Energy Independent Communities

INTRODUCTION

This document is intended to be a practical tool for communities everywhere in taking the first step towards energy sustainability: evaluating their potential for energy independence. It should help communities to quantify their energy needs and choose potential technologies relevant to their circumstances. It provides enough information to determine whether it is appropriate to move on to a full engineering evaluation for generating renewable energy. This tool may also be of interest to policy makers because it provides a practical approach to sustainable energy.

It is possible to power the entire earth on solar power: human consumption of all primary energy amounts to less than one tenth of one percent of the solar radiation. The fossil fuels our economy relies on: coal, oil and natural gas are all merely stored solar energy, which accumulated over millions of years. In addition to solar power, technologies exist to derive power from gravitational forces (tidal power), from wind and from the natural radioactive decay that is the source of geothermal power. Solar, wind and geothermal energy sources are essentially inexhaustible.

Currently there are two basic approaches towards renewable energy: either the off the grid, totally distributed approach that is marketed by technology producers, or the development of “green” energy by power companies. This document presents a third approach: a community based one. It differs in that it is not reliant on a particular technology or a particular provider, but instead allows communities to use the technologies that work for them. Communities are the basic unit of sustainability, and communities around the world are the driver for a more sustainable future. If all communities achieved energy independence, the entire world would achieve energy sustainability. We hope that this document can move us forward at least a little towards this vision.

This assessment methodology was developed and tested on Vashon-Maury Island, and that study provides a real-life example of the methodology throughout this document. Technical and financial analyses were performed under contract by Princeton Energy Resources International LLC, but the study design and this report are the product of the Institute for Environmental Research and Education (IERE), which is solely responsible for its content.

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I. BACKGROUND

Sustainability is at its roots a community issue. Human beings organize themselves into communities, and a healthy community provides for all its members needs: food, clothing and shelter, and well as an intact social fabric. In the developed world, communities also provide ecological services such as clean air and water (through regulation), waste management and electrical energy. The basic needs of food clothing and shelter are provided through an adequate supply of living-wage jobs, even though many of the consumer goods are actually imported. Unfortunately, some communities have provided for their citizens at the expense of other communities, and this is the basic source of disparity between regions within countries and between countries.

This disparity could be corrected if each community became responsible for producing all its needs on a net basis. By that we mean that each community should produce as much energy as it consumes even though it may import and export energy. It should produce as much food as it consumes, and it should produce as many living-wage jobs as it needs to support its population, even though the people holding those jobs may commute to them from other communities. If every community took this approach to sustainability, then the potential for achieving a sustainable and equitable world would be much increased.

In this project, we asked the question whether it might be possible for communities to produce their energy needs, and we tested that question on an island community, Vashon-Maury Island. Once one has decided the boundaries of the community, the question really can be divided into three parts:

1. How much energy is needed;
2. How much renewable energy is available; and
3. What are the financial implications of that renewable energy

In summary, we found that Vashon-Maury Island is a community with a relatively high energy consumption pattern, and relatively low renewable resources, but nevertheless it appears that there is more than enough potential renewable energy to support the community's energy needs. The cost to produce that energy however, will be relatively high, and it will be a political decision whether the benefits of a reliable and non-polluting energy source is worth the extra cost.

Community energy independence means producing at least as much energy as consumed, so that the community is not a net importer of energy. We define renewable energy as all those using an essentially inexhaustible primary power source and that does not exceed the capacity of the environment to absorb emissions and other insults. Renewable energy technologies that meet this definition include solar, wind, hydropower that does not interrupt fish runs, geothermal, tidal and wave power, and biomass.

In order to make best use of existing infrastructure, we do not recommend that communities attempt to move off the grid. The grid is an excellent way for communities to share their energy, producing excess when they can and drawing energy from the grid when their demands exceed their production rate. In this approach, the energy grid acts as an energy pool, with many sources adding energy and many consumers using that energy. Currently, the energy grid acts more like a pipeline, with energy produced at a few power plants and flowing to many consumers. It will be some time before the electrical grid is properly configured to accommodate diffuse energy sources, but it will also be some time before communities can move to an all-renewable energy supply. Early steps are not likely to much perturb the system, and they can act as models for changes in the grid that need to take place.

To evaluate whether a community has the potential for energy independence, the first step is to define the community energy uses, and evaluate the potential renewable energy technologies. The steps are:

1. Define community boundaries
2. Inventory all energy uses
3. Evaluate potential energy technologies
4. Match energy needs to capacity

II. DEFINING COMMUNITY BOUNDARIES

> **Vashon-Maury Island Community Boundaries**
>
> The boundaries of this study are the island itself: Vashon-Maury Island is a community of approximately 10,000 in Puget Sound, a 15-minute Ferry ride from either Seattle or Tacoma. The island is largely rural, 37 square miles of which approximately 80% is forested, and 10% is in agricultural use.

There are many ways to define your community boundaries: they may be physical, political or economic. However, it is worthwhile to consider the objective here of sustainable energy. It makes sense to include within the boundaries of your community the areas that contain the potential energy resources. This is comparable to including surrounding agricultural areas in your community—after all, no community is sustainable without food.

This may mean that your community is an entire county or a region or state. However, be aware that the larger you make your community boundaries, the less sense of “community” you will have and the more political woes you will encounter trying to decide to do anything. To see how we did it on Vashon Island see Vashon.

Once you have decided on your community boundaries, gather some basic facts: what is the area, how many people live there, how many households there are and so forth. This information will be needed to help you gather data. You can get basic demographic information from the census bureau at http://www.census.gov/.

Collect a good set of maps: USGS 7.5 Minute topographic maps are excellent resources, as they show topography (helpful for estimating wind potential), water bodies and streams (hydropower), locations of hot springs and other geothermal features at the surface (potential geothermal energy sites), land use patterns, such as forests, farmland, cities/towns/developed areas (useful in biomass resource inventory). Topographic maps can be obtained through local

map and hiking stores as well as through the USGS website:
http://ngmdb.usgs.gov/Other_Resources/rdb_topo.html

III. INVENTORY ALL ENERGY USES

Energy use includes not only electricity, but also wood and fossil fuel uses such as heating oil, gasoline, natural gas, propane and coal.

The energy profile is a snapshot of energy use, costs, and patterns of demand over time and over the seasons for the community. You will need this information when matching up your energy demand with energy generation potential. At the minimum, you must have estimates of the total use of each type of energy.

A. Electricity

You should be able to get this information from your local power provider.

- Annual consumption
- Hourly demand
- Seasonal variation
- Time-of-day rates (if applicable),
- Peak (the maximum instantaneous demand for electricity) and base load (the lowest instantaneous use, usually found for hours at night and in the middle of the day) rates
- Type of generation (hydro, nuclear, fossil fuel, renewables) in your energy provider's portfolio

B. Natural gas

This data can be obtained through your natural gas supplier, or through your state tax authority, or through surveying a significant number of natural gas consumers.

- Annual consumption
- Price
- Plans for expansion

C. Propane

This information can be obtained through your distributor and through surveying users.

- Annual use
- Price

D. Wood

This information can be obtained by surveying providers to get a range of estimates of consumption in your area. Some places tax firewood or otherwise regulate it, and in this case it may be possible to obtain estimates of usage through taxing or regulating authorities.

- Annual use
- Price
- Availability (locally produced or imported from a distance)

E. Fuel oil

This information can be obtained through vendors, distributors, and (sometimes) trucking companies.

- Consumption
- Price
- Issues with reliability (shortages? price spikes?)

F. Existing renewables in the community

You can begin by looking for this information at http://www.eren.doe.gov/buildings/state_energy/map_contacts.html. You may also get some information from your local banks.

- Wind turbines
- PV panels
- Biomass energy systems (e.g., LFG used at local landfill or anaerobic digesters on farms)

G. Transportation-related use of fuels,

Transportation fuels include gasoline, diesel and biodiesel. This information is available through vendors or through surveys.

- Annual Consumption
- Number of cars and trucks in the community
- Any significant numbers of remote-powered equipment (generator sets, lawn mowers, etc.) and consumption from these sources
- Boat, ferry, other vehicle use

You can compare your energy profile to statewide and countrywide consumption patterns that have been documented by the Department of Energy, and which can be found at: http://www.eia.doe.gov/neic//historic/historic.htm. If any data is missing from your local energy use profile, use per capita data from your state to estimate use.

For convenience, it is useful to convert all your energy consumption to the same units. This allows you to see where your major energy uses are, and also allows you to plan for the big picture: the total amount of renewable energy you will need to generate in order to be sustainable. We find that Megawatt Years per year is a good unit, but kilowatt-hours per year are also often used. There are 8,760,000-kilowatt hours in a megawatt year. Table 1 converts various energy units to kilowatt hours.

Some energy uses, especially those for transportation (gasoline and diesel) may ultimately be replaced by the production of hydrogen and its use in fuel cells. Fuel cells coupled to electric motors are much more efficient converters of energy than are diesel engines or internal combustion engines, and they have no emissions other than water vapors and heat. Consequently, we have also provided a conversion factor for diesel and gasoline that expresses the energy required to displace them with hydrogen. This amount is less than the simple energy conversion because it includes the efficiency of the hydrogen based system.

Table 1 Conversion Factors for Fuels

Energy Source	Units	Energy conversion factor to kWh	H_2 Conversion Factor to kWh
Natural Gas	Cubic feet.	0.30	
Fuel Oil	Gallons	41	
Propane	Gallons	27	
Gasoline	Gallons	37	18
Diesel	Gallons	41	30
Fire Wood	Cords	7,034	

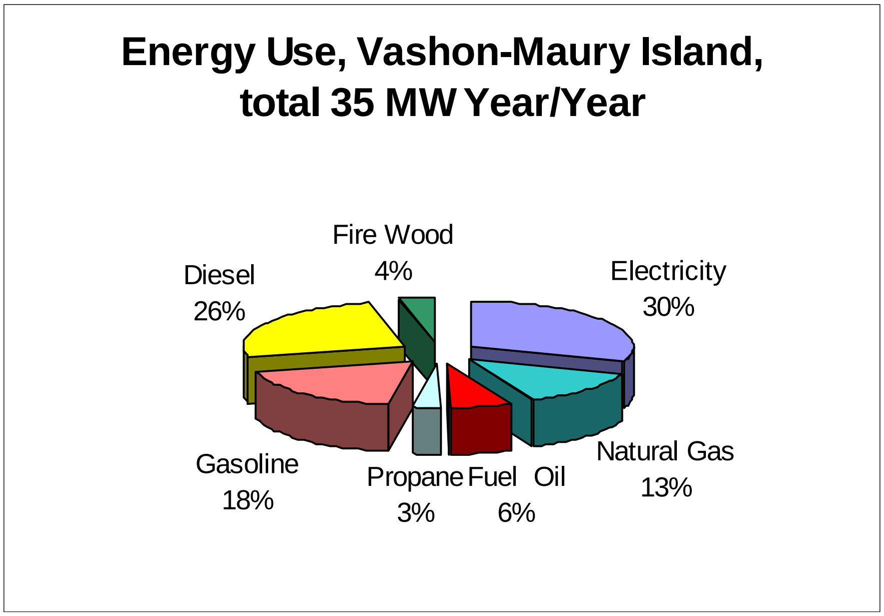
Vashon-Maury Island Energy Profile

The total energy consumption on the island is approximately 35 Megawatt years per year. The lion's share of that use is electricity, which as is noted below, is used by Vashon residents at a higher rate than other residents of Washington State.

Table 2 Per Capita Energy Use on Vashon-Maury Island

I. ENERGY TYPE	Units	Vashon	WA State	USA
Electricity	kWh	9,319	5,568	4,069
Nat Gas	cu ft	14,952	12,216	16,786
Fuel Oil	gal	49	8	21
LPG	gal	38	14	22
Wood	cord	0.21	0.12	0.07
Gasoline	gal	167	445	459
Diesel	gal	215	117	132
Population[1]	#	10,123	5,894,121	281,421,906

See Vashon Energy Profile for more information.



IV. EVALUATE POTENTIAL ENERGY TECHNOLOGIES

Renewable energy resources differ from fossil fuel resources in that they are not dispatchable: they must be made when the resource is present rather than at the convenience of the consumer. Thus, solar energy is only available during sunny days, the wind is only available when it is blowing and so forth. Unlike nuclear power plants that are "on" about 98% of the time, most renewable energy plants are "on" about 10 to 30% of the time. Thus the installed capacity of the plant (or its peaking capacity) is usually much larger than its average output. Typically renewable energy plants have relatively high capital costs and very low operating costs—because the "fuel" is free.

Different locations have a different mix of resources: they are more or less sunny and more or less windy, for example. In the section below, we will describe all the current and some of the near future renewable energy technologies. We'll discuss what renewable energy resources are needed to make them work, and how to decide if you have enough of that renewable energy resource. For western states, there are good maps of renewable energy resources at http://www.energyatlas.org/.

We have also calculated a range of cost of energy for most technologies. Cost of energy is the price that must be obtained from the buyer in order to make the energy production economically viable. Many renewable resources have federal or other subsidies and these subsidies have been incorporated in our cost of energy scenarios. Cost of energy estimates should be compared to current retail and wholesale energy costs. For more details about how we calculated costs, see Energy Costs.

A. Solar Power

1. Resource Assessment

The solar energy has both direct beam radiation and diffuse radiation. Direct Beam radiation is received from the sun without a change in direction, whereas diffuse radiation is received after it has been changed by reflection and scattering in the atmosphere. A tracking system is required to capture the majority of direct beam radiation but not for diffuse radiation. Solar energy can be harnessed through one of three ways, direct conversion of the sunlight to electricity using Photovoltaics (PV), conversion of the heat contained in sunlight into electricity through Thermal Solar Power (TSP) systems, and direct use of the heat in the sunlight through Solar Water Heating (SWH) systems.

The amount of solar radiation you get varies significantly from year to year as well as from place to place, but you can get a good estimate of your potential solar radiation by finding your location on maps at http://rredc.nrel.gov/solar/old_data/nsrdb/redbook/atlas/. Choose annual average and flat plate tilted south at latitude for your best estimate of the amount of energy you get from sunshine in your location. More detailed analyses are available: references can be found in Solar. The US solar radiation ranges from two to seven kWh per square meter per day, on an annual average.

2. PHOTOVOLTAICS (PV)

Photovoltaics convert sunshine to energy directly. As sunlight strikes the solar panel, it “bumps” electrons out of the semiconductor, thus causing a current that is carried away by wires in the panel. Currently available photovoltaics capture about 9% of the energy in sunshine. Multiply your estimated solar radiation by 9% to estimate how much solar PV energy potential you have. If your area has 5 kWh per square meter per day, then your PV potential is:

5 kWh x 9% = 0.45 kWh per square meter per day

PV comes in many different shapes, sizes and looks there are even translucent solar panels that can be used for windows. Some photographs can be found at http://www.bpsolar.com/.

The environmental impacts of PV come essentially entirely in the manufacturing stage. A significant amount of energy goes into making photovoltaics, but this energy is “paid back” after one to two years of operation[1]. New PV systems come with a manufacturer’s guarantee for 20 to 30 years.

a) Costs and availability

The one drawback to PV is that it is quite expensive. Installed cost of photovoltaics is about $550 per square meter for commercial installations and about twice that much for homeowner installations. These costs can be decreased through government buy-downs. Currently the demand for PV is outstripping supply. If you plan a substantial installation, you will have to stand in line to get your production out of the factory.

We have modeled the cost of a commercial scale installation of PV, with the following parameters: 1 MW plant, 3% inflation, 20% of power capacity captured. This represents the US solar capture average. We modeled two scenarios, which correspond to high end commercial cost and low (subsidized) cost. This should capture the range of current commercial cost scenarios. We modeled both an independent power producer (IPP) scenario and a non-profit rural electric co-op scenario. An independent power producer is simply a commercial venture, which

produces power to sell into the grid. It has high requirements for profitability for the investors (the internal rate of return) and borrows most of its money from banks. Cooperatives supply power to their members, and profitability requirements are much lower. Co-ops borrow some money from banks, but they also borrow money directly from the government, at lower rates.

The results show that the cost of power (i.e. the cost that must be paid to the producer) ranges from 18 to 64 cents per kilowatt hour. These results are linear with respect to the amount of insolation at your location. Where there is only 10% capture, the costs are twice as high. For more detail see: Solar. Many states support renewable energy through financial means, via tax breaks and other mechanisms. You can see your state's programs at http://www.dsireusa.org/.

Table 3 Cost of Photovoltaic Electricity

		Nominal Levelized Cost Of Energy (year 2004$/kWh)	After-tax Internal Rate of Return (%)
1	IPP with low Capital Cost (thru volume purchase and buy-down) at $2,500/kW	$0.2152	17.46%
2	IPP with high Capital Cost at $8,000/kW	$0.6461	17.14%
3	Rural Co-op with low Capital Cost at $2,500/kW	$0.1806	12.89%

3. Thermal Solar Systems

Thermal Solar systems are simply standard power plants that use solar power rather than fossil fuel to heat water and turn turbines. Solar power is concentrated using different types of mirror systems, and the heat is transferred using different fluids, such as heavy petroleum products or molten salts. The heat in the transfer fluid is run through a heat exchanger to heat water and make steam.

Thermal solar systems can only operate where there is strong direct sunshine. In the USA, only the Southwest has enough sunshine to operate these systems.

The mirror systems add cost to the system in addition to the capital costs of the turbine power plants. In order to make best use of the capital, thermal solar systems often include a backup, gas fired system, which provides up to 25% of the power. Most thermal solar plants are relatively large, ranging in size from one megawatt to 80 megawatts. Larger plants are planned.

Thermal solar plants can provide power at competitive rates of 6 to 17 cents per kilowatt-hour[2], with larger installations being the most efficient.

4. Solar Hot Water Systems

It is possible to capture sunlight using solar hot water systems. These systems are roof-mounted systems used to heat water there are many different designs ranging from very simple to technically complex, and providing 40 to 80% of hot water heating needs. In the USA, the average household spends about 30% of its household energy bill in heating water, so these systems can considerably offset these costs. Solar hot water systems currently provide water heating at a cost of about 8 cents per kilowatt-hour of thermal energy. More information about options for solar hot water can be obtained at http://www.greenbuilder.com/sourcebook/HeatCool.html.

B. Wind

Wind turbines are the fastest growing energy technology, with wind power increasing 30% per year. The amount of wind energy available increases as the cube of the wind speed. That means that as the wind speed doubles, the amount of electricity produced increases 8 times. As wind speed reach very high levels, the gears automatically disengage in order to protect the turbines. There are different wind turbines engineered for different wind regimes, and newer turbines are relatively large (1 to 2.5 Megawatt capacity).

Wind energy potential is rated from 1 (essentially no winds) to 7 (too high to extract). You can find out your wind energy potential by finding your location at http://rredc.nrel.gov/wind/pubs/atlas/. In general, it is assumed that areas with wind ratings below 3 are not good wind potential areas. However, there are microclimates for winds, and there may be locations within a level 2 area that can support a wind turbine.

In the past, wind turbines were rather noisy and there were cases where they posed a significant hazard to birds, particularly raptors. New turbines have much better sound insulation on their gear boxes, and the rotor speeds are slower (10 to 30 rpm), thus birds are much less likely to be affected. A minority of people find wind turbines to be unaesthetic, and have blocked the siting of them for this reason.

Wind turbines cost about $1Million per megawatt of capacity, and the turbines themselves require some maintenance during their life times, which are expected to be on the order of 25 to 30 years. The cost of electricity from wind was modeled using the same assumptions as above, with the following result that the cost of energy ranged from 6 to 10 cents per kilowatt hour. For more details, see Wind.

Table 4 Cost of Wind Electricity

		Nominal Levelized Cost Of Energy (year 2004$/kWh)	**After-tax Internal Rate of Return (%)**
1	IPP with faster winds, taking tax credit	$0.0689	22.44%
2	IPP with faster winds, no tax credit	$0.0771	17.69%
3	IPP with slower winds, no tax credit	$0.1163	17.35%
4	IPP with slower winds, taking tax credit	$0.1012	17.64%
5	Rural Co-op with slower winds, no Federal Incentive	$0.1017	16.87%
6	Rural Co-op with slower winds, taking Federal Incentive	$0.1017	24.35%
7	Rural Co-op with faster winds, no Federal Incentive	$0.0656	16.07%
8	Rural Co-op with faster winds, taking Federal Incentive	$0.0656	27.49%

C. TIDAL

Tidal power derives from the pull of the moon and the sun on the ocean. There are many technologies in the demonstration stage for tidal power, but none that are fully commercialized. One common method is to build a dam, either across an inlet or in a free-standing impoundment. The incoming tide fills up the impoundment, and as the tide goes out the water is released through a turbine. This is effectively an intermittent hydropower system. This kind of tidal power works well where the tidal range is at least 16 feet[3]. In the United States, these tidal ranges are found only in Alaska.

In France, where a 240 Megawatt tidal power installation based on damming an estuary has been in operation for three decades, scientists have calculated that if tidal power were fully exploited, the earth's rotation would slow, at a rate of about one day per 2,000 years[4].

Figure Tidal Turbine

There is another approach that works by using the tidal currents. Where flow is restricted, tidal currents can reach several knots. If the average flow is at least one knot, it may be possible to install freestanding turbines, which operate much the same way that wind turbines do. As with wind, the amount of energy that can be extracted is a function of the water speed. You can estimate the water speeds by using divers current charts, which provide current speed and direction on an hourly basis versus the tidal cycle.

Both impoundment and free standing turbine systems have the potential to significantly impact marine ecosystems. These potential impacts are poorly understood, but impoundments will certainly affect migratory fish and through shading may have other impacts as well. More details can be found at Tidal.

These technologies are definitely in the testing stage. Estimated costs of energy range from 18 to 33 cents per kilowatt-hour.

Table 5 Cost of Electricity from Tidal Power

	Nominal Levelized COE (year 2004$/kWh)	**After-tax IRR (%)**
IPP with low Capital Cost at $3,000/kW, cap factor of 31.71%, No sales tax	$0.2368	17.36%
IPP with high Capital Cost at $3,600/kW, cap factor of 27.50%, 8.80% sales tax	$0.3350	17.26%
Rural Co-op with low Capital Cost at $3,000/kW, cap factor of 31.71%, No sales tax -	$0.1755	14.64%

There are several technologies in development that depend on wave action, but these are too far from commercialization to provide good evaluations of their potential.

D. BIOMASS

Biomass comes in two basic types: wet and dry. Wet biomass includes manure and septage, food wastes and the like. Dry biomass includes landfill gas, wood wastes, some municipal solid waste and others. In essence, wet biomass is degraded using an anaerobic digester, and the resultant methane and other gases are captured to produce electricity in a conventional generator or power plant such as a gas turbine. Relatively little energy is recovered because much of the energy goes into heating and supporting the biomass of the microorganisms doing the work. However, the energy produced can offset some of the costs of the waste management.

Dry biomass can be treated through a variety of methods: pyrrolysis, which produces a fuel similar to diesel fuel, or gasification, which produces a mixture of methane, CO_2, H_2 and other gases. After some cleanup, these fuels can be used directly in a generator. They can also be used as a fuel for steam reforming, which produces hydrogen, a fully clean-burning fuel. Hydrogen can also be stored and used in a fuel cell, either a stationary one that produces electricity, or a mobile one to power a vehicle.

a) Evaluating your biomass resource

In order to evaluate your biomass resource, you need once again to gather local data. Biomass comes from many different sources. Municipal Solid Waste (MSW), Landfill gas, sewage and septage, and wood wastes are all potential sources of biomass.

(1) Municipal Solid Waste

How much waste is generated? This figure should be available through your landfill. Be sure to ask questions about the composition of your solid waste, because different waste streams have different energy potentials, as shown in the table below

Table 6 Municipal Solid Waste Data[5]

Municipal Solid Waste Component	Typical Wt% Range	Average Wt%	Energy content kWh/lb
Food waste	9.1 –36.0	14.2	1.92
Yard Waste	0.3 – 41.5	14.6	2.16
Glass	6.0 – 23.2	9	0
Metal	5.9 – 14.5	8.2	0
Paper	21.1 – 53.3	37.8	2.23
Plastic and textiles	0.0 – 5.2	7.9	4.26
Wood, leather, and rubber	0.0 – 2.1	5.2	2.99
Other	0.0 –9.0	3.1	0

Figure a - Onandaga County Waste to Energy Plant

The average person in the United States generates 4.46 lbs of municipal solid waste per day. Depending on the type of technology used to extract the energy from waste, from 25 to 60 percent of the energy content can be recovered as burnable gases or liquids. When these are passed through power generation equipment (generators, turbines and the like), the conversion rate is again about 30 percent to electricity. A preliminary estimate of the amount of electrical energy available can be made by multiplying the wet wastes energy by a 25% recovery, and the dry wastes by 50%, then multiplying again by 30% to yield the total electricity available from municipal solid waste. This yields a figure of about 400 kWh per person per year of potential waste-to-energy for the US average.

(2) Landfill methane

One of the by-products of a landfill is methane. Modern landfills have gas collection systems for gathering the gases of decomposition, and these gases are usually about 50% methane. Different landfills produce different amounts of gas, depending on the composition of the waste, the age of the landfill, the amount of trash disposed and so on. You will have to ask your landfill operators how much gas they are producing. There are about 30 kilowatt-hours per cubic foot of methane. This means that there are about 15 kilowatt-hours of energy per cubic foot of landfill gas. This can be used directly to displace natural gas or to generate electricity. Depending on the type of generation system, 30 to 50% of the energy can be converted to electricity.

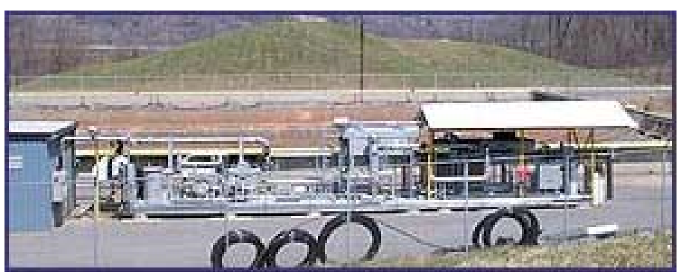


Figure b - Wayne Township Landfill Gas System

(3) Sewage and Septage

Sewage is the human waste material that is pumped directly from homes and businesses to a wastewater treatment plant. Septage is the material that is pumped from septic systems, usually after a few years of passive biological treatment. You can get the amount of each waste stream from your local wastewater treatment plant and your local septage pumping services. In each case, you need to know the total dry weight of the material (less the water). For septage, that figure is usually 1 to 2 percent of the total weight.

The average human being generates about 100 grams dry weight of waste per day or about 80 pounds of waste per year. In a sewage treatment system, essentially all of this waste is available for energy recovery. However, if a septic system is employed, much of the energy goes to feeding the bacteria that break down the waste in the anaerobic digester system.

The same calculations that apply to wet municipal solid waste apply. Multiply the dry weight of the waste available times 25%, and again by 30% to get the total electrical potential of human waste. There is about 240 kWh of energy per pound in the waste. That means there is about 18 kWh of electricity that can be generated per pound of waste, or about 1,450 kWh of electricity per person per year. This number will be much smaller if the waste is septage.

(4) Biodiesel

One interesting use of food waste is the production of biodiesel from used cooking oil. Cooking oil is a disposal problem for restaurants, but it can be converted to biodiesel to run cars and other vehicles using fairly simple and readily available chemical additives (sodium hydroxide, or lye and either methanol or ethanol). After filtration the esterified fatty acids are direct substitutes for diesel for any diesel engine. It can also be used as a substitute for home heating oil.

Biodiesel production is a fully scaleable system, whose only by-product is glycerol, a non-toxic food additive.

Biodiesel production depends on a supply of vegetable oil. In some places, biodiesel is produced directly from virgin vegetable oil. For more information, see http://www.biodiesel.org/.

(5) Cost of producing biomass-derived energy

We modeled the cost of producing energy from biomass, assuming again that a 1 MW plant was built to gasify the biomass and to produce electricity via a steam turbine. Only the Independent Power Producer option was evaluated, but we estimated the costs using two different fuel costs: $2 per ton and $60 per ton. The cost of electricity ranged from 5 to 13 cents per kilowatt-hour.

More information and references on biomass potential can be found in Biomass.

Table 7 Cost of Electricity from Biomass

	Nominal Levelized Cost Of Energy $/kWh	**After-tax Internal Rate of Return (%)**
IPP with $1,110/kW Capital Cost and $2/Ton fuel	$0.0545	23.32%
IPP with $1,800/kW Capital Cost and $60/Ton fuel	$0.1333	17.54%

E. GEOTHERMAL ENERGY

Geothermal energy comes in two types: hot and cold. The cold geothermal source is the average ground temperature, generally 50 to 55 degrees Fahrenheit. This resource cannot be used to make electricity, but it can be used to heat and cool buildings using heat pumps. Heat pumps work best where the average ground temperature is significantly different from the high and low air temperature extremes, or where there are significant heat loads, such as in large commercial buildings. Heat pumps can be very efficient, producing as much as nine times as much heating or cooling capacity as energy input. There are several different technologies for heat pumps, some involving the installation of copper piping filled with freon or other material. Different technologies are appropriate in different climates and specific locations.

Hot geothermal energy comes from hot springs and volcanic features. These systems use hot water or steam from underground to run turbines. Sometimes water is injected into the ground to produce the necessary steam. You can see whether you live in an area with significant resources by checking at http://www.eren.doe.gov/geopoweringthewest/geomap.html.

The major environmental impact of geothermal power generation is the release of hydrogen sulfide, which is a naturally occurring substance in hot springs. Hydrogen sulfide is a corrosive, toxic gas with a rotten egg odor. It can be removed from air streams using conventional technologies.

Geothermal power generation costs are competitive with natural gas power plants (about 2 to3 cents per kilowatt-hour). Most geothermal sources of this type are owned through mineral rights. The limitation on their use is that many of them are in remote regions, and the cost of installing transmission lines to get the power to customers in cities is substantial, and often prohibitive.

F. HYDROPOWER

Hydropower uses the energy of falling water to turn turbines and make electricity. In most of the developed world, the commercial size hydropower locations have already been identified and exploited. Small systems can generate from 50 kW up to several thousand kW. While most plants have dams, some use a small canal to channel water through a turbine. These are called run-of-river plants.

Small hydropower sites are categorized as low or high head. The higher the head the better, because higher heads take less water to produce a given amount of power and use smaller, less expensive equipment. Low head refers to a change in elevation of less than 3 meters (10 feet). A vertical drop of less than 0.6 meters (two feet) will probably make a small-scale hydroelectric system unfeasible.

Detailed directions on how to determines whether a small stream is useful for generating electricity and how much energy production is likely to get can be found at http://www.eren.doe.gov/consumerinfo/refbriefs/ab2.html.

The biggest environmental concern with hydropower is the blocking of fish passage. In streams with fish runs in them, it is advisable to install hydro systems only where there is a natural break in the flow (a waterfall that fish cannot swim up).

G. HYDROGEN AND FUEL CELLS

Hydrogen is not a source of renewable energy. It is an energy storage medium in the same way that gasoline is. The advantage of hydrogen as a fuel is that it burns completely cleanly—the only emission is distilled water. Using renewable energy sources to produce hydrogen makes this fuel an almost impact-free energy carrier. Hydrogen can be used to power cars as well as to make electricity when renewable resources are not available. As such it has the potential to correct the major problem with renewable energy resources, that they are not dispatchable.

The way it should work is that energy from a renewable source, for example a wind turbine, is sent into the grid for immediate use, but when the grid can accept no more energy, that electricity is used to generate hydrogen, which is stored in tanks. The hydrogen in the tanks is fed to a fuel cell that generates electricity when the wind is not blowing. The hydrogen can also be used to fuel cars and other vehicles.

Hydrogen can be made by the direct electrolysis of water, converting water to hydrogen and oxygen. Hydrogen can also be generated by a process called steam reforming, which uses water and a fuel, for example gasified biomass or methane from a landfill. The hydrogen is then compressed and stored in special tanks or in underground storage facilities.

There are several different types of fuel cells on the market, though they are still not a mass market by any means. They all operate by separating electrons from hydrogen to make a current and combining the hydrogen with oxygen to make water. These reactions are all catalyzed, typically with a precious metal. Active research is underway to substitute other materials for the precious metals. This will reduce the cost of the fuel cells as well as eliminating the relatively high environmental impacts due to mining and refining precious metals.

Currently, the cost of fuel cells, electrolyzers and hydrogen storage equipment is quite high. However, they are expected to be quite commonplace in the decades ahead.

H. GETTING THE OVERALL ENERGY RESOURCE PICTURE

Now you have all the information you need to see if you have enough renewable energy resources to meet the needs of your community.

You need simply add up all the energy types to get a total energy resource, and compare it to the total energy consumption for your community.

Vashon-Maury Island Renewable Energy Potential

	MW years/year
Solar PV	24 to 700
Wind	6.7 to 10.5
Biomass	0.6 to 2.4
Tidal	≤1.5

For the Vashon Island case, there was more renewable energy available than there was energy use. Surprisingly, the largest energy resource was from photovoltaics, even in the cloudy Pacific Northwest. Of course, the photovoltaic opportunity is the most expensive one, so significant financial and political barriers will have to be overcome to accomplish energy independence here.

V. MATCHING ENERGY NEEDS TO ENERGY RESOURCES

The data you have gathered and the results you have calculated can only tell you whether it is possible to produce the energy you need. It does not tell you whether or how you should proceed. In most places, making this decision will be a political and a public decision process. To have a good public decision process, you need to educate and involve the public in decision-making, and work with the relevant governmental bodies and utilities.

Educating the public can be done in many ways—none of which are mutually exclusive. Some of the ways to provide education include working with the media, working with the schools and doing direct mailing. Since efforts towards making a community more sustainable are clearly in the public interest, most local media, including newspapers, radio stations, local magazines and even local TV tend to be willing to give you free space. Just deciding to do a community energy assessment gives you a good reason to send the media a press release. Once you have done your preliminary assessment, you have the basis of additional press releases. People like to know about how much energy they are using and how they stand relative to the rest of the country. Thus the project provides good content to the media. Speaking before community councils or similar bodies automatically brings the media coverage that you need.

Educating the public also takes place through the schools. Preparing a package of information that goes to the schools and volunteering your time to speak to school children pays off, because kids take home the information they get to their parents. The children can be your ambassadors to the community.

The next step is involving people. This can happen in several ways. Local governments may form committees of local interested citizens to address the issue. Local non-profits may take up the effort to make their community more sustainable. Most communities have residents with knowledge and skills that are applicable to energy issues, whether they are electricians, engineers, academics or fuel vendors. Seeking out these individuals and asking for their help will improve the outcomes for your community.

Community decision-making can take place through public hearings or through polling (official or unofficial). In most communities there are local leaders who will take on the issue of energy independence, since it speaks to the long-term sustainability of the community. The key to the success of the community decision-making process is that it be open and inclusive. Most people in any community are too busy to attend public hearings, but it is essential that they are given an opportunity to attend and that all discussions and results from the meetings be well covered in the local media. On Vashon-Maury Island, the community action is taking place largely through the community group, Sustainable Vashon.

One thing to consider is that there may be infrastructure changes needed to convert your community to a distributed energy system. Even if that is not needed, there needs to be a change in approach by your utility and regulators in order to accommodate the changes in the electrical grid. Issues such as worker safety, energy reliability and the cost of modifying the electrical grid to accommodate many small sources instead of a few large sources must all be addressed. In many locations these can be addressed in local utility approaches, but in others they are reviewed during the permitting of energy installations.

A. IN CONCLUSION

The process described here can help communities make a first estimate of whether energy independence is a good option for them. This information is enough to begin public outreach and discussions with utilities and others, but a full engineering assessment needs to be done before particular non-housing projects are undertaken.

Moving towards energy independence is an excellent way to secure the needs of future generations, a primary goal of sustainable development. The path moving from fossil fuels to renewable resources will not be traversed overnight, but must be seen as the journey for a generation.

This document points the way for communities, especially in the United States to play their central role in sustainable development of energy resources. We invite communities worldwide to step on this pathway and chart their own journey forwards.

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