CHAPTER 1. RENEWABLE ENERGY OVERVIEW

What are “Renewable Resources”?

The term “renewable” is generally applied to those energy resources and technologies whose common characteristic is that they are non-depletable or naturally replenishable.

Renewable resources include solar energy, wind, falling water, the heat of the earth (geothermal), plant materials (biomass), waves, ocean currents, temperature differences in the oceans and the energy of the tides. Renewable energy technologies produce power, heat or mechanical energy by converting those resources either to electricity or to motive power. The policy maker concerned with development of the national grid system will focus on those resources that have established themselves commercially and are cost effective for on-grid applications. Such commercial technologies include hydroelectric power, solar energy, fuels derived from biomass, wind energy and geothermal energy. Wave, ocean current, ocean thermal and other technologies that are in the research or early commercial stage, as well as non-electric renewable energy technologies, such as solar water heaters and geothermal heat pumps, are also based on renewable resources, but outside the scope of this *Manual.*

For the purposes of establishing a legal regime governing and encouraging private-sector investment in renewable resources and technologies, the policy strategist will make use of three conceptual approaches. As well as the foregoing **technical** definition, both **political** definitions and **legal** definitions, factor into a policy definition of what resources deserve discrete treatment as “renewable resources”.

Broadly define “Renewable Resources, then clarify that definition by defining each specific renewable resource (***e.g., “‘geothermal energy’ means the heat of the earth.”***)

From the political perspective, renewable energy resources can be divided into numerous categories depending upon the political goals or objectives under consideration. For example, in a given country, renewable resources may be distinguished by categorizing those which are well established versus those which are underdeveloped; those which have immediate development potential versus those which do not; and those with potential rural versus those with urban customer bases. The political perspective of the policy maker in one country may be to justify different treatment for established resources such as large hydroelectric from nascent resources such as geothermal. In another country, the reverse may be true. Likewise, all of the renewable resources may be treated differently for urban application than for rural application.

Avoid operational definitions. For example, if different types of hydropower are to be treated differently for political or legal reasons, address such treatment in operational language, not by definition.

From the legal perspective, existing laws such as land use, water, mining, and hydrocarbon laws need to be scrutinized to determine their potential jurisdiction over and applicability to renewable resources. It is important to define what technologies are to be considered "renewable" for the purposes of any piece of legislation. Such legislation can define "renewable resources" as appropriate, given the state of development of the natural resources in that country. If a court, legislator or executive interprets a law strictly, the term "renewable resources" as used in a piece of legislation means what that specific piece of legislation says it means, but only for the purposes of that specific legislation. Thus, if a law defines coal as "renewable", but omits wind, this legal definition will prevail without reference to the technical characteristics of either fuel. In most legal regimes, however, the term "renewable energy" is used to distinguish naturally replenishable fuels from those fuels of which the earth is endowed with fixed stocks. The main examples of stock-limited resources are the fossil fuels (principally coal, petroleum, natural gas, tar sands and oil shales) and the nuclear fuels (principally uranium, thorium, deuterium and lithium).

Can all Renewables be governed by a common policy?

Policy makers should be cognizant of the similarities as well as the variations among renewable energy resources.

From the perspective of the policy strategist, it may be important to determine whether and to what extent energy plans, laws and regulations may be developed using the generic concept "renewable resources":

- *Are the differences among the renewable resources and their applications such that legislation may properly address renewable resources technology by technology?*

- *Are there sufficient commonalities that renewable resource development may be handled as a generic issue?*

The commercial renewable energy technologies

Establish an objective, specific to each renewable resource, which is designed to achieve national goals.

Fundamentally, the answer depends on why the question is being asked, and in which country the policy is being applied. There are, however, guidelines which may prove useful to policy strategists making this determination in any country. Essentially, **form must follow function.** In other words, it is essential that the policy strategist understand the nature of each of the renewable resources and the nature of the process by which each of those resources is developed.

The resources are fundamentally different. Although any resource that relies on the heat or motion of the earth, the moon or the sun (or the sun's radiation) to produce power for human consumption is a renewable resource, the ways one harnesses the resources are sufficiently different that laws and regulations governing these resources usually deal with each resource on an individual basis - treating each resource as unique. At present, the major commercial grid-connected renewable resources are hydroelectric, geothermal, biomass, wind energy and solar. In the majority of legal regimes, hydroelectric and geothermal resources are identified as owned in common by the people of the country and husbanded by the government for their benefit.

- ***Geothermal resources*** require extraction (and reinjection). Drilling for geothermal resources involves many of the same discrete considerations involved with drilling for petroleum (hydrocarbons) and individual treatment is prudent.

  Geothermal resources

- ***Hydroelectric resources*** are inextricably linked with surface water rights, including potable water, navigation, irrigation, navigation and recreational rights. The historical complexities of sorting out these juxtaposed rights usually dictate individual treatment of hydroelectric resource issues.

  Hydroelectric resources

- ***Wind energy and solar*** draw on resources - wind and sun energy - generally thought of as being free for the taking. The principal resource issue with both of these renewables is surface land. Therefore there is no general technical requirement for individual treatment.

  Wind energy and solar

- ***Biomass*** is a broadly inclusive term, often encompassing wood and wood waste, agricultural waste and residue, energy crops, and - sometimes - landfill gas resources. Resource availability and cost can be highly variable, and resources may require management of a type not frequently required for other renewables. Individual treatment is one method of addressing this complication.

  Biomass

What are the renewable energy applications?

Renewable energy applications generally break down into two categories or applications, ***"on-grid"*** and ***"off-grid".***

- A ***"grid"*** may be defined as an integrated generation, transmission, and distribution system serving numerous customers. Characteristically, a grid is a portfolio of generating units operating under the control of a central dispatch center. Grids may be national, regional or local (in the latter case they are typically referred to as *"mini-grids"*).

- ***"On-grid"*** and ***"off-grid"*** are terms which describe how electricity is delivered. Technically, every one of the commercial renewable resources can be and have been installed both on-grid and off-grid. Furthermore, although larger megawatt installations tend to be on-grid, large renewable plants may profitably be built *"inside the fence" - a* term describing a self-generator, a plant built to supply a single customer such as a mine, a manufacturing plant or an agribusiness. Hydroelectric, biomass and geothermal facilities tend to be economical at capacity levels well in excess of one megawatt (1 MW) and, therefore, are typically - but not necessarily - developed and financed as *"base load"* electricity resources (*i.e.,* the normally operated generating facilities within a utility system) and connected to a grid. Solar arrays and "wind farms" also can be grid-connected.

- ***"Off-grid"*** applications, in general, serve only one load, such as a home or small business. Off-grid applications can take many forms, from photovoltaics for an individual village home to centralized windmills to power a village water pump or a commercial battery charging facility. These off-grid applications are most generally used in remote or rural settings.

- ***"Mini-grids"*** have begun to be developed by system engineers over the past few years, for isolated communities. These systems may integrate wind, solar energy and, in some cases, diesel generators and/or storage systems to provide power from a mix of resources to more than one customer, typically a village or cooperative.

For more discussion of off-grid and mini-grid issues, see below, Chapter 5a (*Universal Electrification Policy: Renewable Technologies* & *Universal Electrification Efforts*). *The* *following charts illustrate common on-grid. and off-grid applications for which renewable energy is best suited.*

On-Grid Uses						
	Hydro	Wind	PV	Geo-thermal	Bio-mass	Solar thermal
Bulk Power	•	•	•	•	•	•
Grid support	•	•	•	•	•	•
Demand-side management	•	•	•	•	•	•
Distributed generation	•	•	•	•	•	•
Cogeneration				•	•	•

On-Grid Uses

• In addition to generating bulk electricity, the renewable energy technologies can serve a number of other valuable on-grid roles.

- For grid support, a power station is constructed somewhere along a transmission line to remedy high resistance in the line. This reduces transmission losses and prevents expensive substation equipment from being degraded by excessive heat (this application is a type of *"distributed generation"*).

- In distributed generation, as opposed to central station generation, power plants are smaller and they exist at more locations on the grid. This reduces transmission costs. Distributed generation tends to yield the largest returns in locations where it averts the need to increase transmission capacity.

- Biomass and geothermal are well-suited to regeneration.

• This table is not exhaustive. There are many other uses of each technology.

Off-Grid-Uses						
	Hydro	Wind	PV	Goo-thermal	Bid-mass	Solar thermal
Mini-grid power for village, island, industry, military, tourism, etc.	•	•	•	•	•	•
Individual systems for house, clinic school, store, more	•	•	•		•	•
Water pumping, water treatment	•	•	•		•	•
Unattended loads (e.g., telecom)	•	•	•	•		•
Space heating, water heating	•	•		•	•	•
Process heat, cogeneration				•	•	•

Off-Grid Uses

• This chart is not comprehensive, but lists some of the common off-grid applications for which renewable energy is best suited.

- Power and heat for remote villages, islands, tourist facilities, industrial and military installations, houses, clinics, schools, and stores.

- Water pumping, disinfection, and desalination.

- Communication stations, navigational aids, and road signals.

- For most types of energy applications, on-and off-grid, one or more of the renewable energy technologies is cost-competitive.

- Worldwide, millions upon millions of dollars are wasted by utilities, governments, businesses, and individuals that ignore opportunities to improve cost-effectiveness through the use of renewable energy.

- Energy decision-makers can improve their energy costs and performance by giving full and informed consideration to the renewable energy sources every time they choose an energy technology.

a. POLICY BENEFITS OF RENEWABLE ENERGY FACILITIES

Cost-benefit analysis is a generally accepted method of evaluating the value of competing energy sources.

Although a complete list of the benefits of renewable technologies can be very extensive, they can be categorized under four headings: environment, diversification, sustainability and economics.

Renewable resources are environmentally benign.

Renewable energy facilities generally have a very modest impact on their surrounding environment. The discharges of unwanted or unhealthy substances into the air, ground or water commonly associated with other forms of generation can be reduced significantly by deploying renewables. Clean technologies can also produce significant indirect economic benefits. For example, unlike fossil-fuel facilities, renewable facilities will not need to be fitted with scrubbing technology to mitigate air pollution, nor will a country need to expend resources in cleaning up polluted rivers or the earth around sites contaminated with fossil-fuel by-products. Furthermore, they provide greenhouse gas reduction benefits and should a worldwide market for air emission credits emerge as has been predicted, countries with a strong portfolio of renewable energy projects may be able to earn pollution credits which can be exchanged for hard currency. Finally, having a clean environmental profile enhances the attractiveness of renewable projects in the eyes of investors, especially the multilateral development agencies, many of whom operate under guidelines that require the promotion of non-polluting technologies.

Renewable resources promote energy diversification.

Development of a diverse portfolio of generation assets reduces both a country's dependence on any one particular form of technology or fuel and its vulnerability to supply disruption and price increases.

The primary long-term benefit of renewable technologies is that once a renewable project has been constructed, and fully depredated, it becomes a permanent, environmentally dean, and low cost component of a country's energy system. In effect, the construction of a renewable energy project provides future generations a low cost, energy facility that produces power with little or no environmental degradation.

Renewable resources are sustainable.

Renewable technologies are designed to run on a virtually inexhaustible or replenishable supply of natural "fuels." Expanding a nation's electricity supply by attracting investment to renewable energy projects is, by defintion, a strategy for sustainable growth, since operation of the facilities does not deplete the earth's finite resources.

Renewable energy facilities enhance the value of the overall resource base of a country by using the country's indigenous resources for electricity generation. Moreover, since these facilities operate on "fuels" that are both indigenous and renewable (as distinguished from imported fossil fuels), they may reduce balance-of-payment problems. Reduced dependence on fuel imports reduces exposure to currency fluctuations and fuel price volatility. The construction and operation of renewable projects normally generate significant local economic activity, often in previously “resource poor” areas of a country. Renewable energy projects thus act as engines for regional economic development. In the case of large scale, on-grid projects, easements will need to be purchased and local workers hired to construct and operate the facility. Frequently, a local industry such as a sugar mill or a paper mill (when biomass technology is employed) will be associated with the development, enhancing the opportunities for joint ventures between local landowners and private investors who may supply technological expertise. Smaller scale facilities often attract local private sector involvement. Local involvement, in turn, stimulates new economic activity in a multiplier effect and adds value to the local tax base.

***Appendix A** provides concise descriptions of renewable energy technologies, their applications and environmental impacts. Readers interested in gaining additional knowledge with respect to any of these technologies should also consult US/ECRE’s sponsoring trade associations, also set forth in **Appendix B** of the Manual.*

b. COST-EFFECTIVENESS OF RENEWABLE ENERGY

The ultimate question for the policy strategist is whether power generated from a renewable energy source is affordable given the service it is providing.

Universally, the goal of electric power generation planners is to deliver electricity to the maximum number of customers at the lowest possible price. The political acceptability of power generated from any source will depend upon the ultimate tariff to the consumer relative to the benefits delivered.

Does renewable energy generate affordable power?

On a total cost basis, a new, renewable energy, generating facility is often cost competitive with a conventional fuel facility provided that the cost calculation considers long-term fuel costs - and even more so when one considers environmental costs and benefits. Since this generalization is not true in every situation confronting the policy planner, the policy planner will need to apply cost-effectiveness criteria adapted to each situation.

What are the applicable cost-effectiveness evaluation criteria?

Any given electric generating technology (including renewables) may be cost effective in one market or application and not in another. There is no simple calculus a policy maker can apply, but a number of established criteria will assist in determining the financial viability of renewable energy generation.

The quality and quantity of the resource. Quality and quantity of renewable resources may be determined by a government-conducted resource assessment, but private-sector developers commonly have their own pre-feasibility and feasibility studies which can be more accurate measures of the commercial viability of a given project. The measures of resource quality and quantity are unique to each resource, but for each of the renewables, resource quality and quantity affects the energy input to, and the effective capacity of a generation facility. In geothermal resource development, for example, the temperature of the resource and the dissolved impurities determine the requisite production equipment. The cost of production equipment, in turn, affects the installed cost and the per-kilowatt-hour cost of delivered power. In biomass, the quality and BTU content of the fuel will influence installed costs, and operations and maintenance costs.

The location of the resource. Proximity of a resource to a customer base directly impacts costs, as does proximity to an existing infrastructure (roads, transmission lines, etc.), to industry support facilities (concrete plants, etc.), and to the developer's technology manufacturing base. In the case of geothermal, the depth of the resource is a major cost factor. For the hydro, wind and solar technologies, climatic variations (rainfall, cloud cover, intense storms) affect cost. For biomass, transportation distances between the fuel source and the generating facility may significantly affect the electricity cost.

Government-imposed costs. For the private-sector developer, time is money. The time expended in responding to bid proposals, in obtaining requisite permits, licenses and concessions, and in negotiating contracts increases the costs of renewable projects. The policy maker should consider policies that organize and simplify the local institutional processes. Such policies may prevent adding major costs and time delays to what would otherwise be a highly cost-effective facility. Similarly, government-imposed taxes, fees, tariffs and royalty payments are all passed to the electricity consumer and effect the kilowatt-hour cost of delivered power.

The development process is sufficiently similar that for many purposes the renewable resources may be treated similarly. The development process employed by hydroelectric, geothermal, wind energy, biomass and solar renewable technologies may be described and analyzed in three discrete stages: ***"reconnaissance", "exploration"*** and ***"exploitation".*** Each technology may use different terms for these three stages, but the concepts are similar.

- ***Reconnaissance*** is an activity which determines by visual observation and scientific studies whether an area may be a source of commercially exploitable resources. It does not affect the present surface use of the land.

- ***Exploration*** is an activity which demonstrates the dimensions, position, characteristics and extent of resources by scientific studies. It may affect the present surface use of the land. An extensive outlay of capital may be required for exploring the potential of some renewable resources such as geothermal and, to a lesser degree, wind and hydro resources. Where resource exploration is expensive, this may necessitate that exclusive rights to the relevant renewable resources in the area be awarded to the explorer. These rights may be granted for a limited term, but if exploration proves the commercial viability of the resource, a private-sector developer will require that the temporary exploration rights be converted to long-term exploitation rights.

- ***Exploitation*** is an activity which enables electricity to be produced from renewable resources, either through the intermediate production of steam or the direct production of electricity from a chemical or mechanical process. Exclusive, long-term rights are prerequisite to the sustainability of this production.

The expense associated with each phase of resource development has a direct impact on the cost-effectiveness of the electricity produced. The first generation facilities developed in any resource area are almost always going to cost more per kilowatt hour produced than will later facilities, since most of the reconnaissance and exploration costs will be included in the cost of the first facility. If, however, there is some assurance of a market for power from additional facilities, should the initial facility prove feasible, the reconnaissance and exploration costs may be allocated over more kilowatt hours thus reducing the initial cost. By allocating initial reconaissance and exploration costs over multiple projects, the per kilowatt hour cost may be significantly reduced.

Financing costs. For renewables, the bulk of a project's total lifetime cost is represented by the initial capital cost, and will be incurred before the project ever comes on line. The cost of a renewable energy is in the technology effort exerted at the outset of a project and all of the renewables share ***"front-end-loaded"*** cost profiles. Consequently, the majority of new generation facilities are funded through project financing, whereby the principal and interest (and profit) are paid from the proceeds of the project.

Cost of Electricity

Power purchase agreement. The **"power purchase agreement"** - the power and capacity contract between the owner of a generating facility and its customers - rather than the credit-worthiness of the developer, collateralizes the loan. Since renewable energy projects are front-end-loaded, the costs of capital significantly affects installed cost. High risk factors associated with initial projects developed in new resource areas also translate into higher costs of capital. The challenge for the country policy maker - especially in a country which seeks to attract initial projects to a new resource area - is to implement new mechanisms to lower financing costs. Development of such mechanisms may prove more productive if done in consultation with the private-sector developer. For example, in some situations, municipal customers may have access to tax-exempt or low interest bonds that can be used to finance energy projects at a lower cost than if they were financed with conventional borrowing.

In a rapidly advancing technological era, the most prudent course for a decision maker is to avoid reliance on old information as to whether a given renewable technology can fulfill a given energy need.

System costs. The cost or cost-savings of integrating a given renewable energy generator into a system is difficult to quantify. By diversifying the energy supply mix, a system can protect or buffer the ratepayer from the potential financial risks and volatility of changing fuel prices, changing environmental requirements, and common design flaws that can result in large operational and maintenance costs. Reliance on imported fuels may be eliminated and balances of payment problems thereby reduced. With the exception of biomass, there are no intrinsic fuel costs for an established renewable energy generating facility. Consequently, an established renewable facility serves as a hedge against inflation in an inflationary market.

For an example of a renewable facility as an inflationary hedge one may examine the history of the older hydroelectric power dams. The following chart illustrates the renewable technologies which are currently available in the marketplace.

Important Characteristics			
	Options	**Status**	**Capacity**
Small hydro	Low to high head turbines and dams. Run of river.	Virtually all are commercial.	Factor Intermittent to base load.
Wind	Horizontal and vertical axis wind turbines. Wind Pumps.	Commercial. New designs under development.	Variable, 20 to 40%.
Solar	Photovoltaic. Active thermal (low to high temp for heat or electricity). Passive thermal.	Most commercial. Some under development or refinement.	W/o storage: <25%, intermittent W/thermal storage: 40 to 60%, intermediate.
Geothermal	Cycles: Dry steam, Flash, and Binary	Commercial. Exploration and drilling improvements underway.	High, base load.
Bioenergy	Combustion. Fermentation. Digestion. Gasification. Liquefication.	Many commercial. More under development or refinement.	US wood plants average 95+%. Intermediate, peaking also possible.

Important Characteristics of the Renewable Technologies

- All six renewable energy sectors offer technologies which are proven and are available in the marketplace. All can be purchased today in forms that are reliable and cost-competitive.

• “Capacity Factor” summarizes the output patterns.

- Geothermal and most biomass plants provide baseload energy.

- Most hydro and some biomass plants are highly dispatchable, offering a range of options from baseload to peaking.

- Run-of-river hydro is intermittent, but variations in its output tend to be slow and predictable.

- Solar ranges from intermittent to intermediate, depending on how well it matches the pattern of energy usage.

- Wind is intermittent, but studies have found that most grids can add an intermittent source up to 15% of their capacity without requiring any compensatory action. Higher shares from intermittent sources are usually easy to accommodate.