An Overview of Renewable Energy Potential Studies
Why do them, how to do them, and how to use the results?

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Abstract

The fact that the US has plentiful renewable energy (RE) resources (sun, wind, water, geothermal, and biomass) is not in doubt, but little of this potential has been exploited yet, and today renewables (excluding large hydro) represent only 2.7% of electricity generation.

Renewable Portfolio Standards (RPSs), which now exist in 30 states, are forcing utilities to get an increasing amount of their energy from RE, and the passage of a Federal RPS is looking likely. Coupled with a public wanting to tackle climate change and create green jobs, RE development is becoming more and more mainstream. However, there are several issues that make renewables challenging to implement – changing economics, lack of RE infrastructure, and uncertainty about which technologies are the best fit for an area, for example.

In order to develop the US's large potential for RE, more detailed information is needed on what RE potential exists in each area, which technologies can be deployed in an economic way to make use of those resources, and how much energy could be generated. A RE potential study can fill this gap in the knowledge base. It can be commissioned and tailored specifically for different types of entities – small or large utilities, cities, counties, or states. A RE potential study can build on publically available data and add value by isolating those resources and technologies that would be the most economical in both the short and long term for the entity commissioning the study. The information can enable utilities and state and local governments to focus their monetary resources on the most promising technologies.

Why Do A Renewable Energy Potential Study?

There exists a huge amount of potential in the US for generating power from renewable energy (RE) sources, and many utilities and state and local governments are pushing to get this potential developed. Thirty states now have Renewable Portfolio Standards (RPSs), and many utilities have their own internal goals for generation from RE. A Federal RPS is likely to be passed by the incoming White House administration.

The benefits of RE development are many, and include:

- Fighting climate change by reducing the carbon intensity of the power supply;
- Aiding local economic development;
- A hedge against the risk of fossil fuel price uncertainty (i.e. natural gas and coal); and
- Planning for a future that will most likely include a cap and trade system for greenhouse gas (GHG) emissions, which would raise the price of conventional energy generation.

When it comes to actual implementation, however, RE technologies face many challenges. While both small-scale and large-scale RE development continues to increase every year, renewable generation still represents only 2.7% of electricity generation (EIA 2008). The reasons for this are many, but some of the principle ones are:

- Renewable fuels/resources cannot be easily and cheaply transported, like coal and natural gas can;
- Each geographical area has a different mix of physical resources available – wind, solar insolation, water, geothermal areas, biomass feedstocks – and must be evaluated uniquely. A technology installed in one location may generate a different amount of energy than if it were installed somewhere else, causing uncertainty in planning;
- Each US state has a slightly different business climate for renewables depending on the RE programs and incentives offered, and on utility market structure (i.e., whether it is restructured or not, whether an RPS exists, etc.), and RE incentives change every few years, making it hard to plan and finance for the lifetime of the equipment;
- Regulations regarding planning permission for RE technologies vary by state, and sometimes even by county; and
- There may be transmission constraints in getting the power from the site where it is generated to the load centers that can use it.

Because of these development issues, policy planners need information on what the unique opportunities and challenges are in RE development for their area. Table 1 shows the main players in the energy industry and whether they would benefit from or be likely to commission a RE potential study.

Table 1

Market Player	**Would Commission a Study?**	**Benefits From a Study**
Energy Customers	No	Get appropriate incentives from state or utilities for customer-sited RE installations.
Utilities	Yes	Find the most economic way to meet RPS goals or internal RE goals.
Local governments (county, city)	Yes	Meet local environmental goals, evaluate potential for economic development from RE, streamline local planning and land use issues concerning RE.
State governments	Yes	Plan an RPS or design statewide RE programs to meet an RPS.
Federal government	Yes, but at a much higher level than described in this paper.	Provide national-level information on RE resources that can be used by local entities, plan federal energy policy, direct technology development programs.

How Is A Renewable Energy Potential Study Done?

There are three main phases in a RE potential study:

1) Resource Assessment and Definition of Land Area

The first phase of RE potential study is to define the land area to be studied, and find out what energy resources exist in that land area. The level of detail in this phase will depend on who the study is being done for and the size of land area to be studied. A study that covers a whole county will have a lot less detail than one that covers a small area, such as an Indian Tribe reservation.

The basic developability of land must be established (or rights to offshore development, if this is being considered). Some of the land may be undevelopable due to issues such as: federal or state protection, the land being designated for military use, and the land being too mountainous or inaccessible.

The RE resources that exist on the developable land then need to be estimated. The five main categories of physical renewable resources and the way they are measured are:

1. **Solar:** Solar insolation (in $kWh/m^2/day$)
2. **Wind:** Wind power density class (in W/m^2)
3. **Biomass:** Existing and potential biomass feedstock, from waste and bioenergy crops (in bone dry tons)
4. **Hydro:** Estimates of capacity (in MW) for specific hydro sites, or head (in meters) and flow rates (in m^3/sec) for suitable rivers
5. **Geothermal:** Estimates of capacity (in MW) for Known Geothermal Resource Areas (KGRAs)

There is a large amount of data available in the public domain that has already estimated these resources (for example, from NREL, or from the CEC in California), as well as software packages that can provide estimates. Original research will likely not be needed.

The results of this phase of the study will be a list of land areas and the RE resources that exist on those land areas. For example, the list could contain the amount of land in square miles that is developable and that has wind classes from three to seven; or the amount of land that has a slope of less than 1% and solar resources greater than 6 $kWh/m^2/day$.

2) Technical Potential

Technical potential can be defined as the maximum feasible capacity of renewable generation that could be installed, given land use restrictions and current or foreseeable technology. Technical potential estimates are not useful in themselves, but are a necessary step to determine economic potential.

There are a variety of different types of resources and technologies producing different types of power at different times of day and at different points in the energy system. RE generation can be broadly categorized as:

- Behind the meter electricity generation (that offsets customer's electricity use);
- Behind the meter thermal generation, such as solar hot water (that could offset customer's natural gas and/or electricity use);
- Utility-scale electricity generation, such as wind farms or solar thermal plants without storage, where the power is fed into the transmission grid as it is generated – these are predictable, but not controllable; and
- Utility-scale electricity generation, such as geothermal, biomass, and hydro plants, where a controlled amount of power is fed into the grid – these are controllable and predictable (except for unplanned plant outages).

At this stage in the study, all RE technologies can be considered that can make use of the physical resources available. For example, if there is a large amount of solar insolation available, then all types of solar technologies can be considered – PV, thin film, solar concentrating power, etc. If there are hydro resources available, then different types of hydro turbines (micro, small, and large) can be evaluated, depending on the size of rivers in the area.

The technology options which are deemed to be impractical will need to be eliminated. These could be, for example: cutting-edge and unproven technologies, technologies with a very low capacity factor, or technologies that are unreliable. Predictions may need to be made about technologies for which there is no track record in the US, but which are deployed elsewhere in the world. For example, no offshore wind turbines have been installed in the US, but this technology is now relatively mature in Europe and that existing expertise could be imported into the US.

To calculate technical potential, a value for MW of capacity is first calculated, and then the energy generation is estimated using a predicted capacity factor for each technology, as shown in equation (1).

*[1] Energy Generation (GWh/year) = Capacity (MW) * 8760 (hrs/year) * 1/1000 (GWh/MW) * capacity factor (% hours)*

For **wind** and **solar,** the capacity in MW is calculated using the land area values from the first phase of the study, and a capacity density for the particular technology. For **geothermal** and **hydro,** specific sites within the area being studied will have capacity estimates attributed to them and these can be used directly. For **biomass,** estimates of existing supplies, such as forestry waste or cattle manure, can be converted to an estimated GWh using the particular heat rate of the fuel, and then this can be converted to MW of capacity. Capacity factors can be taken from industry literature, or actual project performance data for projects in the same geographic area, and assumptions will need to be made about the specific types of technologies to base these numbers on. For some technologies, such as solar power towers, there is little or no track record of commercial installations, but for wind, there are some reliable estimates of capacity factors for different wind classes.

The results of this phase of the study will be a capacity (MW) and generation (GWh/year) value for each of the renewable resource categories.

3) Economic Potential

Economic potential reflects the portion of technical potential that is economically viable. Determining what is economic requires consideration of general market drivers and other factors influencing project finances.

The definition of a project being economic will vary depending on who the study is being done for. **Utilities** may see RE as economic only if it can compete with the market price for fossil or nuclear options; however, they may look at the potential income from transmission wheeling charges if the RE is to be transmitted over their grid. **End-use customers**, both residential and commercial, will see RE as economic if they can get the equipment paid off within a certain number of years, and this will partly depend on the rate they pay for electricity and/or gas. **RE developers** will see a project as economic if they can get a good internal rate of return on their investment, and this will depend on issues such as the Time of Delivery factor, the price they get for power (as established in bilateral contracts with power purchasers, or revenue from the spot market), the availability of rebates, and the cost of equipment.

Project-Level Analysis: A project-level analysis can be done for all the technologies that are likely to be economic. This project-level analysis can be done in a pro-forma format. The pro-forma will need to take into account the following factors:

1. Capital costs (total installation costs)
2. O&M costs
3. Degradation of equipment performance over time
4. Above-inflation rises in electricity prices
5. Local, state, and Federal tax incentives (for private investors)

6. Local, state, and Federal rebates on capital costs (different for public or private)
7. Cost of equity and cost of debt, debt as a percentage of cost, and inflation
8. Income taxes
9. Effective year (i.e., year plant starts to operate)
10. Lifetime of the equipment
11. GHG adders for fossil fuels (to be introduced in the future) that are added to the market price
12. A market price for other generation (usually for natural gas) in $/kWh (e.g., Market Price Referent, or equivalent for the area being studied)

The result of a **utility-scale** pro-forma will be a cost of production, which can be compared to the market price that has been chosen. The result of a **behind-the-meter** pro-forma will be a levelized benefits value that includes avoided electricity costs and the costs of the installation and maintenance of the equipment. When the levelized benefits value is positive, it indicates that the technology is economic.

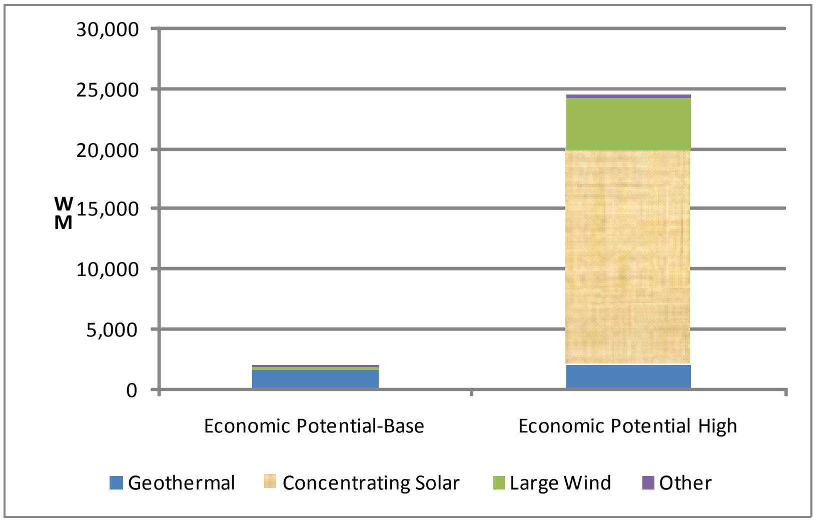
Scenarios: It may be useful to create more than one scenario for the project-level analysis, as there is a considerable amount of uncertainty in inputs, such as the availability of tax credits and rebates, and the cost of equipment, especially over a long timeframe. Having a base case (most likely) and a high case (most optimistic) provides a range of potential into which the actual potential will probably fall.

The final economic potential for each resource category is calculated based on the cost-effectiveness (or not) of the technologies on a project level. So, if small wind is shown to be cost-effective on a project level, then the economic potential for small wind will be the same as the technical potential. If commercial PV is shown to be cost-effective on a project level, but residential PV is not, then the economic potential will be the technical potential for commercial PV only.

Case Study: A RE potential study was done for a utility that provides power to a county in California with large potential for central station solar and geothermal development. The study identified the amount of potential existing within county lines and made recommendations on how to develop the potential. In addition, an estimate of the benefits from economic development from RE in the county was done.

Figure 1 shows a summary of the results of the study. The right hand column shows the more optimistic High Case, and the left column shows the conservative Base Case. Each case included varying assumptions about incentives and technology costs projected to 2016. The high case showed that over 24,000 MW, mainly solar, could be economic by 2016, assuming a slightly more favorable policy environment and/or with some improvement in solar costs. This very large difference between the low and the high cases shows how much variation there can be in the economics of RE.

Figure 1



Source: SBC April 2008

4) Other Areas of Study

In addition to the economic potential numbers, it is useful to study the potential benefits of RE development in terms of **economic development** for the area under study, and the **market barriers and drivers** that can influence RE development. Both of these issues will have a big effect on the likelihood of actual implementation of the economic potential. Economic development can be a very important factor in rural areas or areas of high unemployment.

Market Potential: An additional phase can be added to the potential study if the market potential is wished to be known. This is the percentage of the economic potential that is likely to be actually implemented during each year of the forecasting period (for example, 10, 15, or 20 years). Coming up with market potential is a less straightforward exercise than it is for technical or economic potential; it requires estimating parameters for a technology diffusion curve. As there is not much empirical data on the diffusion of renewable energy technologies on a large scale, this requires some judgment and knowledge of the way markets function. However, models have been built that will estimate market potential, and these can be adjusted for each type of technology and/or market sector.

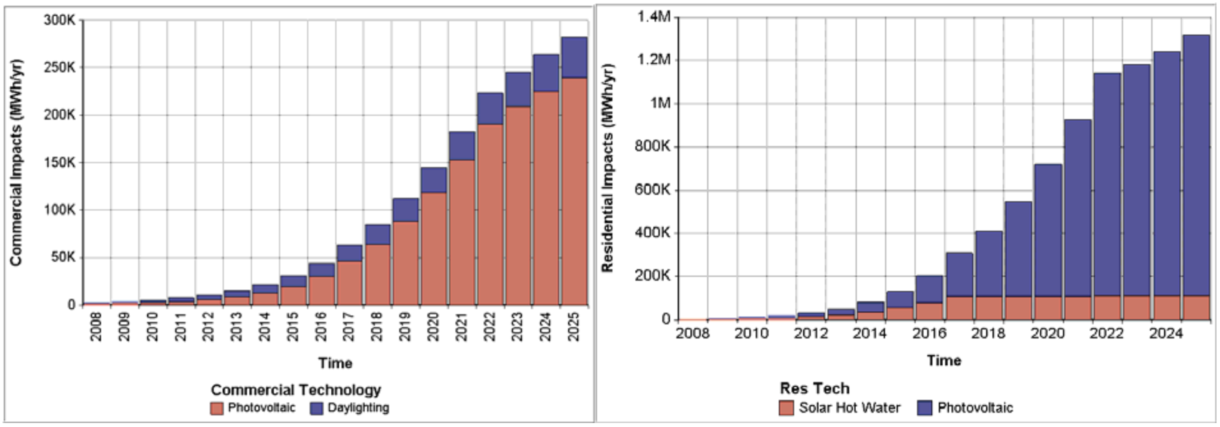
Case Study: A dynamic technology diffusion model was developed for a Southwestern utility to simulate the adoption of distributed solar PV, solar hot water, and commercial daylighting technologies in the customer base, using various assumptions regarding state and federal tax credits and utility incentives (base case and high case).

The analysis began with a detailed characterization of the market for 11 customer segments, including quantification of the total area of suitable roof space, and energy and demand savings per square foot of building space for each technology. Then, an analysis of the cost effectiveness of each technology, again by customer segment, was performed. Payback times were calculated comparing the energy saved combined with assumptions of system costs over time that reflect a) technology improvements, b) state and federal tax credits, and c) utility incentives.

The sector and cost data were then integrated into a dynamic technology diffusion model. The approach used was a modified version of the Bass diffusion model (Bass 1969). Adoption of technologies generally follows an S-shaped growth pattern. The S-shaped growth is endogenously generated by the Bass model based on a well-established theory regarding technology awareness and adoption over time through both external influences (i.e., advertising) and internal influences (i.e., word-of-mouth).

The results of the optimistic scenario from the model are shown in Figure 2.

Figure 2



Source: SBC 2008

How Can The Study Be Used?

RE potential studies are primarily done to scope out what *could* be built. The next step is for utilities or local or state governments to implement policies that will encourage this potential to be developed.

1) Utilities

The resource planning models that utilities use to decide on future generation purchases often compare RE to fossil or nuclear generation on purely a cost basis, and do not include the other benefits of RE, such as GHG reductions, hedging against fuel price uncertainty, and improvements to local air quality. This means that RE options are often not chosen in the planning process when new capacity is needed. However, many utilities are now obligated to meet RPS goals, or have their own voluntary RE goals, so RE development needs to happen. Many of these goals come in the form of both utility-scale and distributed generation.

One positive story is on-shore wind, which has been taking off at a fast pace. According to Renewable Energy World, “the U.S. wind energy industry installed 5,244 megawatts (MW) in 2007, expanding the nation's total wind power generating capacity by 45 percent in a single calendar year and injecting an investment of over $9 billion into the economy, the American Wind Energy Association (AWEA) has announced. The new wind projects account for about 30 percent of the entire new power-producing capacity added nationally in 2007.” Most of this new wind capacity is being arranged through Requests for Proposals for independent developers to supply utilities with RE power.

However, there remains a large amount of RE potential that could be contracted out or even developed by utilities that has not been targeted. This may be because the potential is not known about or because it is not deemed to be economic. A utility needing to implement either utility-scale or distributed (customer-sited) RE can commission a RE potential study and then use the results to design a suite of programs to incentivize RE.

2) Local Governments

Local governments may want to promote RE for many reasons: they may have set goals for GHG reductions; the area may be economically depressed and in need of investment from a new industry; or there may be potential for an increase in local tax/ land lease revenues from RE installations.

Some local governments have set targets for GHG reductions by, for example, signing up for the Kyoto Protocol. They can meet their goals by promoting both energy efficiency and RE. If the area does not have any of the obviously cost-effective renewable resources, such as large wind, a detailed RE potential study can be essential to finding out which ones could work for them and their residents.

If the area is mostly urban or suburban, then technologies such as rooftop or small wind, residential, and commercial rooftop-mounted PV, solar hot water, micro or pico hydro, passive solar, and anaerobic digestion of food or municipal solid waste can be considered. Some of these options are not economic when compared directly to fossil fuels, but this should be expected as RE technologies must make use of energy supplies that are not as concentrated or convenient as fossil fuels. In addition, some technologies are at the beginning of the manufacturing cost curve, and with mass production, their costs are predicted to come down considerably. Local governments can encourage investment in the technologies deemed to be the most suitable for their area by offering appropriate incentives for those technologies and by changing permitting laws to facilitate their installation.

3) State Governments

States that have a Renewable Portfolio Standard or equivalent must design their energy policies to make sure the RPS goals are met. Most states offer tax breaks and rebates at varying levels for different types of RE installations. Some offer a production incentive, thereby encouraging technologies with high capacity factors; others offer a capacity-related incentive, encouraging the installation of RE without regard to the efficiency of operation.

When planning energy policy to meet an RPS, the following four sets of information must be known:

1. The potential for in-state generation from various RE sources;
2. The level and type of incentivization needed for each RE technology to make it economic;
3. Existing barriers and drivers for RE; and
4. The potential for importing RE power from other states.

For example, knowing that there is a large amount of untapped potential in offshore wind, but that it is less economic than on-shore wind, can highlight the need for specific incentives for that technology. Knowing that there is potential for small wind, but that small wind is often not installed due to planning permission problems, can highlight the need for education and outreach and state-wide planning laws that allow small wind installations.

If the RPS allows for imported RE to count towards the RPS goals, then it is important to know how much RE power could be imported from neighboring states, the forecasted cost of that imported energy, and forecasted availability of transmission to import that energy.

State policy makers will want to meet the RPS at the least cost to ratepayers. However, if long-term RE goals are to be met then investments in technologies that are not yet economic are essential. The nuclear and fossil fuel industries have already benefitted considerably, and continue to benefit, from such incentives – mostly from the Federal government. The development of an in-state RE industry can be a boost for the state's economy and this should be taken into consideration also, although it is hard to quantify.

RE potential studies can be used in the process of setting state RE policies in the following ways:

- Project-level analyses that are done as part of the RE potential study can be used to suggest appropriate incentive levels for each technology (i.e., the analysis shows the amount needed to make the technology economic).
- Information on how much economic potential exists for each technology can be used to make sure that technologies with a large amount of potential get the support they need, and those with little potential are not over-incentivized.
- Information on the total generating potential in the state can let policy makers know if they should plan to procure supplies from out-of-state to meet their RPS, or if that goal can be met with in-state generation.
- A ratepayer impact study can estimate what the total cost to ratepayers of meeting the RPS will be for various combinations of technologies.

Combining all this information in a portfolio analysis can enable state policy makers to determine the best mix of RE resources to incentivize through financial incentive programs.

Case Study: A portfolio analysis was done for the state of New Jersey as part of a renewable energy market assessment. The analysis relied on two different RE potential studies that had previously been done – one that examined all possible types of RE (Navigant Consulting 2004) and one specifically focused on biomass potential (The New Jersey Agricultural Experiment Station 2007). Both were state-wide studies.

In the portfolio analysis, two scenarios were developed that met the RPS goals with in-state generation based on the values for each economic potential for each technology from the two potential studies. In each scenario, varying estimates of the percent of economic potential that was achievable were made for each category of RE, as shown in Table 2. This showed policy makers what the build rate would need to be in each year to meet the goals with in-state generation and different mixes of the technologies. The second scenario was then used in developing a budget for the upcoming budget cycle. The budget was designed so that each technology-market sector was funded sufficiently, by funding the programs that incentivized those technologies. The scenario development was combined with a pro-forma analysis for each technology-market sector which was used to set recommended incentive levels.

Table 2.

	Scenario 1 - Good biomass, no offshore, medium wind				Scenario 2 - Good biomass, some offshore, less solar			
Technology-market Sector	**% of Total Potential by 2012****	**MW Capacity Needed**	**Number of installations needed**	**Average Build Rate per Year (start 2008)**	**% of Total Potential by 2012****	**MW Capacity Needed**	**Number of installations needed**	**Average Build Rate (# projects per year, start 2009)**
Solar - Residential	8%	259.6	51,920	10,384	3%	81.1	16,225	4,056
Solar - C&I < 40 kW	33%	140.6	14,058	2,812	11%	46.9	4,686	1,172
Solar - Public > 40 kW	33%	281.2	5,623	1,125	11%	93.7	1,874	469
Solar - C&I > 40 kW	33%	768.5	15,370	3,074	12%	279.5	5,589	1,397
Solar - IPP (Central PV)	33%	29.0	29	6	30%	26.4	26	7
Wind - Small Onshore	40%	5.1	508	102	50%	6.4	635	159
Wind – Large Onshore	40%	45.7	30	6	50%	57.2	38	10
Wind - Offshore	0%	0.0	-	-	12%	270.0	108	27
Biomass - Landfill Gas	75%	16.5	33	7	80%	17.6	35	9
Biomass - Wastewater Biogas	75%	2.3	5	1	75%	2.3	5	1
Biomass - Gasification (CC)	75%	228.0	15	3	75%	228.0	15	4
Biomass - Anaerobic Digestion	75%	18.0	36	7	75%	18.0	36	9
Biomass – Direct Combustion	75%	322.5	13	3	80%	344.0	14	3

Source: SBC March 2008

Conclusion

In order to develop the US's large potential for renewable energy, more detailed information is needed on what potential exists in each area, and which technologies can be deployed in an economic way to make use of those resources. A RE potential study can fill this gap in the knowledge base and enable utilities and state and local governments to focus on the most promising technologies for their area. This will also enable RE development funds to be used to the best effect.

The Federal government can help in this effort by providing data on the physical renewable resources that exist across the whole country (wind, solar, geothermal, hydro, biomass), which it is already doing to some effect, but it is not in the position to provide specific information on the economic potential for RE on a local scale. At the next level, state governments should provide state-wide data on RE potential

which can be used by the state to set policy goals and to design state-wide RE programs. These data can also be used by local governments (cities, counties) and utilities both large and small to scope out the potential for RE in their own area. A study at the local level would require the gathering of more detailed information on issues such as land use and roof space in the area being studied, and then this can be combined with the state and
national level data to provide an accurate assessment of potential**.**

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