + B + C + B + E + H	+E + M
Global environment	Tα	T*α	α(T − T)

Note: RE = renewable energy.

Figure 2.9 Energy Subsidies, by Fuel, in Non-OECD Countries



Source: IEA 2012.
Note: OECD = Organisation for Economic Co-operation and Development.

have declared policies to eliminate these subsidies, but implementation is almost always slower than the announced schedule, for sudden removal of subsidies often has significant political repercussions. Vietnam is a case in point: notwithstanding the declared intention of removing subsidies for fuels used in power generation, and the commitment to market principles declared in the Electricity Law, both domestic coal and natural gas prices for power generation remain subsidized.[16]

Renewable Energy and Employment

A widely cited benefit of RE is employment creation.[17] But assessment of the benefits of increased employment requires caution. Economic analysis normally treats the cost of labor as an *input*, not as an output. A highly labor-intensive biomass technology may create local employment, but if the economic costs of the biomass project are above the avoided social costs, then employment in the economy as a whole may fall (because if households spend more on electricity, they will spend less on other goods and services).

The argument that RE development will create "green jobs" is frequently heard in the United States, European countries, and some developing countries (such as China). Generalizations from limited country experience, mainly in RE equipment manufacturing in the OECD countries, are no substitute for careful country-specific analysis; more research is needed to better understand the issue of green jobs.

The large employment benefits noted in such countries are a consequence of RE technology manufacture, particularly in countries that manufacture and export equipment, such as Spain and Denmark in the case of wind power (see box 2.3). So the question is: what is the extent to which these job gains apply to countries that do not have domestic manufacturing capacity for renewable generating equipment or reasonable prospects for doing so?

Another question that needs to be answered is whether such studies on the job creation benefits of RE also include the loss of jobs in those energy industries that are displaced by the RE. In countries where there are large benefits from RE replacing coal, more RE could mean fewer coal miners, and lower employment in factories that manufacture gas turbines and coal-fired steam generators.

Within this context it is important to build a methodology to (a) contribute to a better understanding of the main effects/mechanisms to depict employment impacts and (b) provide a clear definition of gross impact studies (sectoral) and net impact studies (economy wide). Even if some comparisons indicate that RE and energy efficiency projects generated more employment than fossil fuels, such comparisons fail to consider both the costs of delivery of equal outputs using different fuel mixes and the cost of public funds. Such simplifying assumptions may lead to misleading estimates. First, the lack of evidence on the cost of using alternative energy sources to generate the same

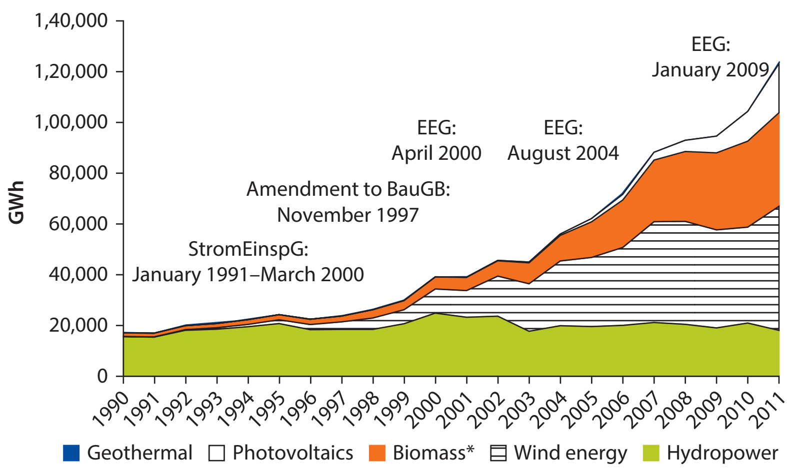
Box 2.3 Lessons Learned from the German *Energiewende* (Energy Transition)

The ideas presented in a book titled *Energiewende* (Energy Transition) by Öko-Institut Freiburg found fertile soil in 1980 in Germany, in the context of anti-nuclear protests, two oil crises, fears of acid rain, and the emerging climate-change problem. It made the case for a change—a transition from fossil fuels over to renewables and energy efficiency. This thinking inspired the Erneuerbare-Energien-Gesetz (EEG or the Renewable Energy Sources Act) of 2000 and its 2004 amendment. Both were adopted by Social Democratic-Green parliamentary groups against intense Conservative-Liberal opposition that came back to power in 2009. In the meantime, the EEG had a strong impact: (a) it was highly effective in stimulating RE with growth and investment, increasing new renewable energy (RE) output (other than hydro) by a factor of five from 2000 to 2011 (see figure B2.3.1); (b) it created a strong wind power, biomass, and photovoltaic (PV) industry, which generated new employment for about 365,000 persons by 2012 (see figure 2.3.2, panel b); and (c) over 50 percent of new RE generation capacity is owned by private persons and farmers (see figure B2.3.2, panel b). All utilities together own from 2 percent to 7 percent (PV, wind)—only for hydro does this go up to 90 percent (see figure B2.3.2, panel a).

There were three Conservative-Liberal attempts to slow down Energiewende in 2010, by scrapping the nuclear phase-out (a bridge technology for renewables), planning caps and steeper degressions for RE, and introducing a flexible cap for PV energy to limit new PV installations to 3 GW per year. In 2012 a plan for new, more drastic caps on PV and other technologies was implemented, and in 2013 there was a proposal to cap the EEG surcharge. From the Conservative-Liberal perspective several emerging issues needed to be addressed. First, the extraordinary deployment of PV since 2009, which surpassed all expectations and cost estimates; the dramatic increase in the EEG surcharge from €1.3 to

Figure B2.3.1 Development of Renewables-Based Electricity Generation and Investment

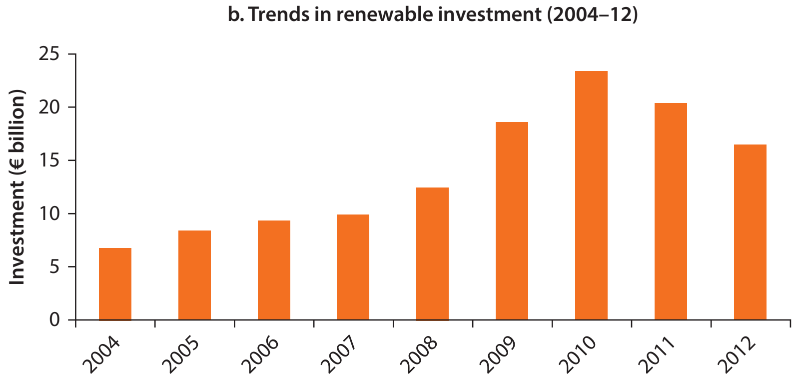
a. Trends in renewable-based generation (1990–2011)



box continues next page

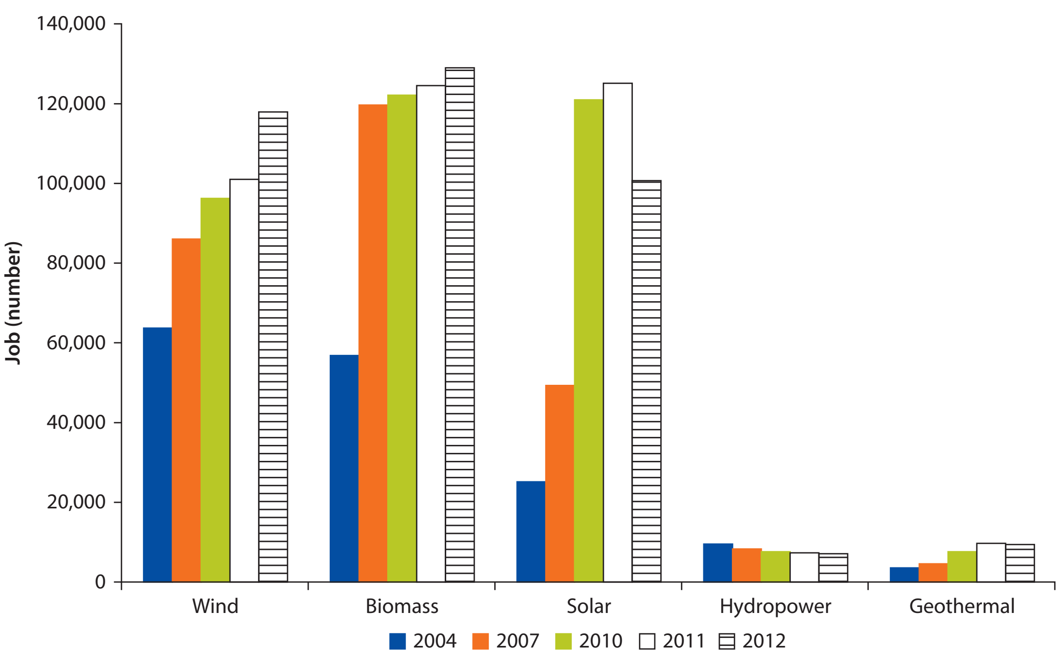
Box 2.3 Lessons Learned from the German Energiewende (Energy Transition) *(continued)*

Figure B2.3.1 Development of Renewables-Based Electricity Generation and Investment *(continued)*



Note: EEG = Renewable Energy Sources Act; GWh = gigawatt-hour.

Figure B2.3.2 Development of Renewables-Based Jobs and Ownership, 2012



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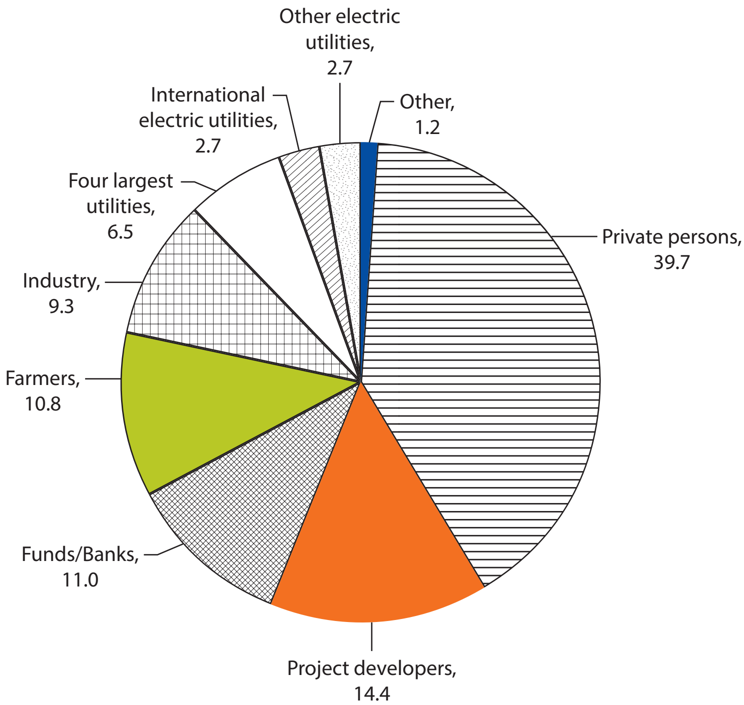
Box 2.3 Lessons Learned from the German Energiewende (Energy Transition) *(continued)*

Figure B2.3.2 Development of Renewables-Based Jobs and Ownership, 2012
(continued)



€5.28 cents from 2009 to 2013; an "imminent" grid congestion from PV and wind technologies; damage to profitability of needed fossil-fuel generation due to the priority dispatch for RE, which implies that hard coal and gas plants lose lucrative operating hours (the noon peak demand is now increasingly covered by PV); and gas generation being affected by cheap coal due to low U.S. shale gas and Emission Trading System (ETS) prices.

Source: Lauber 2013.

output may lead to overestimating the net benefits of job creation by RE and energy efficiency projects (relative to fossil-fuel projects), by not including their cost. A rigorous methodology should first differentiate and illustrate trade-offs among (a) local, regional, and national impacts and (b) short- and long-run impacts. Second, it should illustrate the extent to which classic economic project analysis does not adequately reflect the employment-creation objectives of the government. Third, it must capture distributional impacts (since subsidies to cover incremental costs of RE may have very different beneficiaries) and employment-related externalities. Fourth, it might compare, where possible, alternative projects based on equivalent output and cost between

(a) renewable-energy and energy-efficiency projects and (b) fossil-fuel projects. To our best knowledge, no study reviewed to date compares projects costing the same amount (or producing the same output) along both employment and cost metrics.

Of course, it is perfectly valid for governments to stimulate employment in disadvantaged areas of a country, even at the cost of lower employment in richer urban areas, if this is viewed in the context of social equity. But an important distinction might be noted: promoting employment in specific regions reflects the ***equity*** objective of the government, and not the economic-efficiency objective.

The correct approach for economic analysis is to shadow-price labor costs.[18] For example, the economic cost (or the *opportunity* cost) of employing otherwise unemployed rural workers is zero—and different to the actual wage rate that would be used in the financial analysis. But few RE projects will have much need for unskilled labor, whether during construction, or during operation (when unskilled labor, at best, would extend to the security staff at a wind farm or a CSP project).

Specific Questions for the Case Studies

The analytical framework requires that the effectiveness of incentive mechanisms be assessed and compared by a set of rational criteria, as follows:

- *Economic efficiency*. How close is an RE support tariff to the avoided social cost of thermal energy (which for developing countries means economic cost + avoided local externalities)? How close is the target quantity to the economic optimum (intersection of the economic supply curve with the avoided social cost of thermal energy)?
- *Market principles.* Does the design require the application of market principles? An auction meets this criterion perfectly (provided there are safeguards against collusion and abuses). Access to a subsidy on the basis of first come, first served, or "all come" (as in Germany's feed-in tariff, FIT) does not meet market principles (and constitutes the worst possible way of providing access to support).
- *Transparency.* Is the methodology of preferential pricing published? Can developers and their lenders come to their own conclusions about the future evolution of the tariff level? Does the mechanism provide for adjustment to changes in the law?
- *Sustainable recovery of incremental costs.* Are the incremental costs known? (In a surprising number of cases they are not!) Is the mechanism for recovery of these costs sustainable (that is, is the mechanism for raising the necessary funds, and for disbursing them, seen as credible by developers and their lenders)?
- *Adaptability.* Is there a predictable mechanism for updating the tariff and adjusting it for external changes (changes in technology costs, changes in tax rates, changes in fossil energy prices in the case of ACTs)?

The evaluation of the policy framework should similarly follow a set of rational criteria:

- *Targets.* Are the targets set as political statements, or on the basis of a rational economic analysis (supply curve methodology, or affordability)? Are targets reasonably achievable, and are they in harmony with the support measures necessary to achieve them? In the case of renewable portfolio standards (RPSs) and mandatory renewable shares, are the penalties for not meeting them reasonable?
- *Energy subsidies.* How does the additional quantity of RE—made economic by reducing fossil-fuel subsidies—compare with the quantity of RE to be supported by RE incentives? How does the quantity of thermal energy that would not be required if retail tariff subsidies were eliminated compare with the quantity of RE supported by targeted RE incentives?

Methodology

For each of the case study countries, the following set of calculations will be presented:

- From the current least-cost power sector development plan, the expected generation mix for 2020, the generation shares and gigawatt-hours of each major fuel and technology, and the gigawatt-hours of retail sales.
- Estimate of the consequences if 1 percent of generation were replaced by RE. What would be replaced is the most expensive of the thermal generation, by some RE whose tariff could be calculated to provide the developer with a target financial internal rate of return (FIRR) based on typical commercial lending rates. This allows a calculation of the total financial incremental costs—and the impact on consumers were this amount to be recovered from them.
- An estimate of the tariff (and incremental cost) decrease prompted by the various incentives listed in table 1.1 (taxonomy of incentives): a clean development mechanism (CDM), carbon finance, subsidized loans from government-owned development banks, tax incentives, and so on.
- A comparison of the impact on the consumer from reducing any fossil-fuel subsidies. Reducing fossil-fuel subsidies would increase the generation cost passed to the consumer, for which there is also a GHG emission reduction benefit. How does this compare with the cost to the consumer if the consumer is charged with a levy to recover RE generation costs?
- Finally, a comparison of the residual incremental cost, as may need to be covered from the direct government budget, with government spending on education and health (or some other appropriate indicator of spending for poverty alleviation). This question is core, as developing country governments are reluctant to incur the incremental cost of RE in the face of the overriding objectives of poverty alleviation and economic growth.

Notes

1. Gas delivered to the Ca Mau CCGT project in Vietnam is indexed to the Singapore fuel oil price.
2. Particulate matter (no greater than 10 microns in diameter).
3. Sulphur oxides.
4. Nitrogen oxides.
5. The additional quantity Q_{BAU} is the much lower quantity of renewable energy likely to be implemented in the absence of explicit RE policy, due mainly to institutional and regulatory constraints (such as problems in negotiating PPAs, obtaining permits, and obstacles imposed by utility buyers who have traditionally opposed the emergence of IPPs for fear of losing market share).
6. VSL (value of statistical life) is used in most U.S. and European studies as a basis for mortality and is based on contingent valuation methods typical in American accident liability lawsuits. Most development economists argue that valuations based on YOLL (years of life lost) are more appropriate for the premature mortality typically associated with pollution-aggravated respiratory diseases.
7. The damage cost of $1,333/ton NO_X is consistent with the $473/ton (at 2002 prices) cited in the Bank's 2003 Energy/Environmental Review (though the derivation of that estimate is unclear) (World Bank/EEAA 2003).
8. For example, a study on wind energy in Vietnam (Global Green Energy 2004) argues that "OECD uses a discount rate of 6 percent as standard, thereby justifying a 7 percent rate" (rather than the 10 percent actually used by the Government of Vietnam).
9. In the case of an open economy, capital can be considered a tradable good, and the EOCC will be the world supply price of capital (U.S. treasuries, or long term LIBOR plus some country specific risk premium). Many developing countries now have domestic bond markets which can provide further information.
10. Morocco issued $500 million, 30-year 144a/Regulation S bonds in December 2012 at a coupon of 5.5 percent. The issue was reopened in May 2013 to increase the issue to $750 million for a tap of 237.5 basis points over U.S. Treasuries, and is currently trading at a discount. As such, a nominal discount rate of 6 percent for modeling purposes seems reasonable.
11. For a good discussion of these issues, and a review of the assumptions in the Stern Review, see, for example, Hope and Newbery (2007). See also Grubb, Jamasb, and Pollitt (2008).
12. Interagency Working Group, *Technical Update of the Social Cost of Carbon (SCC) for Regulatory Impact Analysis under Executive Order 12866*, May 2013.
13. DEFRA, *The SCC and the Shadow Price of Carbon*, December 2007; Department of Energy and Climate Change, *Carbon Appraisal in UK Policy Appraisal: A Revised Approach: A Brief Guide to the New Carbon Values and their Use in Economic Appraisal.*
14. The rationale for *not* discounting GHG emissions is that it is the cumulative stock of GHG emissions in the atmosphere that matters, not the time at which it is emitted. However, there is an emerging consensus that the economic benefit of a ton of avoided GHG emissions *increases* over time as the concentration of atmospheric GHGs reaches the tipping point (recall the discussion of SCC, above, and the valuations being used by the U.S. Interagency Working Group on the SCC, and others).
15. The subject first received detailed analysis by the IEA in 1999 (IEA 1999).

16. Whether the use of subsidized fuel prices also distorts power sector investment decisions is unclear. An assessment of the use of financial prices rather than economic prices in Vietnam's Sixth Power Development Plan found little impact on the optimal capacity mix as proposed by the plan (Economic Consulting Associates 2006).
17. An argument made, for example, by Kammen, Nozafari, and Prull (2012).
18. A related problem is the extent to which the cost of accidents and deaths to coal miners should be separately considered as an additional externality and added to the social cost of coal generation (as are included, for example, in the South African damage cost estimates of table 2.1). In economic theory higher occupational health hazards should be reflected in higher wage rates for miners, compared to other potential occupations that experience lower rates of occupational mortality, and hence do not classify as an externality. But this would be true only in a perfectly competitive and mobile labor market. For example, whether miners in the mining areas of northern Vietnam have real alternative employment opportunities (whether in the mining areas or elsewhere in Vietnam) may be debated.

Bibliography

Economic Consulting Associates. 2006. *Economic Chapter of Power Sector Masterplan No.6*. Report to the World Bank, Washington, DC, January.

Edkins, M., H. Winkler, A. Marquard, and R. Spalding-Fecher. 2010. *External Cost of Electricity Generation, Contribution to the Integrated Resource Plan 2 for Electricity*. Report to the Department of Environment and Water Affairs, Energy Research Centre, University of Cape Town, South Africa.

EEA (European Environment Agency). 2011. *Revealing the Costs of Air Pollution from Industrial Facilities in Europe*. Report EEA Technical Report 12/2011, Copenhagen, Denmark.

Global Green Energy. 2004. *Wind Farm Development in Vietnam, Prefeasibility Study: Developing Commercial Wind Energy Projects in Vietnam*. New York, USA: Global Green Energy.

Grubb, M., T. Jamasb, and M. G. Pollitt, eds. 2008. *Delivering a Low Carbon Electricity System: Technologies, Economics and Policy*. Cambridge, U.K.: Cambridge University Press.

Hope, C., and D. Newbery. 2007. *Calculating the Social Cost of Carbon*. Cambridge University Electricity Policy Research Group, Cambridge, U.K.

IEA (International Energy Agency). 1999. *Insights, World Energy Outlook: Looking at Energy Subsidies: Getting the Price Right*. Paris: IEA.

———. 2012. *World Energy Outlook 2012*. Paris: IEA.

Kammen, D., M. Nozafari, and D. Prull. 2012. *Sustainable Energy Options for Kosovo*. Renewable & Appropriate Energy Laboratory Energy & Resources Group, University of California, Berkeley.

Lauber, V. 2013. "Can Germany's Energiewende Still Be Slowed Down?" Presentation made at 8th IEWT, Tech. Univ. Vienna, Vienna, Austria, February.

Lvovsky, K., G. Hughes, D. Maddison, B. Ostrop, and D. Pearce. 2000. "Environmental Costs of Fossil Fuels: A Rapid Assessment Method with Application to Six Cities." Environment Department Paper 78, World Bank, Washington, DC.

Sargsyan, G., M. Bhatia, G. Banerjee, K. S. Raghunathan, and R. Soni. 2011. *Unleashing the Potential of Renewable Energy in India*. Washington, DC: World Bank.

Spencer, R., P. Meier, and N. Berrah. 2007. *Scaling Up Renewable Energy in China: Economic Modelling Method and Application*. Energy Sector Management Assistance Program (World Bank) (ESMAP) Knowledge Exchange Series #11, June, Washington, DC.

Stern, N. 2007. *The Economics of Climate Change: The Stern Review*. Cambridge, U.K.: Cambridge University Press.

Tol, R. 2005. "The Marginal Damage Costs of Carbon Dioxide Emissions: An Assessment of the Uncertainties." *Energy Policy* 33: 2064–74.

———. 2008. "The Social Cost of Carbon: Trends, Outliers and Catastrophes." *Economics e-Journal* 2: 2008–25.

World Bank. 2005. *Economic Analysis for the China Renewable Energy Scale-Up Programme (CRESP)*. Washington, DC: World Bank.

———. 2010a. *Sri Lanka, Environmental Issues in the Power Sector*. Washington, DC: World Bank.

———. 2010b. *Medupi Economic Analysis Background Report*. Washington, DC: World Bank.

———. 2013. *Kom Ombo CSP: Economic and Financial Analysis*. Washington, DC.

———. 2014. *Noor II and III Concentrated Solar Power Projects.* Project Appraisal Document. Washington, DC.

World Bank/EEAA. 2003. *Egypt: Energy/Environmental Review*. Report prepared by ERM, April, Washington, DC: World Bank.