

Community Energy Choices

Guide and Planning Overview

Tristan Morris & Albert R. George (arg2@cornell.edu)

October 27, 2011

Interim Report – With Appendices (Revised 10-27-2011)

This September 26, 2011 Interim Report includes the complete background for a procedure to guide community energy choices. However, it does not yet include all the individual energy sources and energy savings methods that will be covered in the final report. For example, the final report will add further information on such topics as geothermal heat pumps, improved insulation of buildings, biodiesel, and other topics. We expect the final report to be available in early 2012. The Excel spreadsheet that is being used for carrying out calculations is being documented and edited for easy use and easy modification and is expected to be released in the beginning of November 2011.

This document outlines a process developed with the assistance of the Cornell Cooperative Extension and the town of Caroline to help small communities develop new energy use and production models centered around “green” energy sources. It is intended for consumption by community organizers and planning officials, as well as technically inclined members of the general public. As a sample case it uses a community roughly modeled to be similar to the Township of Caroline in New York State to help make the report more applicable to its users.

Community Energy Choices

Contents

Project Statement	4
Planning Overview	6
Declaring Goals	6
Determining Possible Available Funds.....	7
Ranking Available Options	8
Final Selection	8
Sample Case	9
Decision Tree.....	9
Goals and Background Information	9
Reading the Results of the Calculations.....	11
Interpreting Results	13
Final Selection	13
Possible Sampletown Energy Development Plan	15
Appendix A: Power Metrics Discussion	17
Appendix B: Economics of New Energy Systems	20
Overview	20
Raising Funds	20
Collecting Returns	22
Ranking Available Options	23
Appendices C – Summaries of Information on Various Energy Systems & Conservation Method....	26
Appendices D – Detailed Information on Various Energy Systems and Conservation Methods	

Introduction

At the national, state, and local level, many governments in the United States are beginning to perceive a number of benefits in investing in the development of new energy systems. This can be for purely economic reasons – based around the need for a sound energy policy that provides adequate power at a reasonable cost without excessive price fluctuations and that lessens our dependence on foreign energy suppliers. But there is also a growing demand for new energy systems based on less immediate interests. Ethical concerns regarding environmental conservation can be important. There is an increasing demand for sustainable power sources and people are becoming aware of the coming transitions away from dependence on fossil fuels. This creates an environment where many governments are looking to alternate power sources -- even if they do not have any direct objections to their present power supply. The federal government and the individual states have widely varying approaches to this problem, but local governments often find themselves facing sharply limited resources. Information on the development of new power systems at the local level is not widely available, and collecting it is beyond the resources of many local governments.

Cornell University has partnered with the Town of Caroline to help create an information base for an energy development plan for the township that can serve as a model for other localities as well. This plan's purpose is twofold – to offer policy and technical advice to the Town of Caroline relevant to their specific needs, and to outline general information, research methods, and decision making methodology generally applicable to small communities that might be considering a similar development plan. By arranging general information in a format that lends itself to cost-benefit analysis based on the energy resources available in a given location, and giving costs and probable returns for the surveying and research required to find those resources, this report will greatly speed the decision-making process for any local government that wishes to follow Caroline's example of examining what options might be most beneficial. It will also provide local governments that may be unclear as to the nature of their options with a "jumping off" point, allowing them to orient themselves as they consider new power development options.

At the end of this report is a specific, sample plan for a town modeled approximately on the Town of Caroline, fully working through the methods in this report in order to demonstrate their application and produce specific technical advice. This sample is not intended as a direct advisement to action, but rather, serves as an example of how such plans could be generated for the Township of Caroline, allowing them to easily modify it to their needs. This plan was not made in full partnership with the town of Caroline, but rather was made by the authors based on their limited knowledge of Caroline, with the assistance of the organization "Energy Independent Caroline" (<http://www.townofcaroline.org/energyindependent/>) and Cornell Cooperative Extension. However, it was tailored to be more illustrative and, as a result, while it is believed to be fully technically accurate, it may not reflect the actual wants and desires of the overall Caroline community.

Project Statement

This report endeavors to:

- Offer Guidelines for Energy System Modification Decisions
 - Clarify specific priorities that must be established before planning.
 - Offer systems for turning those priorities into specific goals.
 - Introduce 4 “Basic” goals.
 - Cost Efficacy
 - Local Sustainability
 - Energy Independence
 - Environmental Friendliness
- Present Basic Information on Standard and Alternative Power Sources
 - Offer a one-page, two-sided visual summary of each technology’s merits and advantages.
 - Provide technical data on each technology using a series of standardized metrics.
 - Show cost-efficacy data to assist local governments.
 - Present information to help local governments determine if they need to hire professional advisors to perform full technical analysis
- Present Widely Applicable Energy Saving Techniques and Technologies
 - Offer one-page summaries of strengths and weaknesses as with power sources.
 - List possible financing plans for each technology in order to maximize energy saved.
 - Demonstrate methods to select which energy saving techniques are significant return investments on a given timeframe.
- Develop Sample Plan for the Town of Caroline
- Demonstrate Sample Timeline and Budget

Executive Summary

While the actual technical details of developing new power saving and renewable power generation options can be very complicated, they are not something a community interested in developing new power options need consider in the initial stages of energy decisions. Expert assistance is available for a small fraction of the total installation cost, and should always be used before and during the actual construction and installation process. However, such expert assistance is not free, and so communities should only use it for new technologies that they are seriously interested in developing. This report enables communities to determine what new power technologies are practical for their area and budget and to help them decide what new infrastructure they should be considering.

The first step in this process is to create fully defined goals. Formally defining goals can be awkward, but is important for determining what technologies are useful in achieving those goals. This report simplifies that process by using four “basic goals” on which communities can rank themselves, allowing them to create a simple guideline: Cost Efficacy, Local Sustainability, Energy Independence, and Environmental Friendliness.

Once a community has formally determined its goals, the next step is to determine the total amount of money the community could raise in various ways. This includes government grants, bonds, community support, and pledges from supportive businesses. Some idea of these figures is required because often more expensive power sources are more efficient, and so having a ballpark figure for the maximum investment available greatly simplifies that part of the decision-making process.

Using the goals and amounts of money potentially available, unaffordable energy sources can be eliminated; all remaining energy sources can be given an “adjusted price”, reflecting the “value” they bring to the community. Ranking these power sources from most to least desirable and eliminating socially undesirable options produces a basic list of variable power source technologies for the area.

Improving energy use efficiency and preventing waste is almost always the most desirable way to meet energy, environmental, and societal needs. Thus, finally, by combining the ranked source list with already available data on improving energy use efficiency and preventing waste, the community can produce a list of the best investments of their time and resources in order to accomplish their energy goals. This list will then provide an excellent foundation for community discussion and planning on how to best fulfill their town’s energy needs, and allows expert consultation to be arranged without the potential for inefficient use of funds.

The actual process of creating this list requires a reasonable amount of technical data, which is contained in the report’s appendices – however, an Excel file has been created that performs most of these calculations automatically. (This Excel file is not presently attached to this document; it is being edited be usable by the public and is expected to be available by the end of October 2011.) After the main body of this report, a one-page summary of each item of technology considered so far has been included. It gives a brief overview of the technology, as well as a number of standardized technical metrics for evaluating its performance. These sheets are provided in order to give an accessible overview of the technical concerns involved. The final version of this report, which is expected to be released early in 2012, will include more source and conservation technologies than the present interim report.

At the end of the report, the methods contained inside are used to fully work a possible example case for the somewhat similar to the Town of Caroline. This is not intended as a recommendation or even to represent Caroline’s interests accurately, but merely to showcase how the methods contained in this report function.

Planning Overview

Declaring Goals

Abstractly, most community activist groups looking for sustainable power options want the same thing – for their community to be a greener, more prosperous and more verdant place at reasonable economic cost. Practically, there are many different ways renewable and local power options can be used to help accomplish those goals, depending on exactly what the community is looking for. “Make the community better” is not a goal that can be used for decision making by putting it into a community process, computer program, or spreadsheet, and so a more formal definition is required for planning purposes.

One way to more easily produce a formal definition of a community’s goals is to use pre-calculated metrics, which can represent common goals. This report uses four metrics: Cost Effectiveness, Local Sustainability, Energy Independence, and Environmental Friendliness. Each rank, or rating in each of these goals corresponds to, say, a roughly a 2% increase in the value of energy infrastructure that advances that goal. For instance, a town that gives itself a score of 1 on the Environmental Friendliness metric is expressing that it considers green, environmentally friendly power to be about 2% more valuable than normally produced power. Most communities will therefore be unlikely to rate themselves above a 5 in any of these categories as that would imply a 10% increase in energy costs. Thus a rating of 5 in a goal is considered “extremely committed” to that goal. In general, this report assumes a community will rank itself 0 to 5 on each of these goals, though higher rankings are possible in this process.

- Cost Effectiveness
 - Some renewable energy technologies pay for themselves – money goes in, and over time, money comes out. By the same token however, some do not – using up money but producing other desirable results. The cost effectiveness metric helps define the line between those two points – a measurement of how long the community is willing to wait to see a return on an investment. Roughly speaking, a community is willing to wait twice as long in years as their rating on this metric to see a system pay for itself. For instance, if a Solar Panel takes eight years to pay for it, but a community is only willing to wait four years to see a return on their investment, then the last four years are not counted when determining the effective price of the panel. Thus, the higher a communities rating on this metric, the more long term investments the decision system will produce.
- Local Sustainability
 - A solar panel farm owned by the power company and operated in a distant town away is not technologically different from a power farm owned by your neighbor and operated next door. It may have different features, or different add-ons – but fundamentally, panels are panels. They produce power for about the same cost, with about the same environmental impact – but the money you pay for power from one goes to the power company, while the money you pay for the other stays in your town. And for many, that makes the solar panels next door better. Supporting this kind of local business is a key goal of many communities, and this metric supports that.
- Energy Independence

- For communities that pride themselves on their independent nature, true energy independence – that is, the removal of their town or parts of its energy supply from the main power grid -- may be an objective. This is usually much more expensive than simple local power generation, as the grid provides many useful services, but it can be done. This metric is advanced by having enough reliable power at all times to power all the needs of the community. This is difficult to achieve fully but may be possible for some partial power needs.

- Environmental Friendliness

- Environmental friendliness is a broad term, but every day more communities are embracing it in some respect -- becoming aware of the impact they have on the environment around them. At present this report does not include any particularly polluting power sources – every power source inside it is at least somewhat better than the national average for carbon emissions and other measures of environmental friendliness. But, some communities are willing to pay more for cleaner power, and the environmental friendliness metric measures their commitment to that goal.

Obviously, four numbers on a simple scale cannot summarize the full complexity of a town's goals in pursuing new power options – but they can go a long way to defining a community's economic objectives. This report's decision making methodology does not make a final recommendation for power options, but produces a list that sorts potential developments by economic standards for further consideration, and so these simple metrics should be helpful.

Determining Possible Available Funds

Eventually -- for a community that is serious about developing renewable power systems through careful cycles of development and investment -- the money to pay for new developments may come from the proceeds of old developments. But for the initial, smaller cycles of investment, the community will need to raise money on its own. Since most small communities will probably not want pay for this sort of endeavor with taxes, they must raise funds by other means.

The most efficient way to raise these funds – although not necessarily the easiest – is to collect commitments from members of the community, businesses, and other institutions to buy the generated power at a slight markup over common electricity costs. This reflects the approximate measure of economic commitment used in the metrics above, and provides a steady, general source of income without asking for money directly.

Alternative methods of raising money include levying a bond or taking out a loan from a bank or other private institution. Also one can apply for a government grant, or receive private funding. These can be generally lumped under the categories of a subsidy, or a lump sum investment. To some extent, the labor of the community can be counted as a subsidy – reducing the construction and labor costs of a project, if possible.

Appendix B contains more information on potential means of raising funds, as well as calculating the expected return of those means – but the decision-making methodology presented later in this report distills the result into five measures: Immediately available funds (representing money that can be raised immediately), potentially available funds (representing loans and the like), subsidy (a percentage discount of cost), and purchasing percentage (the amount of power that has been committed to be bought at what percentage price increase over normal). In lieu of formal calculations, rough numbers for each category can be used to produce an approximate result.

Ranking Available Options

Once available funds and goals are determined, power options can be properly ranked and sorted – We have automated this in an Excel file which is being made easier to us and is expected to become available by the end of October 2011. Although the details of the math can be fairly complicated, the basic methods used are quite simple.

The first step is to eliminate unaffordable options. Each potential new power source or technology has a listed minimum cost. Power sources with a minimum cost higher than the sum of the immediately available funds and potentially available funds can be removed from consideration – the town simply cannot raise the money for their construction. (Of course, the community could reevaluate how it might obtain more money if they wanted, making this an iterative procedure.)

Power sources with a minimum cost higher than the immediately available funds but within the range of potentially available funds have their construction costs adjusted to reflect the difficulty of raising the money to construct them. The community's Cost Effectiveness rating is used to make the final adjustment to the construction cost – discounting the inflation-adjusted returns the power source will produce over the town's period of patience.

The second step is to adjust the power sources' effective outputs. Here, the other three goal metrics are employed – each one is used to adjust the effective output of a power source by its given percentage, based on how much the power source accomplishes that goal. For instance, a power source that was only at an average level of environmental friendliness would not have its effective output adjusted upwards based on the Environmental Friendliness metric – but a particularly clean power source would. The cleaner the power source, and the higher a community's Environmental Friendliness metric, the more its effective output is adjusted upwards. This makes power sources that accomplish the community's goals proportionally more valuable.

The third step is to rank the power sources by their adjusted cost effectiveness – their effective yield divided by their effective cost. This ranks the power sources by their effective benefit to the town against the effort it would take to raise the money to produce them, creating a reasonable guide for which options should be first considered.

The fourth and final step is to add power saving technologies to the list. Power saving technologies have different technical specifications, and so must be handled somewhat differently, but saving power is often more desirable than producing it. The economic specifications for a number of common power saving methods and technologies can be pre-calculated and included in the Excel file. One example is given in this Interim Report. Adding power saving methods to the list and sorting them with the power sources produces a complete list of the town's power options, arranged in order of likely feasibility.

Final Selection

The list of power source and savings technology produced by the methods above takes into account the key economic factors involved in the options a community is presented with – but it does not reflect other concerns the community may have. For instance, wind power may produce more noise than some persons in the community find acceptable, or there may be a particular strong interest in developing new micro-hydro power in local streams. The list is therefore intended as a guide – allowing a community to move along it from top to bottom, accepting or rejecting the items one at a time. What is left is a greatly truncated list of possible options, making it possible for a community to seek expert consultation for some of them without undue expense.

Sample Case

Decision Tree

This sample case serves as an example of how to employ the data and methodology contained in this report. It is a simplified hypothetical example, Sampletown, derived but modified from the actual Caroline case, so as to make the techniques explained here clearer. The data used in this example case is generally reflective of realistic conditions. However, since it has been artificially generated to ensure it showcases all of the features of this report's decision methodology, it is **not** particularly reflective of any particular real world community's interests, and should **not** be employed in an actual decision making process. I.e., while the Town of Sampletown in this example case is based on the actual town of Caroline, certain assumptions have been made and certain details have been altered in order to make it a more effective example. It should not be taken as any statement reflecting the goals or resources of the town of Caroline.

In order to more clearly illuminate why one power source would be selected over another in full detail, only five power sources and one power conservation method will be considered in this example case. The methods used to analyze them should be applicable to any number of power source or saving technologies.

Some of the information contained in this report has a very large range, making the information somewhat vague – this is because the report must cover a wide variety of potential technologies. For instance, the range of possible productivity for solar power systems includes solar power systems built anywhere from the equator to near-permafrost regions. If more specific information is available, it is possible to manually enter it into the Excel sheet, and then analyze it using the methods covered here.

It is also possible to manually enter new power sources that this report has not yet included. The Excel file will automatically update itself to process them properly.

Goals and Background Information

First, the community's goals must be determined, and its economic information entered. In this example, the Town of Sampletown wants their community to be more independent and environmentally friendly. The town is split on whether environmental friendliness is important, but can definitely agree that they would like the community to produce more of its own power, particularly because that means the money stays in the community. Although they would like the town to produce more of its own power, they do not think that going "off the grid" is particularly important. The community's members are fairly patient, as they plan to live in the community for some time, but not all of them plan to retire there, and so they would like to see their new power developments pay for themselves within 10 years, giving a "Cost Efficacy" rating of 5.

Based on these considerations,

	A	B
1	Goal Data	
2	Goal:	Rating:
3	Enviromental	1
4	Cost Efficacy	5
5	Self-Sufficiency	3
6	Independence	0

Sampletown can give itself an Environmental Friendliness rating of 1, a Cost Efficacy (Acceptable Payback Time) rating of 5, a Self Sufficiency rating of 3, and an Independence rating of 0. These values can be entered into the Excel sheet (as shown above).

In order to try to accomplish these goals, Sampletown has secured a promise from a nearby university to buy 250,000 kWh of electricity from the town at 10% above standard rate. Twenty-six members of the community have also agreed to purchase power at 10% above the standard rate, for no more than one year each. The average house in Sampletown uses 920 kWh of electricity per month, so this amounts to a promise to buy another 287,000 kWh of electricity, for a total of 537,000 kWh pre-purchased. Looking up the price of electricity in the area, Sampletown finds that the average price of electricity, including delivery charges, is \$0.17/kWh, while the power company will buy their excess power for \$0.10/kWh. This information can be

	A	B	C	D
1	Average Price of Electricity per kWh:			
2	Purchase:	\$ 0.17	Sell:	\$ 0.10
3	Economic Data			
4	Inflation Rate	3.5%		

entered into the included Excel spreadsheet, along with the current inflation rate (example left). This general information is important for many economic calculations the Excel spreadsheet will perform later.

In addition to these purchasing promises, the town of Sampletown has been able to raise a total of \$3000 from donations or a bond levy rendered to its members, and another \$4000 from taxes and other funds that have been made available for the towns use. After consulting with a bank and members of the community, the town has estimated it has a potential credit line of approximately \$30,000, available at 8% interest. (Companies responsible for the creation of various renewable power systems also will often provide loans to their clients at varying interest rates in order to aid in purchasing.) In this case, the town is potentially interested in Solar PV, Wind, Mini-Nuclear, Concentrated Solar, and Biomass Gasification. The community was able to research corporate offers for construction loans, and add them to each individual technologies entry in the Excel sheet.

Goal Data	
Goal:	Rating:
Environmental	1
Cost Efficacy	5
Self-Sufficiency	3
Independence	0

Economic Data						
Power Category:	Immediate	Potential	Interest	Subsidy	Purchase (kWh)	Purchase (\$/kWh)
General	\$ 7,000.00	\$ 30,000.00	8%	10%	537,000.00	\$ 0.19
Solar PV	\$ -	\$ 50,000.00	10%	40%		\$ -
Wind	\$ -	\$ 30,000.00	9%	30%	-	\$ -
Nuclear	\$ -	\$ -	0%	20%	-	\$ -
Concentrated Solar	\$ -	\$ 70,000.00	12%	40%	-	\$ -
Biomass Gasification	\$ -	\$ 2,000.00	8%	10%	-	\$ -

Finally, there are numerous state and federal subsidies that apply both in general, and to specific power sources. After some research, Sampletown discovers that they qualify for a \$5000 federal grant to develop renewable power sources in small communities, a 10% federal subsidy for the development of new small town power systems, and numerous federal and state incentives that subsidize solar, wind, and biomass based power sources. They add these to the Excel sheet, completing the economics section of the sheet (as shown).

Reading the Results of the Calculations

With the town's economic and goal data entered, the Excel sheet can perform its calculations. As all of the technical data for the power sources under consideration has already been entered, the Excel sheet will immediately produce the final result. However, all of the intermediate steps are displayed for the user's own reference. They are explained in the planning overview above.

The final results condense this information down into seven key numbers: Payback Period (i.e., Unadjusted Period, Monetary Period), Goal-Adjusted Period, Premium Purchase Capacity, Premium Purchase Period, Targeted Purchase Capacity, Targeted Purchase Period, and Average Cost.

Payback Period is the actual period, measured in years, it will take for a new technology to fully pay for itself (including capital and basic operating costs in the period) assuming the power is purchased at standard market rates. Goal-Adjusted Period is a weighted number, designed to indicate how quickly a technology fulfills the town's goals. For instance, if a town indicates that Environmental Friendliness is only somewhat important, environmentally friendly power sources will just have a slightly lower Goal-Adjusted Period. However, if they indicate that environmental friendliness is very important, environmentally friendly power sources will have a *significantly* lower Goal-Adjusted Period. As with Payback Period – shorter period is better.

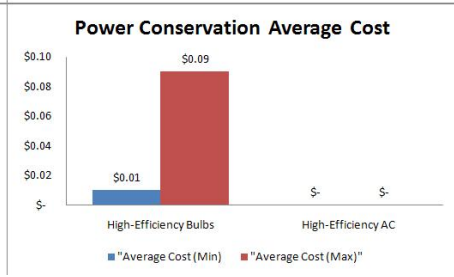
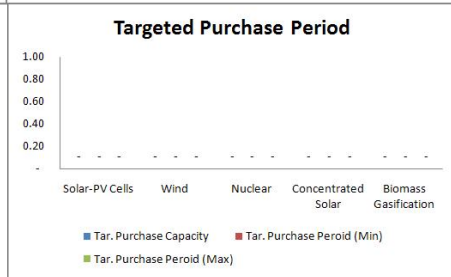
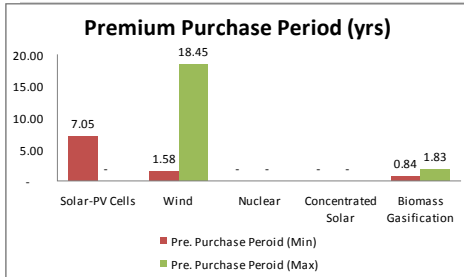
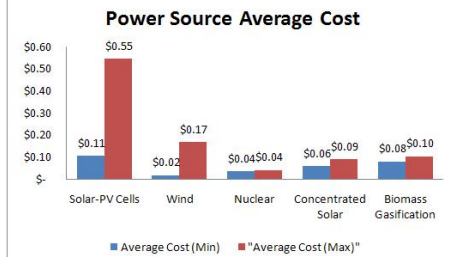
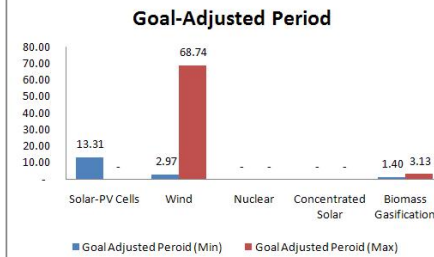
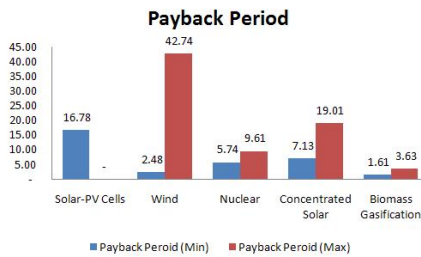
Premium Purchase Capacity refers to the capacity a power plant would need to fulfill all of the town's premium purchase offers – that is, offers to buy a certain amount of power at an increased rate, a common way of raising funds. Premium Purchase Period refers to the payback period if this hypothetical power plant, assuming it sells all its power at the premium rate. Targeted Purchase Period and Targeted Purchase Capacity reflect the same numbers -- except for offers to buy power only from a specific kind of source, instead of from the community in general.

Average cost refers to the total life-to-death cost of a new device, measured per kWh (Kilowatt Hour) produced or saved over its entire lifespan.

These results are displayed in both tabular and graph format.

Final Output (Sorted)															
Name	Minimum Cost	Marginal Cost		Goal-Adjusted Period		Payback Period		Premium Purchase Capacity (kW)		Premium Purchase Period		Targeted Purchase Capacity (kW)		Targeted Purchase Period	
Solar-PV Cells	\$ 5,000.00	\$ 2,318.25	\$ 4,868.32	13.31	N/A	16.78	N/A	32.26	7.05	N/A	N/A	N/A	N/A	N/A	N/A
Wind	\$ 13,121.88	\$ 1,081.18	\$ 3,603.93	2.97	68.74	2.48	42.74	18.86	1.58	18.45	N/A	N/A	N/A	N/A	N/A
Nuclear	N/A	N/A	N/A	N/A	N/A	5.74	9.61	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Concentrated Solar	N/A	N/A	N/A	N/A	N/A	7.13	19.01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Biomass Gasification	\$ 2,400.00	\$ 1,123.60	\$ 2,247.19	1.40	3.13	1.61	3.63	7.01	0.84	1.83	N/A	N/A	N/A	N/A	N/A

	P	Q	R	S	T	U	V	W
Power Saving Data								
Name	Minimum	Average Cost (kWh)			Marginal Cost (W)		Peroid	
High-Efficiency Bulbs	\$ 10.00	\$ 0.01	\$ 0.09	\$ 0.02	\$ 0.26	0.09	N/A	
High-Efficiency Appliances	\$ -	\$ -	\$ -	\$ -	\$ -	-	-	
Solar Thermal Heating	\$ -	\$ -	\$ -	\$ -	\$ -	-	-	
Leak Sealing	\$ -	\$ -	\$ -	\$ -	\$ -	-	-	
Geothermal Climate Control	\$ -	\$ -	\$ -	\$ -	\$ -	-	-	



Interpreting Results

Goal-Adjusted Period is the first result to be considered – it measures how quickly a technology can serve to fulfill Sampletown’s interests. All the relevant data for this consideration is contained in the Goal-Adjusted Period graph (above). The lower the adjusted period, the better a given power option is for Sampletown. In this case, Biomass Gasification is clearly the best option if biomass input is available – followed shortly by wind *but only if* Sampletown is in an area with particularly significant wind resources. Solar power comes in a distant third overall – however, should Sampletown prove to be an area with significant solar resources and inferior wind resources and this information used to refine the estimates of energy costs and outputs and , it could supplant second place. Nuclear and concentrated solar power facilities are beyond the resources of Sampletown, and so may be removed from consideration.

The next factor to be considered is the Premium Purchase Period. Since there are no specific purchase options in this scenario, all the relevant data is contained in the Premium Purchase Period graph (above). In this graph, the fundamental order of power technology favorability remains unchanged – however, the difference in period between wind and biomass is now significantly reduced, with wind possessing a significantly higher Premium Purchase Capacity. This may make wind a more favorable #2 choice, affirming what the earlier graph suggested. Examination of the payback period graph yields similar results.

With biomass as a first choice, wind as second, and solar-PV as third, it is possible to look at the Average Cost graph, in order to compare it to potential power conservation technologies. In this example case, Sampletown is only considering energy efficient bulbs as an alternative to new power generation technology. In comparing these two graphs, energy efficient bulbs have lower average cost than the considered power sources in almost every case. Thus, for comparable period, they are the superior option for Sampletown.

Examining wind powers technical summary, we see that it has surveying costs in the range of \$10,000 to \$15,000 before construction can begin. Given that Sampletown’s total potential budget is only \$37,000, this makes wind an unreasonable consideration unless wind is going to prove to be Sampletown’s only power option. Given that wind is a shaky second in economic consideration, and its average output is significantly worse than biomass or favorable solar-PV, this flaw is likely enough to merit removing it from consideration.

With wind eliminated, Sampletown’s options have been reduced to two power sources – one available only in discrete units, one in flexible quantities – and one power conservation device, available in flexible quantities. This is a sufficient narrowing of possible options to move onto final power plan selection.

Final Selection

Examining biomass gasification’s power handout and appendix, we see that biomass gasification generators tend to come in manufacturer specified sizes, depending on what and how much biomass is easily available in the area. Deciding on the amounts of biomass available and contacting manufacturers would be Sampletown’s next steps in this example case, in order to get more specific information. Likewise, a Solar-PV provider would be contacted in order to ascertain better information for the expected yield of solar panels. This gives Sampletown flexibility in how it allocates its funds. By selecting the optimized sized and typed biomass gasification generator for the area, and then “filling in” their remaining funds with Solar-PV options, Sampletown has the ability to produce a result that is most ideal for their goals and the funds at their disposal.

Power conservation options, such as energy efficient bulbs, may be preferable to new power sources, if their payback period and average costs are less than the available, feasible power options for Sampletown. Earlier, we saw that the average costs for energy efficient bulbs beat both solar-PV and biomass gasification, and

so only require a shorter payback period to be the superior option. Reading through the information for bulbs, we see that a bulbs payback period is primarily dependent upon how often it is used. A bulb that operates 24 hours a day has the startlingly low payback period of 0.09 years, allowing us to do some simple math. Going by fractions of the day, we can calculate that under standard conditions, to have a superior result compared to biomass gasification, an energy efficient bulb must be used to replace a bulb that operates for at least 0.94 hours a day. We can do similar math for the other power options:

Power Generation Option	Energy Efficient Bulbs Equivalent
Biomass Gasification (Standard)	0.94 Hours/Day
Biomass Gasification (Purchase Option)	1.61 Hours/Day
Solar-PV (Standard)	7.72 Minutes/Day (1 Hour/Week)
Solar-PV (Purchase Option)	18.38 Minutes/Day (2.1 Hours/Week)

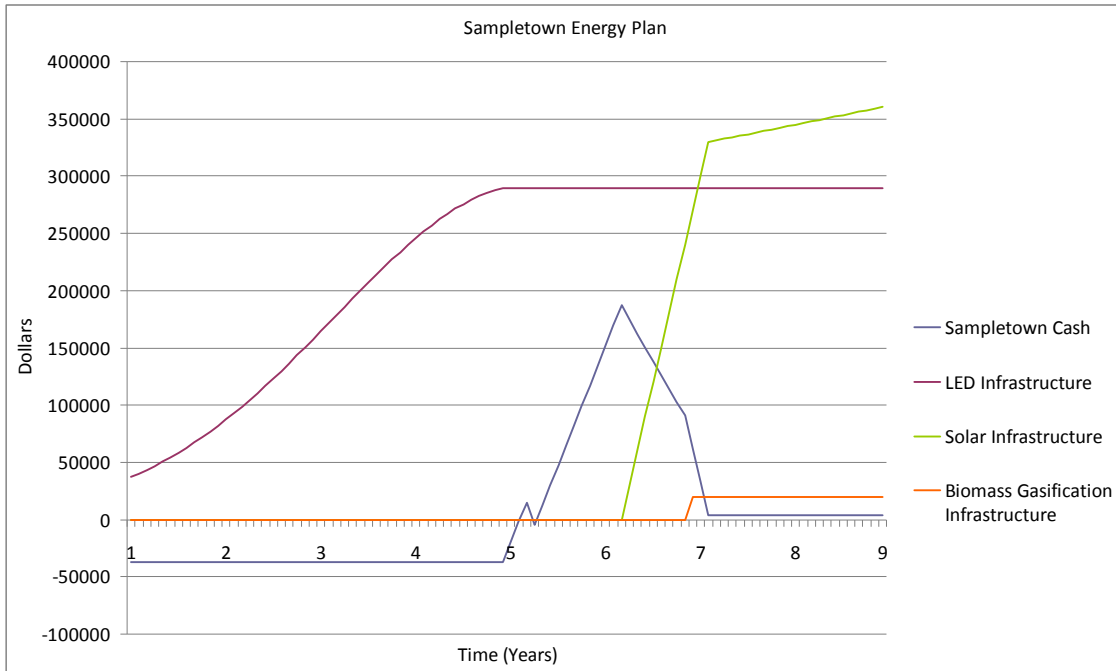
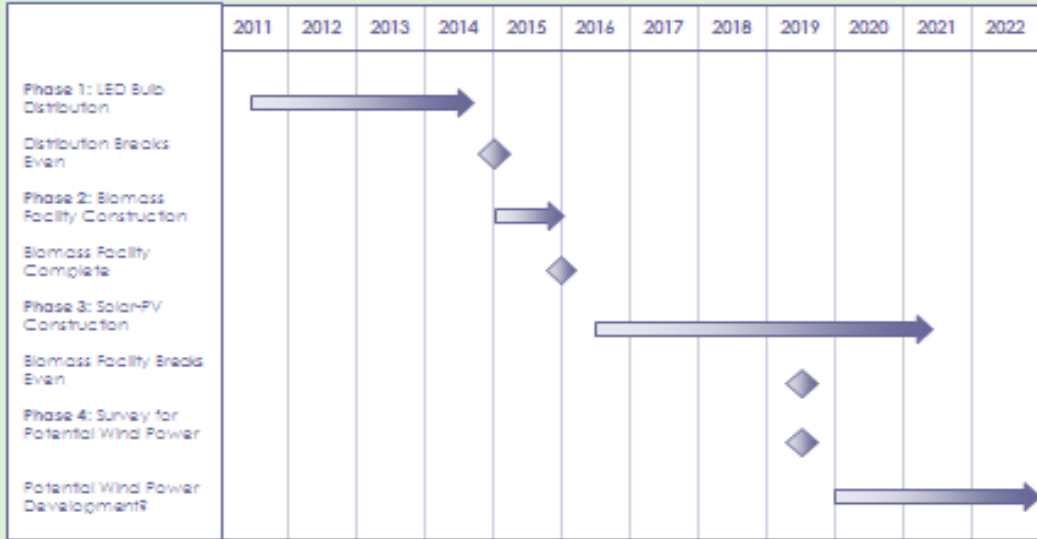
It seems that bulbs are clearly the superior option for Sampletown. The ease of tracking bulbs and measuring their total savings makes them an excellent primary power conservation option. In order to complete its search for more detailed information, Sampletown must determine approximately how many such bulbs can be found within it and might be replaced. Once that information – and the Solar-PV and biomass gasification manufacturer data are in hand – a final power plan can be created, focusing on the options that will most quickly pay dividends that can be used to develop more expensive power sources.

An example, phased, implementation plan is provided below, assuming typical Solar-PV performance for Sampletown’s area of New York, and wood-burning biomass gasification units based on waste wood types found in Tomkins County, including Sampletown.

Possible Sampletown Energy Development Plan

- Phase 1: Distribution of Energy Efficient Bulbs
 - In Phase 1 of Sampletown energy development plan, high-efficiency LED bulbs will be used to replace all remaining incandescent bulbs that meet specified usage limitations. These bulbs will be made available to all citizens of Sampletown, free of charge, assuming the town can fractionally collect the savings induced. (This may not actually be realistic.) From the town's initial investment, \$240,000 of bulbs will eventually be distributed over a four-year period, assuming an average of 8 replaceable bulbs per participating household.
- Phase 2: Construction of Biomass Gasification Facility
 - Once the debts incurred by Phase 1 are repaid in full, Sampletown can begin Phase 2, in which a 5kW biomass gasification plant is constructed to supply the community with electricity, employing waste wood gathered from public areas and neighboring forests, supplemented by imported wood waste. The 5kW size is selected in order to make full use of assumed available waste wood resources, bearing in mind that the availability of local wood waste will vary seasonally.
- Phase 3: Construction of Solar-PV Facility
 - Six months after the biomass gasification facility begins producing power, sufficient resources will have been accrued by the community to begin construction of rooftop solar-PV panels on public buildings and participating local homes. Over the course of five years, construction of a 50kW solar-PV field can be completed.
- Phase 4: Potential Addition of Wind Power
 - Depending on survey results, the addition of wind power to Sampletown's community power systems may be pertinent after the ten year mark.

Possible Samletown Energy Development Plan



Appendix A: Power Metrics Discussion

- **Economic Costs**

The economic costs of a given power system are represented as a *minimum cost*, an *average cost*, a *marginal cost*, and a *productivity ratio*. The minimum cost reflects the minimum dollar investment required to consider the technology, including the cost of any surveying required before construction. The average cost is the average dollar cost per kWh (Kilowatt Hour) the power system will produce under actual conditions over its lifespan. The *marginal cost* is the cost of adding an additional watt of capacity to the system, once the minimum has already been achieved. The productivity ratio is the ratio of the amount of power a facility actually produces, to the amount it would produce if it could run 24 hours a day year-round.

- **Environmental Effects**

The environmental effects of a given power system are represented by measurements of *carbon emissions* and *secondary emissions* as well as a list of *local environmental effects*. The carbon emissions measurement records the total percentage carbon emission of the system relative to the average. Thus, buying power from the existing grid would have a carbon emissions score of 100%, while a particularly inefficient coal plant might have a score of 200% or more. This metric includes the emissions used in producing the system, driving it to the final site, disposal, etc, and so no system has a score of zero. A very clean system, such as solar panels, has a score of 1-10%. The secondary emissions measurement reflects any potential emissions of metals, oils, groundwater contamination, and non-carbon based emissive concerns. The local environmental effects measurement covers erosion, deforestation, noise concerns, disruption of wildlife – and generally any non-numerical environmental concern.

- **Security**

The general security concerns of a power system are twofold – *local security* and *global concerns*. The former covers immediate, practical problems – is this system subject to theft or vandalism? Are there any potential safety risks? With these and other important questions, local security is more generally defined to cover any potential, sudden misfortune that could befall the power system. The global concerns metric reflects less immediate problems, which any given community will need to decide their interest in – will this technology send money which will help people or encourage corruption in the third world? Does it support Middle Eastern oil interests or overseas conflicts? Some communities may wish to consider alternative power just to avoid these questions, and so they are generally relevant to the decision-making process.

- ***Reliability***

An electrical engineer's job would be simpler if a 10 kilowatt power plant actually produced 10 kilowatts of power at all times. But in reality, energy systems of all kinds can have periods when they produce less than full power, and the average output of a system does not necessarily reflect its output at any given time. This is reflected with the two measures of *flexibility* and *regularity*. Flexibility measures the ability of a given power source to produce energy when it is most needed – a hydroelectric dam can fill its reservoir during low hours and drain it during peak load, but solar panels produce power only when the sun shines, regardless of if that power is needed or not. Regularity measures the ability of a technician to anticipate when a given system will actually produce power – while solar powers hours may be outside its operator's control, the movement of the sun is far more predictable than temperamental wind power. Each of these measures is put on a three-point scale: None, Low, and High.

- ***Connectivity***

Connectivity – the ability of a power system to be attached to the grid and supply power back to the power company – is significant for multiple reasons. It allows a power system to sell power and earn money during a period of surplus, and further allow some power systems to repay their creators investment in cash instead of savings. Unfortunately, not all power systems possess this ability – and for those that do, installing it is not always profitable. This metric discusses what interconnection options are available for a given power system, and how much it costs to install them.

- ***Zoning and Planning***

On the average, the government is a distinct positive influence in small communities search for reasonable power solutions. Although they are discussed relatively little in this report, government subsidies and incentives can open options that would never have been otherwise available. Unfortunately, government can also introduce some hindering regulation to the process. Even something as simple and inoffensive as solar panels can have significant zoning concerns associated with it, besides the regulations associated with potentially polluting power systems. This metric offers a brief discussion of the relevant regulations of each system, as well as an approximate dollar cost (should one be required) of meeting these regulations.

- ***Social and Community Impact***

Buying power from your neighbor instead of the power company keeps the money in the community, helping it to prosper. The construction of a solar power facility can bring new jobs, as can the cleanup of old, outdated systems. But in some areas, solar panels can potentially lower property values. It is possible that a temporary influx of hundreds of construction workers for a large new plant might cause spikes in crime, ambulance use, and emergency room visits. The social impacts of a given piece of technology are hard to

quantify, but this metric attempts to give an overview of them, reflecting how important they can be to a community's final decision.

- ***Land Costs***

Almost all power systems occupy land, but not all of them do so obstructively. The land costs of a system can be represented with measures of *exclusive* and *non-exclusive* use. Measured in kilowatts of capacity per square meter, these two metrics reflect a power system that is exclusionary in its land use, or that occupies very little of the space dedicated to it. A wind turbine farm occupies a far larger area than a power plant, but leaves most of that area open for agriculture or natural, wild spaces.

- ***Resource Opportunity Cost***

This report contains only a fraction of the many types of power systems available – but even it contains several distinct solar systems, different methods of lighting a home, and, eventually different sources of natural gas. In considering new power systems, a community must divide a finite amount of resources – and many of the options they face prohibit each other. Presented as a list, this metric lists what other power systems a given technology may exclude with its presence.

- ***Development Time***

Development time reflects the total period it takes to construct a given power system – from the day a final decision is made to the day it begins actually supplying power. This time includes all necessary surveying and professional assessment, as well as construction itself. This metric is important for scheduling as well as economic considerations.

- ***Survey Costs***

The final metric, survey costs reflect the cost of determining if a given technology is viable. The costs of construction surveys and other prerequisites to building a new power facility are included in its economic data – survey costs represents the investment to determine if a technology is suitable for the area, where the answer may be no. In effect, survey costs are how much money must be risked to consider developing a new power technology. For instance, Solar Power tends to have very low survey costs (as the sun's position is easily mapped), while hydro power requires more complicated river and river bank and geotechnical surveys.

Appendix B: Economics of New Energy Systems

Overview

Successful investment is a cycle. Money invested in new infrastructure and technical improvements yields greater returns – which can then be re-invested in more equipment which could not have been afforded before. This basic principle of business has several fundamental implications for community power systems development. It means that no power option is too expensive for a community – some power options just take longer to develop than others. It means that a community should think one step ahead, planning what power options are best now, and what developments will be part of the next cycle. And it means that to fully develop its renewable, local, energy potential, a community needs a way to capture the benefits of its power options in cash or capital.

Thus, the decisions a community needs to make are technical, legal, and economic. Each cycle of investment must suit the community's needs, but must also fit longer term, classical economic interests. It would be almost impossible to do this from the top down – finding the “correct” technical solution and then raising the funds for it. For most communities, it makes far more sense to work from the bottom up – determining what resources are available, and using that information to pick from possible options.

The economic advice given here follows this bottom-up reasoning. Starting with possible means of raising money and estimating available funds, it then moves on to possible methods of collecting a return on energy infrastructure investments, and then onto how energy systems are ranked. This puts all available economic data in the format that is used in Appendix C, which discusses the actual selection process in which, economic and technical data are combined to produce a final plan.

Throughout this appendix, the concepts of inflation and interest are used repeatedly. Most people are already familiar with these ideas, but how this report handles them bears mention. Inflation is, in simplest terms, the decrease of value of money over time. In these calculations, inflation is represented as a loss -- \$100 subject to 1% inflation a year “loses” a dollar for every year it sits unused. This causes options that require money to be stored for long periods to be rated less favorably. Interest – specifically interest on loans or bonds – is directly represented as increased cost. A project that is paid for with a \$100, one year loan at 5% interest has a “real cost” of \$105 dollars. This means that projects that require expensive loans to construct will be rated less favorably.

The actual calculations involved in each of these steps are simple, but can be somewhat lengthy. They are automated in the Excel file.

Raising Funds

The amount of money a community can raise is represented by five measures: Immediately Available Funds, Potentially Available Funds, Subsidy, and Purchasing Percentage.

Immediately Available Funds is the figure most probably thought of as raised money – the amount of money the community can raise in cash within several months time. Potentially Available Funds represents a sum of the amount of money they could raise over a considerably longer period, or through loans – including the interest that needs to be paid on those loans, if any. Subsidy represents a commitment from another organization – usually the government or a private trust – to support the development of the town's energy options, discounting construction price by a certain percentage. Purchasing Percentage represents a commitment by another body or group of citizens to buy a certain amount of power at a

certain percentage of the average price. While not technically money raised, this is an important factor for determining how safe an investment a given technology will be.

In order to raise these funds, communities have a number of different options, each of which contributes to the four metrics in a different way. Some examples are listed here, along with how much each one adds to each of the four metrics, but communities may want to pursue alternate choices.

Taxes

Taxes are an unpleasant proposition for any community – particularly small rural communities, which are often limited to more regressive taxes. However, they are also one of the most effective ways for a community to raise large amounts of money in a short period. By using tax revenue to take advantage of otherwise unavailable federal government subsidy, a community can produce a great value of infrastructure for a relatively small cost. A temporary tax – intended to raise a lump-sum of funds – is represented as an addition to immediate funds. A longer term tax that gradually raises money is represented by an addition to the potential funds measure – in effect, the town is loaning money to itself. The interest rate of this imaginary loan is determined by how long the tax money would have to be stored before being spent. In this case, the interest represents losses due to inflation (if any).

Bond Levies

Bond levies represent a fair, equitable way of raising money, while allowing the members of a community to profit from the community's growth and success. They add to the potential funds economic measure for a community – in effect, bonds are a loan, with interest, paid to the community's members instead of to a bank or other outside entity. The only significant downside to bonds is that it can be difficult to raise a sufficient amount of money with them. The enthusiasm of a community for such investments is important to determining if bonds will be an effective means of raising money.

Individual Ownership

Some power generation systems can be mounted on individuals' homes or property – such as solar-PV cells or micro-wind turbines. In such cases, the community can employ a "rent-to-own" system of development, where the homeowner pays over time for some fraction of the device, and it becomes their property once it has been paid off. This is most effective when the system significantly increases the resale value of the home or property, ensuring the homeowners' investment is safe. This is represented as a subsidy for that particular power source, based on what fraction of the cost the homeowner bears.

Government Grant

Some federal government grants are available for community level planning and development – enabling small towns to develop power systems they could not otherwise afford. Application for these grants is straightforward, and can bring significant money into a community. However, more grants are available for individuals and home development. By helping individuals who otherwise could not qualify for these grants meet the prerequisites, a community can maximize the amount of federal money benefitting their town. It is also possible for the money developed from the infrastructure added to then go back to the town, returning the community's initial investment even as it allows the home owner to benefit. Government grants – depending on whether they are a direct money injection or a discount – add to either the Immediately Available Funds measure or the Subsidy measure.

Purchasing Commitment

A purchasing commitment is an indirect method of raising funds where a group of individuals or outside organization agrees to buy a certain amount of power at a pre-agreed upon price before the new power source is constructed. This ensures a certain return on the initial investment, making the power source a more desirable option – and if the price agreed upon is above the commercial rate for electricity, it can give the power source a shorter return period. Such commitments are represented by their own, unique economic measure – defined by the amount of power, and the price at which it will be purchased.

Collecting Returns

Collecting returns on a new power source is easy – metering is not a significant expense for new power systems of any reasonable size, and so, fees can be charged for the electricity generated. This is true for power systems hooked up to the grid, but can also be used as a method of payment for power sources connected to a house, such as rooftop panels. An increasingly popular method of solar panel financing is for the homeowner to receive the panels for free, but commit to buying power from the panels on his roof at a specified rate, until such time as the panels are paid off. This is an effective way of ensuring a return on investment for small community projects.

Collecting returns on power saving technologies is more difficult. At present, New York State law states that any municipal loan rendered for the purposes of home improvement is secondary to the bank's mortgage. This makes it difficult for communities to take loans against a building itself for the purposes of improvements such as insulation and energy efficient heating systems, a significant legal hurdle.

For efficiency upgrades with a relatively short payoff period – short enough that the owner of the dwelling knows he won't sell it in that time -- this can be circumvented by attaching the loan to a person, instead of to the structure. However, this is a non-ideal arrangement, as many desirable power options have reasonably long payoff periods, or can be attached to homes that might reasonably be sold in two to three years.

Some power saving devices – such as rooftop solar thermal heating panels – significantly increase the resale value of the structure, allowing an arrangement where the owner can buy the panels at any time at a discounted rate, allowing them to sell the structure and still reasonably profit.

As a final option, some power systems can be sold with a mandatory contract – for instance, solar panels may be “rented” to the owner of the house on which they are placed, with ownership to transfer from the town to the landholder at the end of the given period. Such contracts can be held to the building, instead of to an individual, and thus circumvent several legal hurdles to clean energy investment.

Generally, when a community decides to make collective investments in the energy efficiency of its homes, there will be a fraction of homes that have to be excluded due to legal difficulties. This is not a problem – so long as some homes are available, investment can continue. Given the limited budgets most communities face, it is not uncommon for there to be more homes than are needed even with legal limitations.

Ranking Available Options

Once a community has determined available funds, the next step is to rank the desirability of the available power options. This process is automated in the Excel file which will be released later, but will be covered here for the sake of completeness. First, the economic data for each power source and technology is listed:

Power Source Technical Data														
Name	Minimum Cost		Average Cost		Marginal Cost		Productivity Ratio		Emissions		Reliability	Predictability		
Solar-PV Cells	\$	10,000.00	\$	0.21	\$	1.09	\$5,000.00	\$10,500.00	11%	27%	3%	13%	None	High

Figure B 1: The economic data for solar-PV cells as it appears in the given Excel file. In order, minimum cost, a range for average cost, a range for marginal cost, a range for productivity ratio, a range for carbon emissions, and reliability figures.

Next, the goals for the target community – as represented in the four metrics – must be listed. This will allow the effective costs and other measures of each power source to be adjusted to reflect how well it fits the community’s specific power needs. From this point on, the payback period (real period) is referred to as the “unadjusted” period, to prevent it from being confused with the adjusted period.

	A	B
1	Goal Data	
2	Goal:	Rating:
3	Enviromental	1
4	Cost Efficacy	3
5	Self-Sufficiency	2
6	Independence	1

Figure B 2: The goal data for a sample community, as it appears in the Excel file.

After this, the economic data for the community must be listed. Frequently, a community will have access to technology-specific funds. For instance, a grant may be available only for the development of solar power. For this reason, the community’s economic data must be listed individually by each power source, as well as generally for the community as a whole. If funds are available for multiple categories but are still limited – for instance, a grant for wind *or* solar power – the full amount should be listed in both categories. Adding \$1 to every individual category is identical to adding \$1 to the general pool.

Economic Data						
Power Category:	Immediate	Potential	Interest	Subsidy	Purchase (kWh)	Purchase (\$/kWh)
General	\$ 7,000.00	\$ 30,000.00	8%	10%	537,000.00	\$ 0.19
Solar PV	\$ -	\$ 50,000.00	10%	40%		\$ -
Wind	\$ -	\$ 30,000.00	9%	30%	-	\$ -

Figure B 3: The economic data for a sample community, showing only the General and Solar-PV lines as they appear in the Excel file. In a full analysis, there would be one additional line for every power source and technology.

Next, the costs for each power source should be adjusted for any available subsidy, and the unadjusted period calculated. The unadjusted period is calculated as a range, measured in years. The unadjusted period will be used to determine how much real interest a given interest rate adds to a loan. On the Excel file, this is performed in the sheet “Step 1.”

Subsidy-Adjusted Economic Metrics							
Name	Minimum Cost	Average Cost		Marginal Cost		Period	
Solar-PV Cells	\$ 5,000.00	\$ 0.11	\$ 0.55	\$ 2,500.00	\$ 5,250.00	16.78	-60.08

Figure B 4: The subsidy-adjusted economic and period data for Solar-PV cells at a hypothetical subsidy level, as it appears in the Excel file.

Next, the minimum cost for each power source should be compared to the total possible available funds for that power source. Any power source with a minimum cost higher than such is outside the means of the community at this time, and can be eliminated. Power sources that require the community to draw upon potential funds – in essence, power sources that require the community to borrow money – can then have their costs upgraded to reflect the final true cost of the device, including interest. On the Excel file, this is performed in the sheet “Step 1.” Note that these calculations do not yet include the effects of purchasing promises – that is covered later.

Goal Adjusted Economic Metrics						Individual Adjustments		
Name	Minimum Cost	Marginal Cost		Period		Env-Adjust	Self-Adjust	Ind-Adjust
Solar-PV Cells	\$ 5,000.00	\$ 2,318.25	\$ 4,868.32	13.31	-73.35	1.0184	1.06	1

Figure B 5: The loan-adjusted data for Solar-PV cells at a hypothetical interest rate, as it appears in the Excel file.

Once adjustments have been made for any necessary loans, it is possible to go from real, cost-adjusted economic data, to goal-adjusted economic data. In this step, the effective output of a power source or technology is adjusted upwards to reflect how well it meets the community’s goals. For instance, a community that ranked 3 on the Environmental Friendliness would add 6% to the effective output of a completely clean, environmentally friendly power source. Less environmentally friendly power sources would benefit less, and an average source would not benefit at all. On the Excel file, this is performed on the sheet “Step 2 and 3.”

Goal Adjusted Economic Metrics						Individual Adjustments		
Name	Minimum Cost	Marginal Cost		Period		Env-Adjust	Self-Adjust	Ind-Adjust
Solar-PV Cells	\$ 5,000.00	\$ 2,318.25	\$ 4,868.32	13.31	-73.35	1.0184	1.06	1

Figure B 6: Goal-Adjusted cost data for Solar-PV cells in hypothetical background conditions, as they appear on the Excel sheet.

The fourth step is the addition of power-saving technologies to the generated table of power sources, so that they can be economically compared to the other options available. The technical information for power savers is included in the “General Technical Data” sheet, and is run through some of the calculations mentioned above. Unlike the power source data however, most of the information for power saving technologies is pre-calculated for the average case in order to make calculations easier. On the Excel file, this is performed on the sheet “Step 4.” Note that, due to the

small scale of many power saving devices, their marginal cost is specifically measured in watts, as opposed to kilowatts – the marginal cost of power sources is also measured in watts. Some power savers do not list a period – this indicates that the power saving technology depends heavily on how much it is used. For instance, a light-bulb saves a set amount of energy over the course of its lifespan, but how long it takes to save that sum of energy depends entirely on how frequently the bulb is used.

Power Saving Data							
Name	Minimum Cost	Average Cost (kWh)		Marginal Cost (kW)		Period	
High-Efficiency Bulbs	\$ 10.00	\$ 0.01	\$ 0.09	\$ 20.00	\$260.00	N/A	N/A

Figure B 7: Sample power saving data for high-efficiency bulbs, as it appears in the excel file.

Once this step is completed, the final data set can be calculated. This is included in numerical form under the sheet labeled “Final Output,” and in graphical form on the sheet labeled “Output Graphs.” These two sheets do not contain distinct information – one is a graph of the other, in order to enable easier use of the data.

Appendix C – Summary Information on Various Energy Systems and Conservation Methods

Solar PV

At-a-Glance Metrics

- Cost Effectiveness: **Average.**
 - Solar PV systems pay for themselves in 8-10 years, depending on location and prevailing electrical prices.
- Environmental Friendliness: **Very Good**
 - Solar PV cells have very limited environmental impact, almost all of which is caused by construction, deployment, and disposal.
- Local Sustainability: **Good**
 - The ability of Solar-PV systems to be used at any scale makes them a common and efficient choice for communities interested in developing local power systems.
- Energy Independence: **Below Average.**
 - Solar panels lack of ability to produce power at night leaves them poor baseline power sources.



Solar photovoltaic cells -- also known as solar-PV, solar panels, and simply “solar cells” – are one of the best known types of solar power collector. Consisting of two, connected sheets of p and n-type semiconductors, they employ the photoelectric effect to turn sunlight direction into electrical current. The actual "solar panel" consists of a number of individual semiconductor cells mounted inside a metal frame. For this reason, solar panels can be made at any size by varying the number of cells that compose the panel, although sizes larger than two square meters are uncommon.

As with all solar collector power sources, solar cells do not produce power at night, or during periods of significant shade. Their reaction to shading is essentially instantaneous – a temporary period of shade produces a dip in electrical output of exactly the same duration. They experience decreased yield in the winter, and in locales that are further from the equator. Collectively, these factors give solar photovoltaic cells a widely varying but predictable power output.

The social impact of Solar-PV cells is primarily aesthetic – when deployed in large quantities, they are sometimes considered unsightly. This is usually not a problem with smaller scale systems, particularly rooftop systems. As an easily deployable local power system, they can be combined with purchasing commitments to provide a means of keeping money in the community.

Overall, Solar PV cells are a safe and environmentally friendly source of alternative power, with essentially zero environmental impact after production and minimal environmental impact during fabrication. Low total productivity and power yield limitations related to the day/night cycle make them a relatively poor choice for the purposes of electricity independence, but they are well suited as an addition to another larger power system.

Solar PV

Standard Metrics:

- Economic Costs
 - Minimum Cost: \$10,000
 - Average Cost: \$0.21-\$1.09/kWh
 - Marginal Cost: \$5-\$10.50/Watt Capacity
 - Productivity Ratio: 11-27%
- Environmental Effects
 - Carbon Emissions: 3-13%
 - Secondary Emissions: None Significant
 - Local Effects: None Significant
- Security
 - Local Security: None
 - Global Concerns: None
- Reliability
 - Flexibility: None
 - Regularity: High
- Interconnection:
 - Optional. Interconnection is standard, and assumed in given prices. Non-interconnected systems are slightly cheaper.
- Zoning and Planning:
 - Zoning requirements are minor, friendly, and mostly limited to aesthetic concerns in residential areas.
- Community and Social Impact:
 - None Significant
- Land Area
 - Exclusive: 80-220 kWp/Acre (Dedicated Power Systems Only)
 - Non-Exclusive: 130-180Wp/m² (Rooftop Systems Only)
- Resource Opportunity Cost:
 - Rooftop Solar Thermal Systems (Rooftop Systems Only)
- Development Period:
 - Less than 1 year.
- Survey Costs:
 - Trivial

See Appendix D-1 for More Information

Wind

At-a-Glance Metrics

- Cost Effectiveness : **Good**
 - Properly placed wind turbines can pay for themselves in as little as two years.
- Environmental Friendliness: **Very Good**
 - As long as they are not placed near migratory bird habitats, wind turbines have no significant environmental impact. Some visual & noise impacts.
- Local Sustainability: **Average.**
 - Wind systems are low maintenance and easily placed, making them a good local choice – but their high initial cost can be prohibitive for small communities.
- Energy Independence: **Poor**
 - Wind power can be intermittent and inconsistent, making it a poor baseline power source for any kind of energy independence plan.



The descendant of the windmill, modern wind turbines come in both vertical and horizontal axis mounts. The more common Horizontal Axis Wind Turbine (HAWT, above), features a large, propeller like blade on a swivel mount, enabling it to rotate to that the turbine is always facing directly into the wind. The support pole serves to keep the spinning blades away from the ground, but it also serves to alter the height of the turbine blades, as wind altitudes can significantly change even a short distance above the ground. The sharp change in wind speed between tower height and ground level also makes wind a survey intensive power option, as ground-level data is not sufficient to determine if the technology is viable.

Of all of the power sources presented in this report, wind is arguably the most difficult to model. The fact that wind turbine output varies with the cube of wind speed renders most simple approximations impossible. This makes surveys expensive, such that wind power is an option that is likely only attractive to communities with unusually great wind power potential.

Microturbines of either axis configuration, built to use near ground level wind, are safe for urban and residential use – including as a building modification. These provide a lower initial investment option for wind power, although they are less efficient than their larger counterparts. These systems do not produce a significant amount of power on their own, but can be a good add-on to another power plan or individual home development.

Wind is a capital intensive option for most communities – although it pays for itself quickly, the turbine itself is usually a significant initial investment. Wind is a clean and very environmentally friendly power source, but wind turbines should not be placed near major bird habitats or along bird migration routes, as birds can be killed by the turbine blades. Reports of the amount of noise generated by wind turbines are inconsistent – some models are loud, some are not.

Wind

Standard Metrics:

- Economic Costs
 - Minimum Cost: \$20,000
 - Average Cost: \$0.03-0.28/kWh
 - Marginal Cost: \$1.5-5/Watt Capacity
 - Productivity Ratio: 20-45%
- Environmental Effects
 - Carbon Emissions: 3-5%
 - Secondary Emissions: None Significant
 - Local Effects: Some possible harm to wildlife if turbines are build adjacent to major bird nesting area or migration routes.
- Security
 - Local Security: None
 - Global Concerns: None
- Reliability
 - Flexibility: None
 - Regularity: None
- Interconnection:
 - Assumed, cost included in given prices.
- Zoning and Planning:
 - Zoning requirements vary, but in many locations are either antiquated or hostile. Legal fees of up to \$10,000 may be required for large projects.
- Community and Social Impact:
 - Turbines built inside or adjacent to urban areas can potentially cause noise pollution.
- Land Area
 - Exclusive: None
 - Non-Exclusive: 0.085 Hectares/kWp
- Resource Opportunity Cost:
 - None
- Development Period:
 - Less then 1 year.
- Survey Costs:
 - \$10,000-15,000

See Appendix D-2 for More Information

Nuclear

At-a-Glance Metrics

- Cost Effectiveness : **Good**
 - Nuclear power produces electricity extremely efficiently, however, the absolute costs of building one are high.
- Environmental Friendliness: **Very Good**
 - Even including the carbon generated in plant construction and fuel collection, nuclear power is virtually carbon-emission free.
- Local Sustainability: **Good**
 - Nuclear powers high absolute output, efficiency, and flexible production schedule makes it perfect for ensuring local sustainability and net production.
- Energy Independence: **Good**
 - Nuclear power is a classical baseline power source, able to run at full capacity at almost all times, making it perfect for independent power generation at the state level.



A controversial source of power, nuclear energy has been a safe and effective part of the power grids of America, France, Sweden, and Switzerland for decades. Incidents such as the Chernobyl meltdown have created a public perception of nuclear power as inherently dangerous, or environmentally unfriendly. The more recent Fukushima reactor leak has even prompted Italy and Germany to ban nuclear power entirely, seeing it as an inherent risk to the population and environment.

However, not all nuclear power has been dangerous. France generates almost 80% of its electricity using nuclear power, and has never experienced a single safety incident. Sweden, likewise, produces almost half of its electricity with nuclear power with a flawless safety record. Chernobyl and Fukushima were both tragedies, but it is important to remember that they are the exception, not the rule. For a community willing to tolerate an element of risk, nuclear power can be an efficient, environmentally friendly source of electricity.

The potential advantage to nuclear power is that it can provide cheap electricity while avoiding some of the pitfalls of fossil fuels – such as carbon emissions, or the safety dangers of coal mining and coal emissions. For counties and states interested in developing environmentally friendly, safe power options, nuclear energy presents an effective baseline power option, capable of offering a strong contribution to local sustainability and energy independence.

Nuclear powers most serious downside is its very high initial cost. The installation of new reactors is extremely expensive – because of the safety regulations and permits required as much as the plant itself. This means it is primarily an option for states that are interested in major long-term power development. However, as the price of electricity continues to increase and the feasibility of fossil fuel reactors continues to decrease, nuclear power may become the strongest investment, making new reactors a potentially outstanding long term investment.

Nuclear

Standard Metrics:

- Economic Costs
 - Minimum Cost: \$25 Million
 - Average Cost: \$0.05-\$0.06/kWh
 - Marginal Cost: \$5,5000-\$8,10000/kW Capacity
 - Productivity Ratio: 90-92%
- Environmental Effects
 - Carbon Emissions: 1-2%
 - Secondary Emissions: None Significant
 - Local Effects: Some changes to property values, in either direction.
- Security
 - Local Security: Nuclear power plants require a significant security force, however, they have little security impact on surrounding communities.
 - Global Concerns: None
- Reliability
 - Flexibility: High
 - Regularity: High
- Interconnection:
 - Included.
- Zoning and Planning:
 - Extreme zoning concerns, requiring several years
- Community and Social Impact:
 - Potential disruption from a large influx of workers during construction, and altered property values in proximity to the plant afterwards.
- Land Area
 - Exclusive: 4,000-16,000 kWp/Acre
- Resource Opportunity Cost:
 - None
- Development Period:
 - Approximately 5 years for larger plants, 1 year for smaller designs, not including zoning delays and considerations.
- Survey Costs:
 - Significant, but included in the above price.

See Appendix D-3 for More Information

Concentrated Solar

At-a-Glance Metrics

- Cost Effectiveness : **Good**
 - Concentrated solar provides a strong balance between initial investment costs and efficiency in output.
- Environmental Friendliness: **Very Good**
 - Like most solar power, concentrated solar has no significant environmental impact.
- Local Sustainability: **Good**
 - By providing regular power during the peak of the day, concentrated solar serves as a strong addition to a communities sustainability.
- Energy Independence: **Average**
 - Concentrated Solar provides consistent power throughout the day, but cannot serve as a baseline power source as it is still vulnerable to weather.



A recently developed form of renewable power generation, concentrated solar power uses mirrors to focus the sun's light – boiling water to run a traditional steam turbine generator. This has the advantage of being more efficient than solar photovoltaic cells – and since the water continues to boil even if the sunlight is momentarily interrupted, it does not suffer sudden dips in output due to shade like a photovoltaic cell will. The sunlight is usually focused in one of two ways -- the 'Solar Power Tower' design (above) uses a field of mirrors that focus light onto a concrete "power tower" in the center, while the lower tech 'Power Trough' design runs pipes through fixed, parabolic mirrors. Either way, the result is more efficient than other solar power options, but also tends to have a higher initial investment cost.

Like all solar power sources, concentrated solar depends on the intensity and period of sunlight available. It is less effective in far northern latitudes, and in areas that experience regular cloud cover. Concentrated solar power is particularly valuable in areas that suffer from regular high temperatures during the summer, as the power station produces maximum output during the hottest part of the day, when that power is needed to run air conditioning and other climate control units. Likewise, it is less effective in northern latitudes, where energy demand is highest at night for lights and heating units.

Unlike solar-PV and solar thermal power options, concentrated solar power has an option that allows it produce power at night. By using high-density salts instead of water, a concentrated solar station can store energy, allowing it to continue to produce power several hours into the night. Cutting-edge power stations in Europe can continue to produce power for twelve hours straight after sunset, allowing them to last until morning, producing power continuously. This option is more expensive than direct water boiling, but may be desirable for areas with strong solar resources.

At present, most concentrated solar stations have been built on or near the 37th parallel. The metrics presented here reflect that – communities above the 37th parallel will experience less output than these numbers would suggest, while communities closer to the equator will experience more.

Concentrated Solar

Standard Metrics:

- Economic Costs
 - Minimum Cost: \$20 Million
 - Average Cost: \$0.12-\$0.18/kWh
 - Marginal Cost: \$3.00-\$5.00/Watt Capacity
 - Productivity Ratio: 25-30%*
- Environmental Effects
 - Carbon Emissions: 3-15%
 - Secondary Emissions: None Significant
 - Local Effects: None Significant
- Security
 - Local Security: None
 - Global Concerns: None
- Reliability
 - Flexibility: Moderate
 - Regularity: High
- Interconnection:
 - Included.
- Zoning and Planning:
 - Variable, but generally minimal zoning concerns. Zoning costs in the range of several thousand dollars, depending.
- Community and Social Impact:
 - None Significant
- Land Area
 - Exclusive: 520 kW/Acre
- Resource Opportunity Cost:
 - None
- Development Period:
 - Approximately 1 Year.
- Survey Costs:
 - Trivial

*Typical for CSP plants in southern Italy near the 37th parallel. Number is highly dependent on typical weather conditions in construction area.

See Appendix D-4 for More Information

Biomass Gasification

At-a-Glance Metrics

- Cost Effectiveness : **Poor**
 - Biomass gasification is almost twice as expensive as fossil fuels – but areas with natural low cost biomass supplies can offset the biomass costs.
- Environmental Friendliness: **Varied**
 - Biomass gasification's environmental friendliness level is entirely dependent on the quality of biomass used.
- Local Sustainability: **Average**
 - Although they produce much more power than they consume, gasification plants need to draw on electricity from another power station to start the reaction.
- Energy Independence: **Good**
 - A cleaner, renewable alternative to fossil fuels, biomass gasification is a strong addition to any communities baseline power needs.



Biomass gasification – the process of reacting biomass at high temperatures in a low oxygen environment – presents a more efficient and environmentally friendly use for biomass than burning. In the gasification reaction, biomass such as wood or peat is superheated in a low-oxygen environment, producing a material called *syngas*. Syngas can be burned in a similar fashion to natural gas, in order to produce electricity. This produces more energy and less pollution than burning the biomass directly, and so is widely used in industry as a means of generated electricity – particularly in industries that produce large amounts of biological waste as a side effect of other processes.

Because it can use any biomatter, biomass gasification is a renewable source of electrical energy. However, the quality of the reaction is determined largely by the quality of the products that go into it. Top quality biomass – such as clean wood chips – can be used to produce a carbon-neutral reaction, such that the plant produces no net emissions. Inferior quality biomass on the other hand, produces smoky, less efficient reactions, even if they are still cleaner than direct burning. For this reason, biomass gasification is most viable for communities with access to an ample, renewable source of good biomass.

The biomass gasification reaction – both the initial heating, and the combustion of the syngas – produces significant waste heat. For this reason, biomass gasification power plants can also be used as a source of heat for nearby communities or structures. Small syngas generators can be placed in the basement of existing structures – burning the syngas in place of natural gas, while the actual gasification facility is off site. Larger facilities can pipe heat directly into nearby communities, in a process similar to traditional steam tunnels.

Biomass gasification can also be performed with coal, as a cleaner alternative to traditional coal burning plants. Because such reactions tend to be more carbon intensive, and consume coal as a fuel source, they are covered under coal power facilities later in this report.

Biomass Gasification

Standard Metrics:

- Economic Costs
 - Minimum Cost: \$3,000
 - Average Cost: \$0.10-\$0.13kWh
 - Marginal Cost: \$1.5-\$3/Watt Capacity
 - Productivity Ratio: 85-90%
- Environmental Effects
 - Carbon Emissions: 0-120%
 - Secondary Emissions: None Significant
 - Local Effects: None Significant
- Security
 - Local Security: None
 - Global Concerns: None
- Reliability
 - Flexibility: High
 - Regularity: High
- Interconnection:
 - Assumed.
- Zoning and Planning:
 - Zoning requirements are minor, except in residential areas, where the severe aesthetic concerns are likely more significant.
- Community and Social Impact:
 - None Significant
- Land Area
 - Trivial for plant but variable for biomass sources
- Resource Opportunity Cost:
 - Composting, traditional stoves and ovens, potentially some biofuels.
- Development Period:
 - Less than 1 year.
- Survey Costs:
 - Trivial.

See Appendix D-5 for More Information

Appendix D-1: Solar Photovoltaic Systems

Overview

Solar photovoltaic cells -- also known as solar-PV, solar panels, and simply “solar cells” – are one of the more common and arguably best known types of solar power collector. Consisting of two, connected sheets of p and n-type semiconductors, they employ the photoelectric effect to turn sunlight directly into electrical current. The actual "solar panel" consists of a number of individual semiconductor cells mounted inside a metal frame.ⁱ For this reason, solar panels can be made at any size by varying the number of cells that compose the panel, although sizes larger than two square meters are uncommon for reasons of practicality. The flow of electronics through the semiconductor cell is one-way, and all of the cells are arranged in parallel – as a result, solar-PV cells produce direct instead of alternating current. In small applications, such as charging batteries or exterior lights, this is not a problem, but any purpose that requires the solar panel to interact with regular electrical sources will require an AC to DC converter (an inverter).

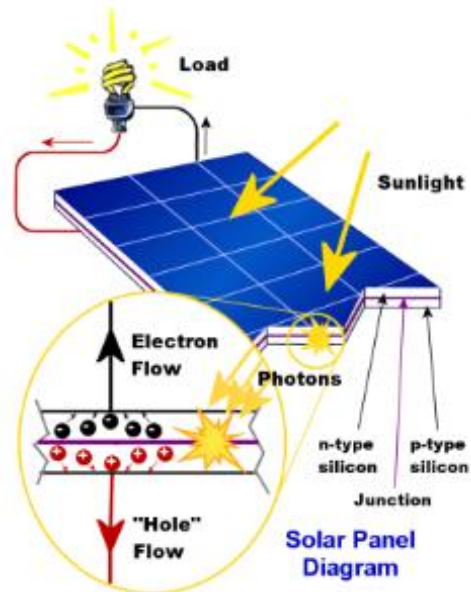


Figure A1 1: A cross-section of a solar-PV cell.

The addition of an inverter is a minor deviation from solar photovoltaics' otherwise constant marginal cost, making larger arrays of solar cells and collections of solar panels slightly more cost effective. Despite this, solar panels are a remarkably scalable power source, suitable both for single-building rooftop application and large “solar farms.”

As with all solar collector power sources, solar cells do not produce power at night, or during periods of significant shade. Their reaction to shading is essentially instantaneous – a temporary period of shade produces a dip in electrical output of exactly the same duration. They experience decreased yield in the winter, and in locales that are further from the equator. Collectively, these factors give solar photovoltaic cells a widely varying but predictable power output.

As a popular source of “green” power, production of photovoltaic cells has increased dramatically in the last five years, and they are subject to a variety of government subsidiesⁱⁱ. The cost information presented in this report uses prices of goods presently available for shipping to New York State, and does not factor in any government subsidies.

Performance Factors

While quality of solar panel construction, and thus overall efficiency, can vary, the power output of any given solar-PV cell is proportionate to the amount of incident sunlight that strikes it, and it only produces power when in direct sunlight. This defines the three factors in a solar cells performance – the

fraction of the time it is in light, the intensity of the light it is exposed too, and the angle of the solar panel relative to the sun at the time it is exposed.

The most obvious determining factor of when the panel is in light – the day/night cycle – is also the most important. It causes predictable but extremely important changes in the power output of the panel, as well as how the panel's period of maximum yield corresponds with peak load hours. Time of year and latitude of the solar panels location determine the exact frequency of the day/night cycle, causing locational and seasonal changes to output. The fraction of the year which is significantly cloudy likewise plays a significant factor – while solar panels yield during such days is nonzero, it is significantly impaired. As a result, the overall climate of an area must be taken into account in order to determine solar panel yield, as well as its geographic location.

The intensity of the light striking a given area and the angle at which the light arrives are closely related. In space, the intensity of light arriving at any section of the Earth's atmosphere is a constant – it is the effects of air mass, the amount of atmosphere between space and the ground, which causes a difference in solar intensity at ground level. The effects of air mass are determined by latitude, which is also responsible for determining the angle at which incoming sunlight arrives. This makes latitude a determining factor in the performance of solar photovoltaic cells in several respects, leaving solar cells performance highly location dependent.

However, latitude is not the sole factor in determining the angle at which light impacts the solar cells. Put simply – the solar panels can be tilted in order to adjust the incidence angle. Solar panels placed on the roofs of buildings tend to be oriented in whatever direction the roof happens to be facing for ease of construction, however, dedicated solar panels will be oriented in whatever position gives them maximum productive yield over the course of the year. It is also possible to mount solar panels in active tracking mounts that allow the panels to rotate in one or two degrees of motion, such that the panel is optimally angled, allowing the sunlight to strike it head on. Simple versions of these systems allow the panels to be manually rotated once or twice a month, improving performance over the course of the year for a relatively low investment. More advanced versions of the devices will use servos to actively rotate the solar panel over the course of the day, producing the optimal possible output.

The cost of such mounts is independent of the cost or productive yield of the solar panel, making their inclusion a question of the solar productivity of a region. The more productive a solar cell would be in a fixed brace, the more economically sound it is to replace that fixed brace with a tracking mount.



Figure A1 2: A solar-PV panel with two degrees of freedom in its' movements.

Cost and Output

Estimating the cost of solar-PV systems is extremely straightforward – the components are all regularly priced, and the cost of installation does not vary significantly by area. The complex aspect is estimating the performance of a given solar-PV system over the course of the day, month, or year. The actual math involved in doing a precise calculation of output is somewhat complex, and so this report will present a simplified calculation method, and reference more accurate methods for ease of access. Even the most complex estimation methods *can* be performed with only high school level math, but they are lengthier than most readers are likely to want to go through. In general, the longer the period the output is averaged over, the simpler the calculation becomes, but the more error is induced. However, even the least accurate calculation presented here is accurate to within about 10%ⁱⁱⁱ, and so should not be discarded, as they are excellent tools of estimation.

The simplest estimation of a solar-PV systems output is an average over the course of the year, based on experimentally observed factors. This is determined by a quantity called the Regional Factor (RF) of an area, which is determined by intensity of light, day-night cycle, etc. Actually calculating the RF of a given area is complicated, but unnecessary; such values are tabulated for most locations worldwide. The RF of an area is expressed as a function of ideal output – that is, a location where the sun always shines at the ideal angle and intensity would have an RF of 1 multiplied by the length of a year. Thus, the actual yield is RF multiplied by the theoretical yield of the solar panel at any given moment C , producing the actual yield over the course of a year. The inverter and wires that carry power from the cell induce a certain efficiency factor η . This gives us the final equation:

This equation neglects any losses from the solar panel being at a non-ideal angle. As a result, it is most accurate for a two degree of freedom servo-mounted solar panel, becoming progressively less accurate for fixed solar panels in progressive less efficient arrangements. The ease of this calculation means that it is the first we will perform in attempting to determine if solar-PV is a cost effective power solution for an area. If this equation produces highly favorable results, then two degree of freedom servo-mounted solar panels may be taken as the ideal solution immediately. However, this will not always be the case, and so more accurate estimates may be employed.

If data from other solar panels in the area is available, the corrective factors for orientation and weather conditions are constant across all solar panels, and thus the same constant corrective factor can be employed to gain a more accurate estimate. If that data is not available, more complex calculations must be employed. Those calculations are available in the book *Energy Systems Engineering* by Francis M. Vanek, available online or through Cornell's library systems. These calculations are too long to repeat here, but are easily performable in Excel with minimal training.

Environmental Impact

The environmental impact of solar photovoltaic technology is based entirely in their production and disposal – they produce no emissions during operation, and as long as they are spaced, their shading does not ‘blight’ the foliage beneath them^{iv}. Factoring in the waste gasses created during their production, solar cells are effectively 87-97% emissions-gas-free. This allows them to reach ‘clean energy payback’ in one to four years. This does not include the emissions involved in the creation of servo motors, steel frames, and other secondary components which are required for the PV-cells effective use. These systems can be minimized by design in order to remain close to the ideal value, however, even with them, PV-cells generate 9 to 17 times the total energy involved in their production^v, and it is worth noting that many of these frames are reusable.

Waste products involved in the full lifecycle of PV-cells – such as heavy metals, sulfur dioxide, and nitrous oxide -- originate entirely from the gathering of raw materials required to produce them – primarily diesel fuel. Recycling of PV-cells is not currently available in the United States, but the technology is proven, and the lifespan of current generation solar cells makes it likely such an option will be available by the time they reach the end of their productive life. However, modern PV-cell designs are nontoxic, and can be disposed of normally without risk of landfill leaching or toxic runoff.

Summary

Solar PV cells are a safe and environmentally friendly source of alternative power, with essentially zero environmental impact after production and minimal environmental impact during fabrication. Their yield is easily estimated, and they can be integrated into existing power systems for only a small, flat increase to their cost. Low total productivity and power yield limitations related to the day/night cycle make them a relatively poor choice for the purposes of electricity independence, but they are well suited as an addition to another, larger power system.

References and Tools

A number of estimation systems are available for Solar-PV systems, and most PV-cell providers will survey a potential installation area for no additional charge. Currently, the best generally available free program is the National Renewable Energy Laboratories (NREL) PVWatts program (<http://www.nrel.gov/rredc/pvwatts/>), which can effectively estimate PV cell yield and productivity for any location in the United States.

ⁱ (US Government, 2011)

ⁱⁱ (MarketBuzz, 2009)

ⁱⁱⁱ (Vanek, 2009)

^{iv} (Good Company, 2008)

^v (Good Company, 2008)

Appendix D-2: Wind Turbine Systems

Overview

The conversion of wind into power is an old staple of human civilization – through windmills, sails, or wind driven pumps. Even the more recent technology of converting wind power into electricity can be accomplished with a diverse variety of systems – such as the electrical “kites” many supertankers now employ. But the overwhelming majority of wind-derived electrical power is produced by wind turbines, and such turbines are the most affordable means of wind power generation for small communities -- so that particular technology is what this report will focus on.

The descendant of the windmill, modern wind turbines come in both vertical and horizontal axis mounts. The more common Horizontal Axis Wind Turbine (HAWT, top left), features large, propeller-like blades on a swivel mount, enabling it to rotate so that the turbine is always facing directly into the wind. The support pole serves to keep the spinning blades away from the ground, but it also serves to alter the height of the turbine blades, as wind altitudes can significantly even a short distance above the ground. The stresses put on the support pole by the force of the wind on the turbine blade are significant, such that the support pole can in some cases be the most expensive part of the turbine. Vertical Axis Wind Turbines (VAWT's, bottom left), feature a radially symmetric blade, removing the need for an elevated gearbox and servo's to rotate the turbine into the wind. Although VAWT systems benefit from being elevated into stronger winds just like their horizontal counterparts, they can safely be built much lower to the ground than HAWT's. They also have a smaller profile on the ground and in the air, allowing them to be placed closer togetherⁱ.

Microturbines of either axis configuration are safe for urban and residential use – including as a building modification, though building vibration can sometimes be a problem. Turbine failure of larger models is rare, but when it does occur, can be dangerous – flying pieces of rotor could damage buildings or cause severe injury in anyone nearby. For this reason, while the space around large rotors is empty and can be left as a natural or agricultural space, they cannot be placed in the middle of parks or other



areas that are likely to be densely inhabited. The deployment of turbines near agricultural fields and other sometimes lightly occupied but not directly inhabited land is possible, but is subject to special safety regulations. The full details of such regulations are beyond the scope of this report, but references can be found in this appendix. The deployment of turbines over forested or other completely wild land is possible, but can be difficult due to the necessity of moving construction equipment to the site.

With either configuration, the turbine produces AC power, suitable for introduction into the grid, however, intermittency – the fraction of the time and regularity with which the wind powers the turbine – is also a problem in either case. The intermittency of a given turbine is not a function of the technology, but of the wind conditions, which can vary widely by turbine height and geographical area.

Performance Factors

Wind power has only one performance factor, and it is just the one that might be expected – wind speed and its intermittency. However, wind power potential can be expensive to measure – a dedicated measurement tower to assess the wind potential of a single site can have an initial cost as high as \$15,000ⁱⁱ. Portable LIDAR installations can also be used to measure wind speeds – at present, the costs of such devices are roughly equivalent to a traditional measurement tower but it is likely to decrease. Measurements closer to the ground are significantly cheaper, usually under \$1000, but near ground-level wind installations also tend to be much less productive due to lower wind speeds.

Even the simplest calculations of turbine yield by an area's wind conditions are non-trivially complicated – there are programs that can perform these calculations automatically, given in the references of this report – but the more important calculation that a town considering wind power must perform is the rule-of-thumb calculation to determine if a more detailed survey is cost-effective or necessary. Ideally, there will be other, geographically close townships that have performed a complete wind survey, and in such a case, their data should be taken as a best estimate. Otherwise, the NREL 80m wind resource mapⁱⁱⁱ should be employed, with an 80 meter wind speed of 7.5m/s or higher being a reasonable minimum.

The yield of a wind turbine varies with the cube of wind velocity – so even a small increase or decrease in average wind speed can have a large impact on yield -- likewise, a wind that blows significantly less often at slightly higher speeds may be more productive than its alternative. For this reason, while intermittency is important, it should be ignored during rule of thumb calculations in favor of an emphasis on typical wind speed, which is more important for determining yield.

Cost and Output

The construction costs of turbines can range widely and their output is highly dependent upon local wind conditions. While the programs given in the appendix can help automate this calculation, it is

recommend that localities using this report examine the Caroline-based sample case first, as it fully demonstrates and explains a typical wind power cost and yield estimate.

Environmental Impact

Wind power results in no carbon emissions except for those created during construction of the facility, primarily diesel fuel. As with many “green” power sources, these emissions are trivial compared to the energy the power station produces. There is some evidence^{iv} that wind power can be hazardous to birds, bats, and other local flying wild life, but the exact extent to which this is the case is disputed, and there is a consensus that wind power is not excessively harmful as long as the wind facilities are not constructed directly on local avian creature migration, feeding, and breeding routes^v. For this reason, wind farms are generally not constructed near peat bogs or other areas notable for airborne wildlife.

Reports of significant ‘noise pollution’ against those living near wind-turbines are inconsistent, and many smaller turbines are available in “whisper quiet” models designed to be beyond the normal range of human hearing^{vi}. However, reports of such noise are numerous enough that those living near a potential wind power site should be reasonably surveyed for noise sensitivity.

Summary

Of all of the power sources presented in this report, wind is arguably the most difficult to estimate and model. The fact that wind turbine output varies with the cube of wind speed renders most simple approximations impossible. This fact, combined with the high cost of wind potential surveying, means that wind power is an option that is likely only attractive to communities with unusually great wind power potential. Low-altitude models, particularly of the VAWT configuration, do not suffer from this limitation, and so sit alongside solar-PV as a power option that cannot replace traditional power on its own, but can serve as a simple, scalable, profitable supplement to another local power plan.

References and Tools

The National Renewable Energy Laboratory (NREL) offers helpful calculators, charts, and instructions on their Wind Resource Assessment webpage, available for free online. They also offer typical pre-calculated values by religion, as a very rough estimation of the suitability of any given area for the development of wind power.

ⁱ (Eriksson, 2008)

ⁱⁱ (Cunningham, 2011)

ⁱⁱⁱ (US Department of Energy, 2011)

^{iv} (Birds, 2008)

^v (Birds, 2008)

^{vi} (Fast Furnishings.com, 2010)

Appendix D-3: Nuclear Power Systems

Overview

There are many ways to use atomic energy to generate electricity – but when one refers to nuclear power, what they are almost certainly referring to is a modern, supercritical steam pressure fission reactor. In this design, rods of fissible material – usually uranium – are placed close together, generating heat. That heat is used directly or indirectly to boil water to supercritical temperatures, which is then used to run a traditional steam turbine. The large, curved concrete towers that are visually associated with nuclear power plants have nothing to do with the fission reaction at all – they are condensation towers, used to reclaim the water boiled in the process of running the turbine. These cooling towers also appear on some steam turbine coal plants that operate in areas with limited water supply. The actual reactor of a modern nuclear power plant is contained entirely in the reactor dome – the small, concrete structure usually located between the condensation towers.

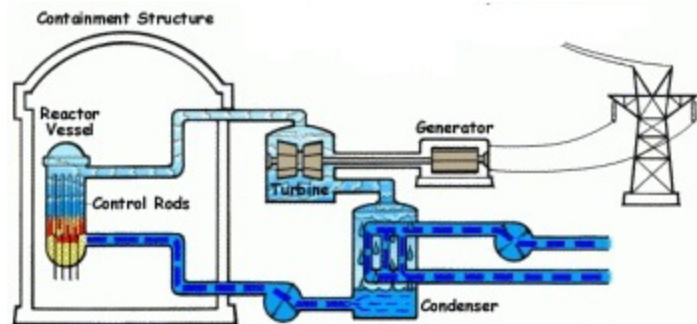


Figure A3 1: A Boiling Water Reactor (BWR) design. It is distinct from the Pressurized Water Reactor (PWR) design in that the nuclear material heats the water directly, instead of indirectly.

The actual reaction – inside the reactor vessel – is process of nuclear fission, by which uranium slowly undergoes nuclear decay and becomes thorium. Uranium 235 – the isotope of uranium employed in many reactors – is naturally unstable, breaking down into radiative heat energy, thorium and high-energy neutrons. It is the heat produced by this breakdown that causes the water around the radioactive material to boil. If one of the energetic neutrons released strikes another atom of uranium 235, that atom will break down in turn, releasing more energy and more neutrons. Nuclear reactors employ “control rods” made of substances that absorb neutrons to determine how many neutrons are allowed to continue the reaction in this manner. Thus, by controlling the rate of neutron propagation, reactor technicians can control how much heat the reactor generates, and how much power it produces.

Contrary to some myths and urban legends, it is impossible for a nuclear reactor to explode the same way a nuclear bomb does. The reactor vessel does not contain enough fissible material in a sufficiently refined and concentrated state to explode, even under ideal circumstances. All nuclear disasters to date have instead been “nuclear meltdowns” – a situation where the fissible material gets so hot, it melts the structural supports and safeguards around it, causing the radiation-laced steam in the reactor vessel to escape into the environment.

In the recent Fukushima disaster, the damage to the reactor chamber was caused by the earthquake, and then made worse by a tidal wave and a technician error. In the more damaging Chernobyl disaster, the reactor had a design where the neutron moderator in the control rods became less effective when the reactor was running at its lowest output. This led to a problem where the

reactor suddenly spiked from the lowest possible output to the highest without warning during a test – causing the reactor technicians to panic and worsen the problem in their attempts to fix it, leading to meltdown. Modern nuclear reactors are required to have more effective neutron moderators in order to correct this flaw, however, they are still vulnerable to natural disaster, as the Fukushima disaster demonstrates.

Traditional, large scale nuclear reactors have a minimum cost of approximately six billion dollars, making them an intimidating long term investment. In the past, governments and utilities have tolerated this high initial cost because – once the plant is constructed -- nuclear power is one of the cheapest and most productive power sources available. However, more recently, smaller reactor designs have emerged – with an initial cost of \$20-\$30 million dollars¹. These miniature reactors – some as small as 2.5 meters on a side – are produced in a central location, and shipped by rail to be installed on site. Such designs offer a more affordable, less risky option for states or counties interested in developing nuclear power, although they are somewhat less efficient than the larger, traditional reactor designs.

Performance Factors

The performance of nuclear reactors is independent of their location – determined entirely by their design. However, nuclear reactors can only be placed in locations that are secure against natural disasters. They cannot have a history of earthquakes or flooding, must be built directly upon solid ground, etc. This can mean that some locations are unacceptable for building reactors over a certain size, limiting performance. The amount of power larger reactors produce also needs significant electrical transmission capacity, which can limit output.

Cost and Output

The costs and output of nuclear reactors are highly specific to plant designs, rather than being based upon external factors. However, the output of the reactor is entirely under the control of its operator, up to the power facilities maximum output. This means that the reactor can produce power during peak hours, increasing the reactors effective value and allowing it to serve as a baseline power source.

Environmental Impact

Although the impact of a nuclear meltdown is devastating to the surrounding environment and communities, it is important to remember that in the entire history of nuclear power, there have only ever been two meltdowns – one of which was caused by one of the worst earthquakes in recent history. Someone living next to a nuclear power plant arguably has higher odds of winning the lottery than they do of being harmed in a nuclear accident.

However, nuclear power plants can have more immediate impact upon the environment. As many power plants, most nuclear power plant designs release hot water into their environment, which can be harmful to nearby rivers or lakes. They require a significant amount of land to be cleared, as well

as support machinery and housing for power plant workers and support staff, which can have further environmental impact. Compared to fossil fuels however, the impact of normal operation of nuclear power is minimal.

Summary

Despite a very small risk of serious accident, nuclear power is one of the most environmentally friendly baseline power sources available. For communities willing to tolerate the risk, it serves as an efficient, cost-effective source of peak load power. The high initial investment of traditional nuclear power plants can be intimidating to smaller counties or states, but smaller, shippable reactor designs may potentially alleviate this problem.

References and Tools

The output of a nuclear reactor has to be estimated design by design – there are no simple metrics for estimating how much nuclear power an area can support.

ⁱ (Hyperion Power)

Appendix D-4: Concentrated Solar Overview

The use of the sun to warm water is an efficient method of reducing heating costs – used in homes as Solar Thermal power saving technology. But in greater concentration, sunlight can be used to boil water, allowing it to power a traditional steam driven turbine. Such an arrangement, called Concentrated Solar Power (CSP), is much more efficient than solar photovoltaic cells, both in terms of money and land area. However, unlike solar cells, this technology is not infinity scalable – there is a certain minimum size of reflectors required to boil water effectively. Concentrated solar technology therefore represents a certain minimum investment for any community hoping to use it, but offers long term rewards in the form of a less expensive, more productive power station.

CSP stations come in two general forms – the sunlight is either focused onto a pipe by a series of mirrors running along that pipe’s length, or a field of mirrors focuses an area of light



onto a single elevated tower located in the center of that field (called “Solar Power Tower”, see picture above). A hybrid of these two designs called the “Dish Stirling” system employs a series of small focal points in the center of parabolic mirrors, effectively forming many small towers, but the basic principle is the same. Pipe systems offer greater scalability, and generally lower investment costs, while solar power tower designs and variants offer potentially greater efficiency due to the higher temperatures generated at the focus point.

CSP offers another advantage over solar photovoltaic in the form of stored energy. By using the sun's focused light to heat and melt salt, a CSP station can store the sun's energy in the form of heat, which can then be slowly released over time to power the station's turbines even when the sun is not shining. The most immediate application of this is that CSP stations do not suffer production failure if they are momentarily cast into shade by clouds or in temperate weather, but it is also possible for CSP stations to hold power for longer periods. Currently operating CSP stations can hold power for up to 50 minutesⁱ, while power plants currently under construction in Europe will be able to store enough power to continue production for 24 hoursⁱⁱ. At any length of time, the goal of such energy storage is to even the plant's production curve, and to ensure that it can produce electricity during peak hours.

CSP's advantage in productivity over Solar-PV is decisive, but the additional investment costs it incurs can be prohibitive. For a town or local government interested in developing solar power, CSP represents a significant financial commitment, but one that can ultimately prove rewarding.

Performance Factors

CSP stations have largely the same performance factors as solar-PV installations – while their ability to store energy prevents them from suffering immediate power failure during dark periods, they do not collect any power when the sun is not shining. Likewise, more intense sunlight enables them to produce greater power for less reflector area. CSP installations will therefore be less effective in far northern latitudes and in areas where the weather is frequently overcast, as well as experiencing seasonal variations in total overall power production.

Unlike solar-PV installations, CSP stations do not have options regarding panel orientation. All of the panels in a CSP station, regardless of the plants exact configuration, must be placed on active tracking systems in order to ensure proper sunlight concentration. This is a necessary design feature, and the cost of it is included in total construction and production costs.

Finally, while they are constructed with climatic conditions in mind, CSP stations feature large arrays of mirrors directly exposed to the elements, and so can be damaged by inclement weather. Areas that suffer regular or semi-regular destructive weather likely faced increased maintenance expenses to maintain such reflectors.

Cost and Output

Formally estimating the yield of a CSP station is a task that requires expert council as well as a finalized power station design, and so is beyond the scope of this report. Generally, any town potentially interested in Solar-PV power should consider if they are willing to forward a larger initial investment, and if so, should consider CSP as an alternative. A helpful “rule of thumb” for determining if such a move would be profitable, is that almost all current CSP facilities have been constructed at the 37th parallel or closer to the equator – and so towns and localities near the 37th parallel may take the figures in this report as typical for their area. Locations further south may take them as a conservative estimate, while locations further north should apply a 4% decrease in likely yield per parallel above that point.

The initial investment of CSP varies depending on plant size – at 5MW, Sierra Sun Tower is one of the smallest CSP facilities in the world, but it produces power at the prohibitive initial investment of \$26,000/kWⁱⁱⁱ, as compared to solar-PV's more reasonable price of \$7000/kW capacity. Spain's larger; 10MW PS10 facility produces power for a competitive initial investment \$4000/kW^{iv}, a figure which should be considered typical for larger CSP facilities. Between the improvements in efficiency granted by scale and minimum plant size, \$20-50 million dollars can be taken as a reasonable range for plant construction costs. It is noteworthy that a significant fraction of that cost is land and other expenses that

fall under the public domain, and so a township need not have that much on hand in cash to be a significant partner with private industry in the creation of a new plant.

Environmental Impact

CSP produces no carbon emissions, and has negligible environmental impact outside the cost of its production and the land employed^v. Although the CSP facility does shade the land beneath it, preventing foliage growth, the area it occupies is comparable to a fossil fuel plant of equivalent productive capacity. Some carbon emissions are created in the process of constructing CSP facilities, primarily in the form of consumed diesel fuel, but these emissions are comparable to those of Solar-PV, resulting in 85% or greater emissions free power produced.

Summary

While their \$20-50 million dollar initial investment cost renders them beyond the means of most small communities and regions, CSP facilities represent a clear and dramatic improvement over alternative solar power technologies, both in production efficiency and in ability to store power over extended dark periods. On the four scales of cost efficacy, environmental friendliness, energy independence, and local sustainability, CSP is one of the few technologies that ranks well on all four scales. Townships that can bear the cost or that can offer a contribution to a private partner in the form of land should consider CSP as one of their primary choices in alternative power.

References and Tools

There are no simple calculators for concentrated solar yield, as it is heavily dependent on specific plant design. However, the metrics given here are primarily for facilities built on or near the 37th parallel. Locations further from the equator should apply roughly a 4% decrease in output for every parallel above the 37th in order to gain an estimate of likely plant output.

ⁱ (Solucar, 2005)

ⁱⁱ (Ortega)

ⁱⁱⁱ (gigaom, 2009)

^{iv} (Solucar, 2005)

^v (US Gov DoE, 2008)

Appendix D-5: Biomass Gasification

Overview

Biomass is one of the oldest power sources employed by mankind. Wood, grasses, peat, and animal waste have all been burned for fuel, and continue to be useful for that purpose even in industrialized nations. A simple wood or peat burning stove can be a useful addition to a home, lowering heating costs, and providing a sustainable alternative to electric or natural gas heating. Using biomass to produce electricity is more difficult. Biomass tends to have a low burning temperature, making it difficult to work with, and the reaction can easily become smoky and inefficient, producing more carbon than coal or fossil fuel plants. For this reason, biomass is most efficient when it is converted into some other format before burning. Biofuels are one approach to this problem, but biomass gasification – the process by which the fuels are superheated before burning -- presents a more practical, larger scale approach.

Biomass gasification is the process of superheating biofuels in a low-oxygen environment, in order to produce a material called *syngas*. The syngas can then be burned in a similar fashion to natural gas, resulting in a net carbon-neutral reaction, suitable for producing electrical energy, or and/or providing heat to large buildings or communities.

Syngas can be shipped or transported in the same manner as natural gas, in order to provide heat or power in other locations – but it can also be burned on site, in a single biomass gasification power facility. Like

all combustion based power sources, burning syngas produces a significant amount of waste heat, and so greatest efficiency is achieved when the waste heat from power generation can be used to provide heat for nearby structures, particularly in winter. This can be achieved with small generators in the basement of buildings that require heating, or by pumping heat directly from the power plant.

As a theoretically carbon-neutral power source, biomass gasification has the potential to be a renewable, environmentally friendly source of power. Practically, the quality of the reaction – both to produce the syngas and to burn it later – depends highly on the quality of the biomass used. Low quality raw materials can produce smoky, inefficient reactions that are as emissive as coal, and so the biomass used is extremely important. This also increases costs, as the low quality biomass takes more energy to convert into syngas and produces less energy when burned. As high-quality biomass can be expensive to

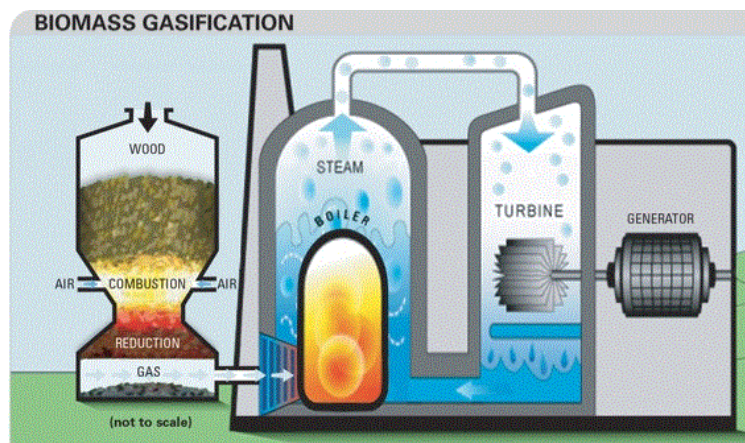


Figure A5 1: An illustration of a wood-burning biomass gasification power facility. The wood is combusted in a low-oxygen controlled environment to create syngas, which is then burned in a traditional boiler to produce steam.

import to a community, biomass gasification is most efficient for communities that have access to natural biomass reserves that would otherwise go to waste. Examples of this include agri-waste or natural forest areas.

The initial reaction – where the biomatter is heated to produce syngas – is often powered by electricity. Although in this case the total biomass gasification reaction produces more electricity than it consumes, this reaction adds cost. As a result, if the cost of the biomass fuel isn't subsidized or reduced in some way, biomass gasification can be almost twice as expensive as typical fossil fuel based power plants. This makes areas with some kind of surplus of biomass even more suitable for biomass gasification, but a more traditional subsidy of other clean or renewable power sources might also be suitable.

When performed improperly, or with certain fuels, biomass gasification produces tar as a byproduct. Historically, biomass gasification has been used primarily as a means of producing tar, and its applications to power generation are more recent. If a buyer for the tar and other byproducts can be found – not unreasonable, since most of them have industrial uses – this can actually be a boon. However, if a buyer cannot be found, the cost of safely disposing of this tar waste must be included in the final cost estimates for new power facilities.

Performance Factors

Quality of fuel is the single, defining performance factor in the efficacy of a given biomass gasification facility design. Quality generally refers to the *purity* and *consistency* of the fuel being used. While some fuels are genuinely better than others at a basic level, the far more important factor is the level of non-combustibles in the fuel, and the predictability of factors such as humidity and density. The slow combustion reaction used to produce syngas cannot be easily adjusted in the face of variable fuel, and so inconstant humidity, density, and other factors produce an inefficient, smoky reaction. Likewise, fuel with significant impurities burns poorly and can produce harmful byproducts.

Cost and Output

The cost and output of biomass gasification power facilities is almost entirely dependent on the specific design of the facility, which is in turn dependent on the type of fuel it is expected to consume. Manufacturers will have to be contacted for specific quotes.

Environmental Impact

The environmental impact of the biomatter gasification itself is minimal – just the emission of some carbon, and if the reaction and fuel processing are performed properly, even that is negated. The bigger potential impact of biomatter gasification is in how the raw materials for the reaction are gathered. With replanting and careful soil management, the gathering of the raw materials for biomatter gasification can have no significant environmental impact. However, excessive gathering of

biowaste or decaying plant matter can disrupt natural or agricultural environments. A detailed discussion of land management practices is outside the scope of this paper, but attention should be paid to where the raw material for gasification will come from, particularly if it involves a sudden change in land management practices.

Summary

Biomass gasification is an environmentally friendly, renewable way to generate power by disposing of excess biomass and biowaste. Particularly useful in agricultural areas that naturally produce large amounts of such high-quality waste, biomass gasification can provide power for a community for a low, affordable cost – particularly for locally generated power. As it is a bit more expensive than fossil fuels, biomass gasification is not well suited for areas that have to import their biomass waste, and they will find their electricity costs to be significantly higher than they would experience on the standard electrical grid.

References and Tools

Estimating the output of a biomass gasification plant requires a quote from the manufacturer, but is fairly straightforward. Once the type and quantity of fuel available has been assessed, manufacturers will be able to suggest the most appropriate model and scale of biomass gasification facility, from which a number of quotes can be generated.