Biomass Strategies for Connecticut

Prepared for:

The Connecticut Clean Energy Fund

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Executive Summary

Biomass electric power, biofuels, and biochemical products are already available in the market and currently meet more than 3 percent of U.S. heat and electric power needs and are increasing by more than 2 percent annually in most regions. Several conditions are contributing to the rapid commercialization of the next generation of biotechnologies and biorefineries – the conversion of cellulosic biomass into fuels, chemicals and energy (both thermal and electrical). These conditions include:

1) Presidential and Congressional biomass Initiatives;
2) Scientific and technological advances (including incorporation of fossil-fuel refining technologies);
3) Environmental imperatives including air, water and soil enhancement, and the stabilization of greenhouse gases; and,
4) National and energy security imperatives, including reduced oil and petroleum product imports and improved balance of payments.

As promising as biomass is on a national scale, its recent history in Connecticut has not been very productive. With the exception of a small 150 kW unit, there is no biomass electric energy being generated in the state. While there have been proposals for three biomass electric plants in the past 12 years, public opposition to each of them was fairly intense, and none of them was ever built. Importance of this past history cannot be underestimated in fashioning new biomass strategies if it biomass power to become a major renewable energy source in the State.

In general, Connecticut and the rest of the Northeast are plentifully endowed with biomass resources. In fact, the impact of these resources could far surpass that of any other renewable resources when considered in terms of storability, availability and dispatchability. During the 1980s and '90s several assessments were performed, but these studies have typically produced only gross overall figures for the state or region. Unfortunately, there is still need to further define both the nature of the available biomass (e.g. the waste content detail) and the specific locations of the biomass in order to estimate what percentage is actually recoverable in relation to the strategies outlined. As such, making a solid estimate of the total potential of biomass to provide power is difficult . Recognizing that, there is on the order of 100 to 300 MW of electric generation potentially available from biomass in Connecticut depending upon resource availability and technologies employed.

The predominant technology in use for biomass power currently is the direct combustion of solid biomass to produce steam to power a turbine generator. This technology is well developed and well understood, but suffers from low efficiencies, higher emissions and high capital costs compared to new gas-fired Combined Cycle Gas Turbine (CCGT) plants.

Recently we have seen the reintroduction of an old technology -- gasification -- which involves heating the biomass at high temperatures to drive off the combustible components in a gaseous form. Gasification goes back to the 1800's when coal was gasified and used as "city gas" for lighting and cooking. The same process is basically used to gasify biomass. Although gasification offers numerous advantages, it is relatively unproven in the U.S. (although it is becoming much more common in Europe) and still holds a variety of technological unknowns.

Biomass, using either direct combustion or gasification, could be used in any of these application strategies which are listed from near term to long term:

Co-firing. Co-firing involves the direct combustion of solid biomass in existing coal-fired boilers or, if gasified, with coal, natural gas or oil burners.
Repowering. Repowering is the reuse of some of the components (boiler, turbine, fuel handling, interconnects, etc.) which could be adapted to biomass combustion at an existing, but closed power plant.
Micro Scale Biomass. On-site micro scale units (below 1 MW) would employ small biomass facilities placed at the biomass source to minimize transportation cost, often the largest expenses associated with biomass energy.
Biorefinery. A biorefinery is an integrated approach that uses biomass to produce multiple products, including electric power, liquid biofuels and bio-based chemicals.
Biomass Powered Industrial Park. A biomass-fired industrial park would combine one or more elements of any of the preceding three strategies but also including combined heat and power (CHP, frequently known as cogeneration).
Biomass Powered Industrial Park with Industrial Ecology. This strategy would encompass all the benefits (and risks) of the biomass-powered industrial park but would also include an "industrial ecology" component in which each of the byproducts of a process is used as the input to another process to provide a zero emissions result.

Biomass combustion has significant potential to help Connecticut develop green power within its borders. However, in-state political opposition to power plants involving any kind of combustion can be expected to be stiff. It is likely that updating the environmental community's understanding of current biomass technology can ameliorate many of the objections raised. Similarly, the political leadership in the state will need solid information about the current state of the technology in order to make reasonable and informed decisions. The recommendations for future actions given below reflect these conclusions.

Recommendations for future Clean Energy Fund activities include:

- Undertake educational activities with members of the environmental community pertaining to the benefits of biomass

- Fund an assessment of the Connecticut biomass that focuses on identifying the type of biomass available and combining that information with recommended technologies for each type of biomass.
- Define partnerships with Connecticut agencies or groups having a regulatory or business interest in biomass power.
- Define partnerships with other states that may also be engaged in the same or similar activities to the mutual benefit of both.
- More accurately assess which technologies might lend themselves to success within the given time horizon. (Once the technology assessments are refined, the decision-making process as outlined should be enhanced to advance one or more strategies.)
- Provide timely and accurate information to local and state political leadership
- Aggressively seek out privately-financed biomass power plant development opportunities, and assist the developer to work with the environmental community on their acceptance and promotion of this development

At best this report can only be considered a cursory overview of the current and upcoming technologies and biomass potentials for Connecticut. Although several strategic activities have been proposed, they require additional investigation in order to determine if they are technologically, economically and politically viable.

Biomass Strategies for Connecticut

Background

The recent history of biomass projects in Connecticut has not been very productive. With the exception of a 150 kilowatt unit owned by William Pinchbeck in Guilford, there is no other biomass electric energy plant known to be currently in use in the state.[1]

Beginning in 1986 there were proposals for three medium-size biomass electric generation plants. These were:

1. a 15 MW Biogen plant in the Winsted/Torrington area,
2. the Killingly (KELP) plant at 32.2 MW and
3. the Uniroyal plant in Naugatuck at 24 MW.

To recap the history, these plants were met first with curiosity, which prompted a trip by local officials to visit the 50 MW McNeil plant in Burlington VT. This was followed by concern over both siting issues and the nature and source of the wood that would be the fuel source. Finally outright opposition came from those living in the immediate area of the proposed plants (including consumer activist Ralph Nader, a native of the Winsted area). This opposition developed despite the ability of these plants to meet the requirements set by the Connecticut Siting Council, the Department of Environmental Protection and the Department of Public Utility Control. While some environmental groups and well-known environmentalists supported the construction of the plants, other environmental and health-related groups joined the local opposition.[2]

The major points of opposition included:

- air emissions including claims of dioxins and furans,
- excess use of water resources,
- increased truck traffic delivering fuel,
- increasing the cost of electricity (PURPA) at a time when there was already excess generation.

In order to satisfy the opposition the plant developers made a number of concessions. For example, the developers of the Biogen plant modified the design to make it air-cooled and incorporated a system to reduce nitrogen oxide emissions. The developer also established wood chip harvesting regulations to insure responsible, environmentally

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[1] The Hitchcock Chair Factory in New Hartford was in use in the mid-80's but for thermal energy, not for electrical generation. The Warner Theater in Torrington is heated by wood.

[2] The Connecticut Forest and Parks Association and Public Citizen supported biomass in general but the American Lung Association and local environmental groups opposed it.

sound procurement practices that would be reviewed by the State Co-op Extension Forester. They also agreed to limit the amount wood chips derived from demolition wood waste to 20%.

Despite these concessions, several bills were introduced into the legislature to either ban biomass power or significantly limit various aspects of their operation. Finally the plans to build a plant ended with a controversial deal wherein the plant contracts were bought from the developers before the plants were ever built.

Importance of this past history cannot be underestimated if biomass is to become a major renewable energy source within the state. While biomass was included as an eligible renewable resource within Public Act 98-28 (which created the Clean Energy Fund), biomass plants may still be difficult to site.

This history may also make it difficult to attract private financing to biomass projects in Connecticut. With this in mind, the strategies proposed here have been carefully designed to address many of the former criticisms levied against the earlier proposed projects. Further analysis of this past history is suggested in order to provide background on where educational efforts can provide the best leverage.

Current Legislative Mandate

Public Act 98 -- 28 states, “For purposes of this section, "renewable energy" means solar energy, wind, ocean thermal energy, wave or tidal energy, fuel cells, landfill gas **and low emission advanced biomass conversion technologies** and other energy resources in emerging technologies which have significant potential for commercialization and which do not involve the combustion of coal, petroleum or petroleum products, **municipal solid waste** or nuclear fission.”

It goes on to say, “CT Innovations Inc., may use any amount in said fund for expenditures which promote investment in renewable energy sources in accordance with a comprehensive plan developed by it to foster the growth, development and commercialization of renewable energy sources, related enterprises and stimulate demand for renewable energy and deployment of renewable energy sources which serve end-use customers in this state. Such expenditures may include, but not be limited to, **grants, direct or equity investments, contracts or other actions which support research, development, manufacture, commercialization, deployment and installation** of renewable energy technologies, **and actions which expand the expertise of individuals, businesses and lending institutions with regard to renewable energy technologies**.”

Assessment of Connecticut Biomass Resources

In general, Connecticut and the rest of the Northeast are plentifully endowed with biomass resources that far surpass other renewable resources when considered for storability, availability and dispatchability. During the 1980s and into the early '90s several studies were performed under the auspices of the Northeast Regional Biomass Program. Some of these may be obsolete and NRBP has plans to publish an updated study on their Internet site.[3]

The resources that may be of most interest to the Clean Energy Fund fall into several different categories. The first category is biomass that can be used for power generation. This category may come from forest products waste, bulky waste from site development or what are termed "special wastes".[4]

The second major category is biomass that can be used for the production of liquid fuels. This might include byproducts from food waste or manufacturing processes as well as certain crop residues.

A third category includes sewage sludge, paper sludge and other byproducts that present significant disposal problems. These waste products, although typically more difficult to handle, often command significant tipping fees for disposal, and may be able to contribute significantly to the positive economics of a plant.

The tables on the following page provide general information on the Connecticut resources which have some potential to be available for biomass power and/or liquid biofuels.

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[3] Personal communications with Rick Handley on 12/29/99. As of 1/29/00 this is not yet available at www.nrbp.org.

[4] Because of the manner in which the legislation was written, there is some question as to the exact ability to use certain portions of what is broadly termed "municipal solid waste." (See legislative excerpt above.) As currently stated it is comprised of "solid waste from residential, commercial and industrial sources, excluding solid waste consisting of significant quantities of hazardous waste as defined in section 22a-115, land clearing debris, demolition debris, biomedical waste, sewage sludge and scrap metal."

Estimated Annual Generation in Connecticut of Bulky and Related Wastes[5,6]

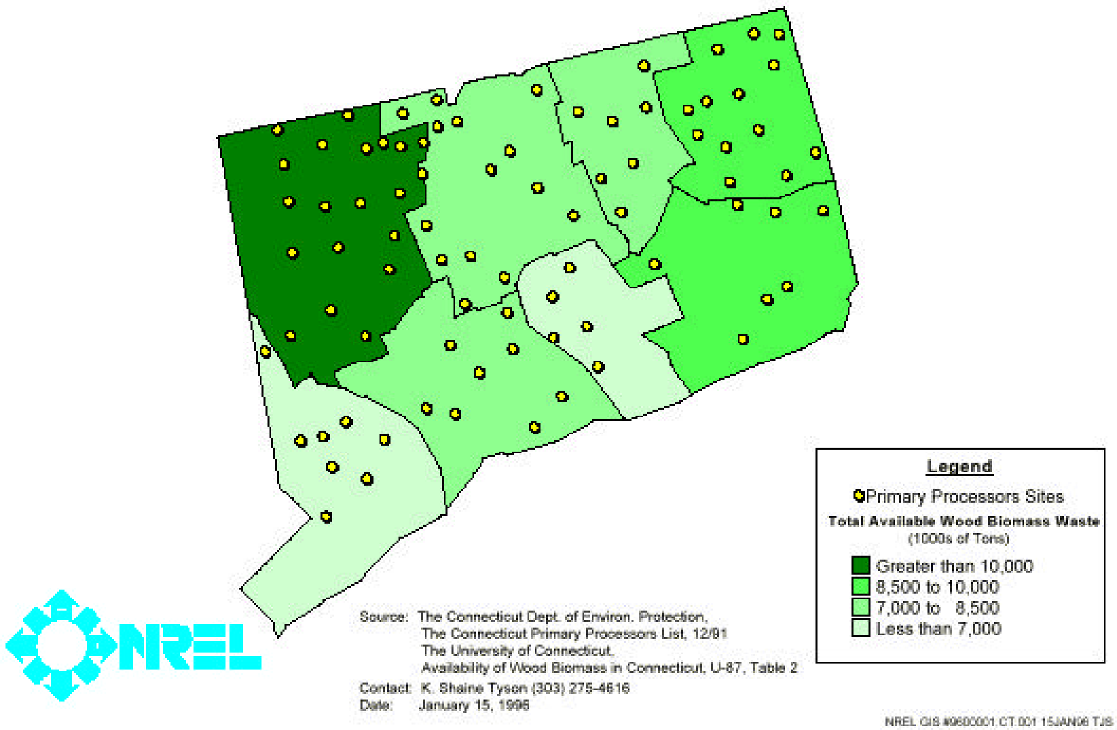
Type of Waste	Examples	Estimated Generation (tons/year)
Landclearing debris	Tree stumps, tree tops	>300,000 including <100,000 disposed at solid waste disposal facilities and >200,000 chipped or left on site)
Demolition waste	Rubble, wood, roofing material, Wallboard,metals,carpeting, insulation	>500,000
Construction wastes (from buildings)	Pallets, wood scraps, gypsum, siding and roofing scraps, packaging, paints and stains, carpeting foam padding, insulation.	>240,000
Highway construction and demolition waste	Asphalt, concrete, steel, related construction and demolition wastes, utility poles, railroad ties, marine pilings, etc.	>840,000
Oversized MSW	Furniture, furnishings, carpeting, rugs	Approx. 131,000

Estimated Annual Generation in Connecticut of Certain Major Special Wastes[7]

Waste Type	Quantity (tons/year)
Construction and Demolition Waste, Landclearing Debris	800,000
Wastewater Treatment Biosolids (dry)	100,000
Paper Sludges (dry)	48,000
Utility Poles	8,000

[5] Proposed Solid Waste Management Plan, Connecticut Department of Environmental Protection, December 1999, P.24.
[6] NOTE: The 300,000 tons/year coincides well with an earlier figure provided in "Study of the Potential Impact and Benefit of Woodburning Facilities in Connecticut," by Bruce Carlson in January 1990 but that this figure may vary by 50% due to building swings. It further notes that attempts to market chips in New England from this source have not been successful due to transportation cost
[7] op. cit. CT DEP. p. 26.

Despite the availability of these gross figures, there is the need to delineate further the details of the waste content, as well as the locations of the resources, in order to develop



estimates of what percentage is actually recoverable. This is essential to determine the economic viability of resources to be used for either power generation or liquid biofuel feedstocks. A 1996 biomass waste map of Connecticut from NREL is also useful in a general way but still does not provide the detail required. (See above.)

Additional Biomass Resources

Of the other Northeastern states, to our knowledge, only New York state is actively engaged in research and development of a closed loop biomass supply system although they have involved Vermont, Pennsylvania and New Jersey in their activities. For several years they have been working under a DOE contract to grow certain strains of Willow as a feedstock for co-firing at a Niagra Mohawk facility.[8]

Waste products are not the only resource which should be considered. The state is heavily forested and the sustainable harvest of some of that resource could be significant. One study of biomass use for Connecticut estimated that forest harvesting of 219,200 tons

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[8] Personal communications with Jeffrey Peterson of NYSERDA.

annually could take place on a long-term sustained yield basis.[9] Included within these estimates are some large holdings which might be considered for siting of installations including: 27,000 acres of private watershed land holdings by the Metropolitan District Commission, other water company watershed resources, lands held by the Mashantucket Pequot tribe, state forests and family land holdings such as the 10,000 acres held by the Child family in Norfolk.[10]

Wooley Adelgid to Decimate Hemlocks in Connecticut[11]

Another opportunity in biomass resource is quickly becoming available due to a serious and unfortunate ecological disaster which faces Connecticut. This is the result of an infestation by the wooley adelgid, a non-native insect first introduced into Connecticut woodlands in 1985 which destroys hemlock trees, a significant species in Eastern forests.

The wooley adelgid has been found in 145 of 169 Connecticut towns and is expected to decimate an estimated 23 million hemlocks in the state. The Metropolitan District Commission is already planning the removal of hemlocks from its 3,000 acres of forest holdings in West Hartford and Bloomfield and will probably consider the same action for its more extensive holdings in the Barkhamsted, New Hartford, Colebrook and Hartland watershed area. They cite danger of wildfires, erosion and reservoir protection as some of the factors influencing this decision.

This tragic loss of the species may necessitate special waste handling considerations that might provide a driver in favor of a biomass facility. Discussion with DEP, MDC and other sizeable landowners should commence on how best to handle this environmental emergency.

The total potential capacity of biomass to provide power in the state is a difficult figure to determine. One guideline which may set a maximum technical potential (as opposed to a market potential) is the figure of 100-199 MW[12] for the state of Connecticut. Even, this, however, must be viewed with some degree of suspicion since this figure was based upon use of low-efficiency steam cycle plants. Any substitution of more efficient gasification and/or turbine technology may allow an expansion of this capacity by a conservative estimate of 30%.   Another way to envision the resource draws upon the requirements of planned and existing plants. The Biogen plant was projected to use approximately 135,000 tons of wood per year and was rated at 15 MW. That could be used to determine

[9] Bruce Carlson ,"Study of the Potential Impact and Benefit of Woodburning Facilities in Connecticut," Office of Policy and Management. January 1990. p. 9.
[10] Communications with Starling Child on 1/10/00.
[11] Robin Stansbury, "Community Meeting Slated on Tree-Cutting Plan," The Hartford Courant, 1/29/00. P. B3.
[12] Biomass Electric Technology Rationale, U.S. Department of Energy. January 1991. P. 14.

a technical potential which might approximate the maximum capacity which could be accommodated from various sources. A rule of thumb that has been used in biomass circles is that each 800 acres of forest can sustainably fuel 1 MW of power. [13] The difficulty in determining a realistic figure is highlighted by a recent study undertaken by the Northeast Regional Biomass Program which notes:

> Hundreds, possibly thousands, of resource assessments have been conducted on waste and residue materials. However, these resource assessments often present what appear to be contradictory results. The appearance of contradictory results often lead to a loss of confidence in the data.[14]

Based upon a number of previous studies as well as rules of thumb, it is estimated there is on the order of 100 to 300 MW of electric generation potentially available from biomass in Connecticut depending upon resource availability and the efficiency and mobility of technologies employed to use it.

Technology Assessment

Existing State of the Art - Direct Combustion of Solid Fuel

Most of the existing technologies used in New England for biomass power production use a steam cycle (Rankine) employing the direct combustion of solid biomass which produces steam to power a turbine generator. In New England there are currently 824 Megawatts (MW)[*] of capacity available (669MW operational) broken down as shown below. In Maine as much as 48% of their electricity needs have been met due to biomass while in Vermont the figure has approached 30 percent.

Biomass Gross Generation, 1996[15a]

[13] Personal communications with Jeffrey Peterson of NYSEDA revealed that they use a figure of 1000 acres of willow to fuel each MW. This also brings up the legislative definition of how "sustainable" biomass is considered as a Class I resource for RPS eligibility since it may come from either a closed loop system or through natural regeneration.

[14] "Analysis and Interpretation of Existing Assessments and Databases for Waste Biomass Resources," Northeast Regional Biomass Program Technical Projects Status Report March 31, 2000. http://www.nrbp.org/

[*] A megawatt is a measure of the size of a plant. There are 1000 kilowatts in one megawatt A one megawatt plant can supply the needs of approximately 300 homes. When operated for one hour, a one megawatt-sized plant generates one megawatt-hour of electricity which equals 1000 kilowatt-hours. A typical monthly residential bill may be for 500 kilowatt-hours.

[15] Summary of Biomass Emissions Data New England Region," Environmental Risk Limited, May 1999. p. 1.

MW and Million kWh

	MW Available	MW Operational	Million kWh
Connecticut	150 kW	150 kW	?
Maine	622.55 MW	486.8 MW	3,075
Massachusetts	18 MW	18 MW	W (1-facility) (c)
New Hampshire	113 MW	94 MW	921
Rhode Island	0 MW	0 MW	None(c)
Vermont	71 MW	71 MW	W(b)

Steam/Rankine technology has been in operation for many years and is very well-developed. However, it suffers from low efficiencies (table on following page) and fairly high capital cost per unit capacity compared to new gas-fired combined cycle gas turbines.

Total Biomass Energy System Efficiency[16]

Wood-Fired Power Plant Size	Efficiency
5 – 10 MW	~17%
10 – 20 MW	~20%
40 – 60 MW	~24%

A fairly current cost in the C.T. Donovan report was modeled on the proposed plant in Killingly, Connecticut (KELP) and adjusted for inflation to provide $2,868/kW.[17] This figure is still considered accurate but some units may require additional NOx reduction equipment to meet EPA standards if they are located within non-attainment areas. NOx control may also be required too meet Green-e certification regardless of location.[18] Compared to oil or gas-fired units, much of the cost is in the fuel handling equipment as well as the boiler and generator itself. Comparison of direct combustion, biomass steam to other technologies is show in the chart below:[19]

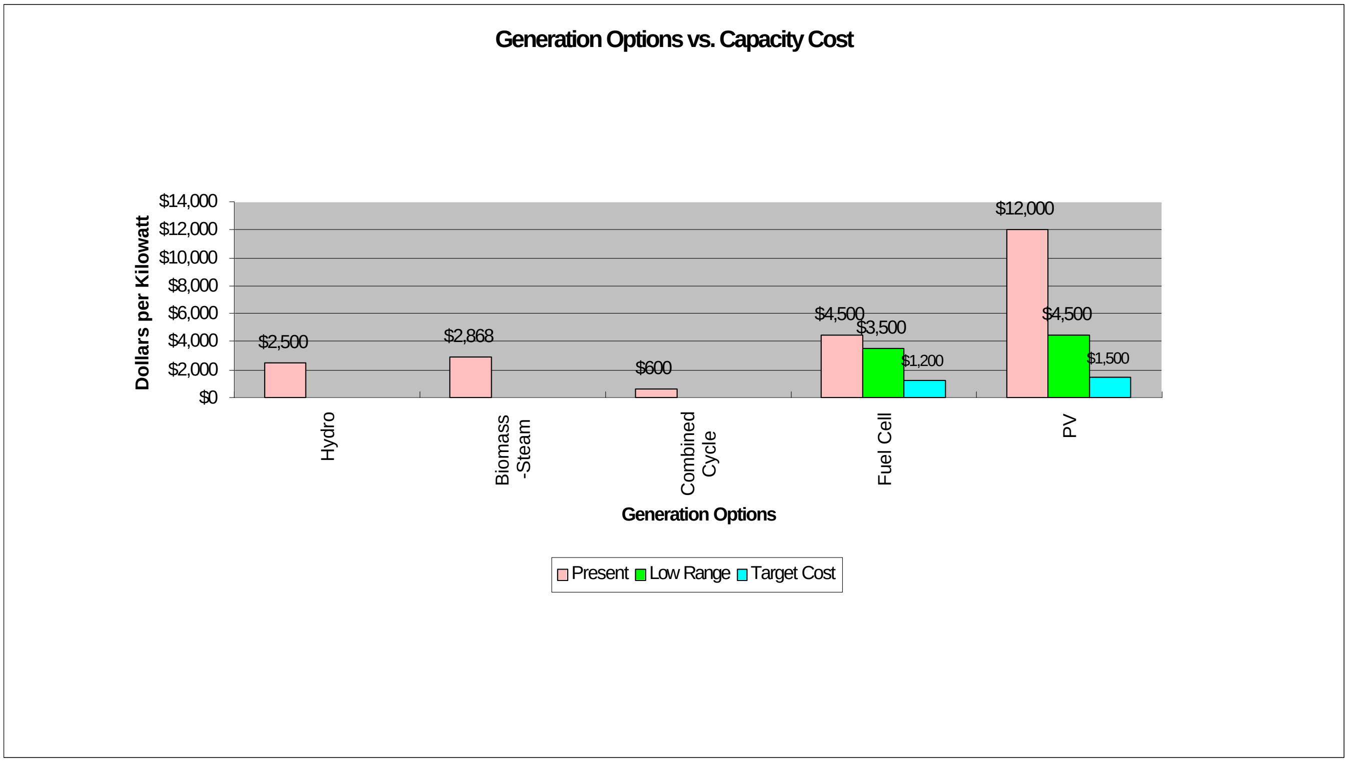
(a) Source: www.eia.doe.gov/cneaf/electricity
(b) W = data withheld to avoid disclosure of proprietary company data
(c) Data obtained by discussions with various environmental agencies

[16] "C.T. Donovan Associates, Inc., "Scoping Study of Renewable Electric Resources for Rhode Island and Massachusetts," November 1997. p. 8-6.

[17] op cit. Donovan. p. 8-22.

[18] Personal communication with Jeffrey Fehrs, P.E. on 7/7/00

[19] Gas Turbine World 1999-2000 Handbook, Volume 20, pp. 20-30. New England Solar Electric catalogue, Spring/Summer 2000, pp. 34-35. "Become a Solar Pioneer," SMUD literature. Donald Osborn, "Commercialization and Business Development of Grid-connected PV at SMUD," ASES Conference, June 1998, p.4. Energy User News, "Med Center Takes Honor with Fuel Cells that Save Energy, Cut Pollution," Dec. 1994. ONSI Literature, "Introducing the ONSI Model PC25C. Alan C. Lloyd, "The Power Plant in Your Basement," Scientific American, July 1999, pp. 80-86.



Another direct combustion technology uses a wood-fired gas turbine with an external combuster and cyclone clean-up system. This was first employed by Aerospace Research Corp. (Joseph Hammrick) in a 3 MW unit that produced power for the TVA.

Bioten in Knoxville, TN has recently advanced the same general concept in a 6 MW unit. Their unit has been through partial testing and recorded a thermal to electric conversion efficiency of 21% -- a value more typical of a 20 MW unit. They estimate that this unit could reach efficiencies of 35-40% in a combined cycle configuration. (Since EUA, the parent company of Bioten, has recently been acquired by National Grid (UK), they are anxious to sell the Bioten as a business or liquidate all assets separately.[20])

A similar unit designed at a 500 kW size is being developed by Power Generating Inc. of Fort Worth which reports that it completed testing a unit on 85% wood with 15% natural gas and was preparing to market systems between 500 kW and 5 MW.[21] (An update on this is provided later in the report.)

[20] Personal communication with Bill Freve of Bioten on 10/7/99 and subsequent letter of 3/9/00.
[21] Victor de Biasi, "Alfalfa-fueled 75 MW Power Plant Back on Track for 2002 Operation," Gas Turbine World Magazine, July/August 1998, pp. 26-30.

New Technology - Gasification

Gasification goes back as far as 1800 when "city gas" was produced by gasifying coal and used for lighting and cooking. The same process is basically used to gasify biomass. As opposed to direct combustion, gasification offers numerous advantages, including:

- Greater ease of control
- Operation is possible which allows gasification to continue with storage of the gas separate from the electric energy production.
- Intense combustion which increases the heat transfer by an order of magnitude compared to direct combustion of coal and wood
- The ability to be used in high efficiency internal and external combustion engines.[22]

The combination of gasification and high efficiency gas turbines may offer the best hope for biomass to attain broader use than it has now and to meet lower price requirements set by a competitive market.

> Gas turbines are inherently simpler and cheaper than conventional steam turbines. And whereas the latter have shown no improvements efficiency since the late 1950's, gas turbines have improved continuously. The most promising way to use biomass in gas turbines is to gasify it with air and steam at high pressures and clean the gas of impurities that might damage the turbine blades before burning it).[23]

There are many methods by which to gasify biomass and thousands of different gasifiers have been designed and built. The variations in their design are a function of the fuel(s) used, method of heat delivery to the gasifier, method by which air and fuel are supplied to the gasifier and the clean-up and storage mechanism.[24] A major division among gasifier types includes those which are "fixed bed" as opposed to those which are "fluidized bed" wherein the pressure of the gases levitates the solid particles which move up and down in a fluidized motion.[25]

One of the most widely used fixed-bed designs is the updraft or "counterflow" gasifier. In it the biomass is fed into the top of the gasifier through a pressure resistant lock-hoppers

[22] Thomas B. Reed and Siddghartha Gaur. "A Survey of Biomass Gasification 2000." NREL. September 1999.
[23] Carl J. Weinberg and Robert H. Williams, "Energy from the Sun," Scientific American, September 1990. pp. 147-155.
[24] op. cit. Reed and Gaur. P. 1-5.
[25] op. cit. Reed and Gaur. P 1-10 - 1-18.

and as it flows downward it undergoes drying and gasification as it settles to the bottom. Simultaneously, air and steam are introduced into the gasifier. The usable gas flows from the top of the gasifier and the ash from the bottom. In this process, the efficiency of conversion of the biomass to gas is quite high and the actual design is fairly simple making it a popular commercial choice. It is best used with large size biomass fuels such as wood waste as opposed to agricultural byproducts which require formation into larger pellets for use with this technology.[26]

In a fluidized-bed gasifier, biomass is fed continuously with an inert heat absorbing and distributing medium (i.e. sand) and is "fluidized" by the flow of air (or oxygen) and sometimes with steam. Heat can be supplied directly from the combustion of char within the gasifier vessel or indirectly from char burned in a separate vessel. In the latter, the heat is transferred to the gasifier vessel by either heat exchangers or by recirculating the sand heated in separate vessel. (See visual explanation of Battelle gasifier on page 16 for a diagram of this.) With indirect heating there is the advantage that the gasification product is not diluted with the char combustion by-products. The usable gas is taken from the top of the gasifier. While fluidized beds do leave greater particulate levels in the gas product they offer multiple advantages including:

- Superior mixing leads to excellent heat and mass transfer resulting in uniform temperatures

- Fuel moisture, which keeps bed temperatures below the ash melting temperature becomes a positive factor

- Faster reactions take place allowing higher throughput of biomass material

- Its reduced size also reduces the capital cost of the gasifier.

- Because average temperatures are higher than in a fixed bed, significant amount of tars and oils are converted into permanent gases.

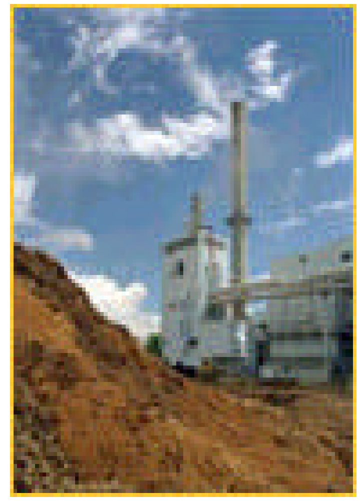
- Can handle smaller, less dense feedstocks such as agricultural waste materials[27]

In most instances the product gas from either gasification process has a low to medium Btu content (e.g.125- 500 Btu/scf vs. pipeline gas which contains about 1000 Btu/scf) and requires some degree of cleanup before it can be used directly in an engine. The presence of certain tars presents one of the largest obstacles to using gasified biomass in high efficiency engines for power production. Another common contaminant is alkali metals

[26] op. cit. Reed and Gaur pp. 1-10 - 1-18 and http://www.eren.doe.gov/biopower/projects/ia_tech_gas5.htm
[27] op. cit. Reed and Gaur pp. 1-10 - 1-18 and http://www.eren.doe.gov/biopower/projects/ia_tech_gas6.htm

(e.g. sodium or potassium) which are often found in crop residues. Fortunately, these can be scrubbed from the product gas by well established procedures.

Of particular note is the Battelle gasifier, which is currently undergoing testing at the McNeil Station in Vermont. Originally developed by Battelle Memorial Institute and now licensed to Future Energy Resources (FERCO) it is a high throughput, gasifier which has the capability to produce a gas product with 500 Btu/scf without need for an expensive oxygen plant required by other gasifiers to even approach this fuel value. Developmental work began in 1980 on a 10 ton per day (TPD) unit which accumulated over 22,000 hours of operating time on a variety of fuels and was successfully coupled with a gas turbine in 1994. The Vermont project is currently in Phase 2 which constructed a scaled up version this previous and testing which will involve feedstock throughput test from 200 to 400 TPD. Gas generated during this phase will be used in the McNeil Plant's existing boiler as a supplementary fuel to the existing biomass and natural gas.

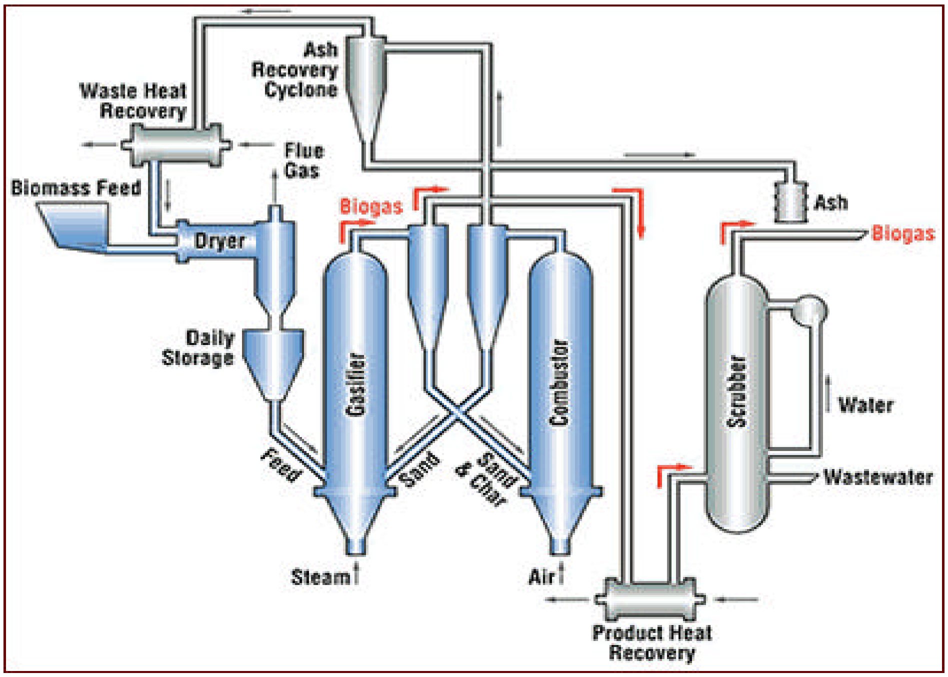


As in any project concerning new technology, this one has had certain early technical problems including: not being able to sustain gasification beyond three hours, lower Btu content gas than projected (410 Btu/scf vs.500Btu/scf) sludge systems problems, inefficient cyclones and rectification of the fuel screw feed to water cooling.[28]

Phase 3 will provide for long term testing and add a gas turbine to the system to generate electricity. To eliminate the problem of tar formation which can ruin gas turbines, the process makes use of a low-cost disposable catalyst (DN-34) to eliminate them before they hit the turbine section.[29] A schematic of the plant is shown below. If the long term testing does provide the proof of concept, this facility will have the advantage of producing biomass power at 35% efficiency in a combined cycle configuration with the potential to reach as high as 45% in later versions.[30] The normal efficiency for a steam plant of this size would approximate 20%. This would allow for greater utilization of a given biomass resource and lower the cost of power.

[28] Personal communications with John Irving (Plant Manager) on 1/04/00.
[29] op. cit. de Biasi
[30] Discussions with John Irving and Ralph Overend on 6/23/00.

The Battelle Gasification Process Used by FERCO[31]



Gasification Cost Estimates

While numerous studies and articles have appeared over the past decade describing the marriage of biomass gasification with gas turbines, there is not yet what can be called a fully commercialized product which could be bought "off-the-shelf". It appears that such systems would have to be produced in large numbers in order to reach the economy of scope often pegged at approximately $1500/kW. Two breakdowns of projected project and per kWh costs are provided in the table on the following page:

[31] http://www.eren.doe.gov/biopower/projects/ia_tech_gas4.htm

Gasification Project Economics[32]

			EPRI (initial)		DOE (1st Plant)
Capital Cost			$2000-$3,500		$1,504
Fuel Costs			$15-20/ton (green)		$17/ton (green)
O&M			$8-20/MWh		$14.56/MWh
Heat Rate			9,000-11,5000 BTU/kWh		11,059-9,545
Busbar Cost		Capacity	$.0328-.0574		$0.0247
		O&M	.008-.020		$0.0146
		Fuel	.018-.023		$.022-.0191
		Total	**$.0588-.1004**		**$.0613-.058**

Even at the most optimistic electric energy price of $0.058/kWh, this is in excess of electricity produced from the newest combined cycle gas turbines using natural gas which are coming in at approximately $.03/kWh. In addition, since these cost estimates are no longer current, there is some doubt as to their present validity. Experience with other medium to large gasification/turbine projects have also not been encouraging including a much heralded 75 MW unit in Minnesota which was to have used alfalfa stems but has been cancelled.[33] Still, gasified biomass has decided advantages over wind which has been quite saleable at approximately $.05/kWh in the emerging green power markets. Biomass has the added advantages of being dispatchable upon command with a capacity factor[34] of approximately 85% compared to wind at a modest 25% to 30%.

The matrix on the following page [To be inserted from an Excel File] showcases some of the more promising gasification prospects. Small units (10 kW to 1 MW.) to large units (1 MW and larger.) In many cases, as of this writing, there is incomplete information by which to make a valid comparison.

More recent discussions on the state of the technologies and business development status can be found in **Appendix B**.

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[32] George J. Sterzinger, "Integrated Gasification Combined Cycle and Steam Injection Gas Turbone Powered by Biomass Joint Venture Evaluation," NREL, May 1994.
[33] Leyla Kokmen, Against the Grain, City Pages, Vol 20, archive/20/982/Issue 982 · 9/29/99
[34] Capacity factor is the percentage of a year's 8760 hours which a plant runs at its equivalent full capacity and can translate into the number of kWh produced in a year, an important factor in economic viability.

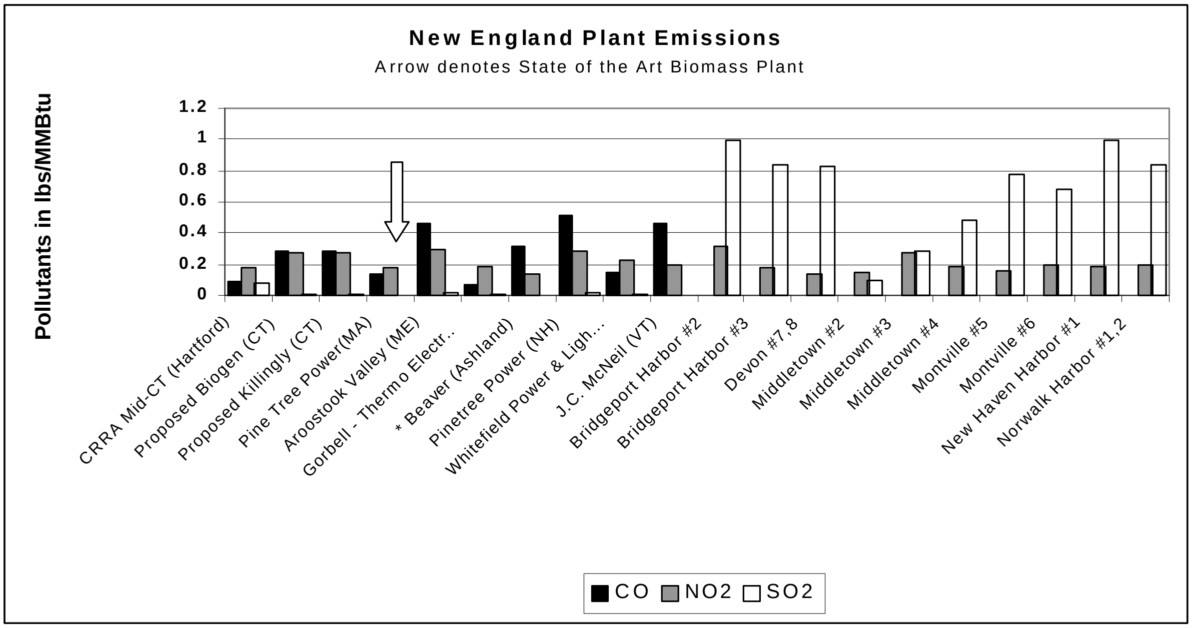
Environmental Considerations

Because of Connecticut's past history with biomass plants it is critically important to understand the environmental characteristics of the various biomass technologies as well as the concerns voiced by the environmental community in regards to them. Too often, the technologies are lumped into the one label of "incinerators" with no differentiation between either the operating principles or intent of the plant.[35] With the exception of the use of gasified biomass in fuel cells, biomass, whether through direct combustion or gasification, still releases certain pollutants into the atmosphere and has some effects upon water and plants site. This should be considered but only in relation to the environmental advantages associated with biomass energy as well as in respect to the full fuel cycle environmental effects of fossil and nuclear plants.

Toxic Air Emissions

Of greatest concern during the previous attempts to site biomass facilities in Connecticut were the toxic air emissions which would be released from the plants as well as by vehicular traffic used to transport biomass to the facilities. Those particular plants were steam cycle and, for their time, extremely clean in terms of emissions. Today, the Pine Tree Power unit in Westminster, MA may best epitomize the state-of-the-art for the existing steam cycle technology. This plant is an 18 MW generator equipped with the latest emissions reductions equipment. The chart below provides the emissions profiles of this facility along with a number of typical woodburners in the Northeast and emissions projections for the Biogen and KELP projects proposed in the late 1980's in Connecticut.[36] It also portrays the "Filthy Five" and the CRRA Mid-Connecticut waste to energy plant as points of comparison.

[35] The word "incinerators" has traditionally been applied to technolgies whose primary concern has been to eliminate solid waste as opposed to biomass plants whose primary use has been to provide energy but may provide a waste solution as a secondary mission.
[36] "Summary Of Biomass Emissions Data New England Region," Prepared For: Center for Resource Solutions, by: Environmental Risk Limited, Revised May 1999. Table 4. Biogen and KELP information from the CT Siting Council application.



It is obvious that the Pine Tree Power plant has approximately one-half the CO emissions of the proposed Biogen and KELP plants and only about two-thirds of the NOx emissions. As such, the Pine Tree Power plant might be said to set the standard for "***low emission advanced biomass conversion technologies***" as specified in the legislation. If past history of biomass in Connecticut is any indication, any plant envisioned for Connecticut, which in its entirety is rated as a Clean Air Act serious or severe non-attainment area, would most likely have to meet these parameters or better.

One of the major concerns brought up by the opposition at the time of the Biogen and KELP plant-siting process in the early 90's was on dioxin generation. Follow-on work has noted that:

> Dioxins are of concern from any combustion process including waste, wood and landfill gas combustion systems. However, with properly operated and controlled systems dioxin levels are very low and have not resulted in high-risk levels. Waste burning facilities routinely test for dioxins (at least every couple of years) and perform risk calculations for the respective state agencies. If the risks were high the facility would be shut down.
>
> Testing performed on wood fired boilers indicates that dioxin is not an issue. Only several of the newer fired systems have been tested and routine dioxin testing on wood fired boilers does not take place. EPA has listed dioxin of marginal concern from landfill gas and will possibly be evaluating it in the future. However, I know of no available data of dioxin from this combustion source. Because EPA has given a low priority in testing landfill gas emissions, I don't see it has an important issue for this study.[37]

[37] Environmental Risk Limited, "Summary of Biomass Emissions Data New England Region," Prepared For Center for Resource Solutions, San Francisco, CA, March 1999. p. 9.

In addition, discussions with those involved with testing the FERCO gasifier at the McNeil Plant have specifically indicated that chlorine containing fuels will not present a problem since chlorine will be recovered as HCL.[38]

Forestry Considerations

During the early 1980's one of the main points of opposition to the McNeil generating plant in Vermont was the potential impact it might have on the forests of the state. Posters were distributed which graphically and negatively portrayed what the appetite for wood by the plant might mean for the forest. This same argument, while secondary in the Connecticut deliberations, did give rise to recommendations by the State Office of Policy and Management's 1990 report on biomass power which suggested that:

- Insure that a professional forester is involved in the design and implementation of all chip harvesting activities.[39]

- The State should consider adopting a Forest Practices Act.

- A portion of that act should establish a system to deal with public reactions and complaints due to biomass harvesting.

- The act should also require registration and monitoring regulations for chip harvesters.

- The state should adopt regulations concerning the testing and the use of ash resulting from biomass power facilities.

This report directly influenced the drafting and passage of the Connecticut Forest Practices Act (Connecticut General Statutes 23-65 f-o, Chapter 451a)[*] which includes many of the recommended provisions.[40] Subsequent legislation (PA 98-228) modifies this to exempt land clearing which is not connected with commercial forestry operations. Most notable in the act is that it does provide for certification of loggers as well as for penalties for infractions. Harvesting regulations are currently receiving comment for revisions by DEP. Missing from the legislation appears to be any mention of ash testing and use resulting from biomass power plants.

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[38] Discussions with John Irving and Ralph Overend on 6/23/00.
[39] op. cit. Bruce Carlson, OPM. p. 29. The report leads to suggesting these last five points.
[*] The act in its entirety can be accessed at http://www.cslnet.ctstateu.edu/statutes/title23/t23-p8.htm#I2
[40] Personal communications with Judd White of CT DEP on 7/20/00.

Solid Waste

Another environmental consideration also closely related to resource assessment is the solid waste policy of the State. Because the State's solid waste management policy has traditionally been heavily weighted toward composting as the favored solution, this appears to discourage the use of biomass for either electricity production or biofuels. An initial draft of the current plan has followed this path but DEP has recognized that certain market limits have been reached for use of composted materials as well as management problems taking place in one major facility.[41] The DEP position appears to be evolving in a direction which would consider multiple solutions for the organic waste component and may include:[42]

- Production of ethanol as a replacement for MTBE if it does not present vapor pressure problems with the fuel in summer and could provide local source not prone to hydration in transit.

- Exploration of other biomass technologies that might mitigate a potential solid waste crisis projected to emerge within ten years which would otherwise necessitate waste export.

- Flexible and environmentally clean alternatives to building additional resource recovery burn facilities and solutions to problems with sludge management.

It is anticipated that later drafts of the plan may include elements which:

- Adds greater flexibility to encompass the use of new technologies

- Discuss specifics how new technologies could be used to produce energy through gasification or as biofuels

- Strengthen statements in support of landfill gas utilization

- Seek to include more specific technology solutions for other waste products such as manure and chicken litter. While manure does not present the magnitude of problem it does in the West and Midwest, one account from Colchester has involved potential fines on farmers who are unable to manage their chicken manure piles better.[43] A study reports that a 20 MW CFB facility could handle the litter from 11 million birds

[41] Proposed Solid Waste Management Plan, Connecticut Department of Environmental protection, December 1999.
[42] Personal communications with DEP on 3/30/00
[43] Peter Marteka, "Town to Take Aim at Flies," The Hartford Courant, 4/24/00. p. A3.

annually.[44] BG Technologies (which manufactures gasifiers) has successfully used chicken litter as a fuel.[45]

- Generally support renewable fuels

In addition, the Solid Waste section of DEP will confer with others within their department to further investigate "yellow grease" and whether it may or may not be a problem and how it might dovetail with efforts to collect organic material from restaurants.[46]

Biomass Treatment by Environmental Rating Systems

Environmental rating systems are being developed to gauge the "greenness" of the energy being built and sold in the region. The ability of a biomass project to meet certification under either Green-e criteria or Power Scorecard, two of the rating systems, should be considered whenever the power is to be sold into the grid. While not absolutely certain, there is a significant possibility that a renewable energy source with a favorable rating and environmental characteristics can enjoy reduced siting time and command a higher price in the market than one that doesn't. In project finance this could conceivably make the difference between one project which is viable and another which is not.

Green-e

The Green-e program is administered by the non-profit Center for Resources Solutions. Green-e provides third party certification for "green" electricity offerings that meet Green-e environmental and consumer protection standards. Companies who sell Green-e certified electricity use the Green-e logo on their marketing and advertising, so that consumers may easily identify environmentally superior electricity.

Electric companies participating in the Green-e program must adhere to a Code of Conduct and undergo an annual third party verification of their power contracts, to ensure compliance. To meet the Green-e standards, an electricity offering must meet the following qualifications:

- ♦ At least 50% of the electricity supply for the product must come from renewable electricity resources as defined by Green-e. This includes those generated from sun, water, wind, biomass (the burning of agricultural or other wastes),

[44] Bioenergy Update, "EPI Fluidized Bed Combustors," May 2000. p.3.
[45] Personal communications with William Partnaen of BG Technologies on 3/10/00.
[46] Personnel communications with Lynn Stoddard on 4/13/00.

and geothermal (heat from the earth).

- ♦ If there are non-renewable portions of the power mix, those must have equal to or lower air emissions than the traditional mix.

- ♦ Air emissions included in the rating are sulfur dioxide, nitrogen oxide, and carbon dioxide.

- ♦ The mix can not contain nuclear power other than what is included in the system power purchased for non-renewable portion of a product's mix.

- ♦ One year after deregulation, the product must contain at least 5% new renewable electricity. This requirement increases to 10% the following year.

- ♦ The company offering the product must agree to undergo a biannual review of advertising materials, to ensure they are not making any false or misleading statements about their products. The company must abide by the Green-e Code of Conduct.

As noted, Green-e has indicated that biomass is an eligible renewable resource, but Green-e uses several advisory committees located in the different regions to further narrow the types of biomass resources that are eligible. In the Northeast, Mid-Atlantic and New England municipal solid waste is not considered an eligible Green-e biomass fuel.

Green-e is a "living standard" that is open to modification, whenever changes can be justified. Changes in the Green-e standard must be agreed upon by regional stakeholders and presented to the national Green Power Board where they will be approved or denied.

While a number of biomass generators could encounter difficulty in meeting *new renewable* source standards for air emissions in non-attainment areas, biomass is considered neutral as far as carbon emissions are considered. The Mid-Atlantic stakeholder group allows clean untreated urban wood waste and other more benign forms of biomass.

Green-e does not certify specific generators and for this reason has been criticized by some environmental groups. Spokes persons for Green-e believe that in order for there to be more widespread acceptance of biomass as a clean renewable resource, the biomass industry must invest in education at all levels.[47]

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[47] Personnel communication with Kirk Brown on 4/10/00 and e-mail communication with Vanessa Mercer on 7/21/00.

Power Scorecard

The Pace University Energy Project has been instrumental in constructing Power Scorecard which is an impact-based, complementary environmental rating system compatible with Green-e. Unlike Green-e, Power Scorecard asks a different set of questions and does not decide what qualifies based on a "50% renewables" level. Instead, it has six categories from "unacceptable" to "excellent" and they are less concerned with the fuel source than on the ultimate impacts. For this reason they also look at coal plants. They have four air impact issues including NOx, SOx, CO2 and Mercury under which a unit would receive a rating. There are also water impacts and land impacts which affect the plant site itself as well as effects which might take place off-site. Power Scoreboard also examines the permanent site impact. Under this, a generator which requires large acreage might receive a poor rating. Specifically for biomass they note:

- Co-firing biomass is a complex issue particularly if it is perceived as extending the life of plants which should otherwise be shut down. In other instances it is less controversial such as the use of landfill gas co-fired would natural gas.
- On land impacts biomass could receive a positive if the fuel would have otherwise gone into a landfill.
- The site impact for biomass is also more favorable than for fossil fuels since the effects would be less enduring.

It was also noted that the quality of communications on biomass-related issues is poor and that people who are against biomass are disturbed with Green-e since their analysis does not investigate any site-specific problems such as road traffic. The Pace representative believes that biomass education is essential particularly on the life cycle environmental impacts of biomass as well as the advantage of the dispatchability of the resource.[48]

One interesting article which highlights stakeholders views on biomass options appears in **Appendix A**. As opposed to clean energy proponents who have set up environmental indices, the study describes first hand views from 25 environmental organizations. The work was conducted by Elizabeth Peele, of the Energy Division, Oak Ridge National Laboratory. The study found high interest and concern about which feedstocks would be used as well as the energy conversion technologies employed. There was consensus that renewably based energy sources were preferable to nuclear or fossil fuels but diversity of opinion over favored biomass sources. Approximately 50% favored biomass "in general", while others only showed varying degrees of support from "favor-with-conditions" to outright "opposed."

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[48] Personnel communications with Sam Swanson on 4/6/00.

Strategies

The major strategies through which biomass power could be introduced into Connecticut include the following:[49]

Co-firing. Biomass co-firing involves the combustion of biomass in existing coal-fired boilers mixed with varying percentages of coal?. Co-firing should not be confused with the use of multi-fuels in boilers specifically designed to burn multiple fuels. Co-firing differs in that it is done in a boiler originally designed to burn only a specific type of coal. [50] The primary advantages are:

- An existing facility can be used with little modifications to its boiler except for burner and the addition of some specialized equipment necessary to feed the biomass fuel(s).

- The boiler is not significantly "derated" meaning reduced from its design power output to a lower value.

- It reduces siting, construction time and cost since it often includes existing rail and/or barge facilities as well as some fuel handling equipment. Time and cost to obtain environmental permitting as well as transmission interconnections are also reduced when compared to greenfield sites.

- The approval process is usually far less cumbersome for this form of biomass utilization since it has the overall effect of reducing emissions such as SO_x, NO_x and CO_2 as well as diversifying the fuel mix. It may present an optimal waste management solution, particularly if a tipping fee can offset a majority of the fuel processing cost.

- In co-firing, the amount of biomass used is typically limited to 5-15% of the total heat input to the boiler. However a report from Lawson[51] indicates success in co-firing wood at ratios as high as 50%. In any case, specific studies are probably required for each candidate site to limit derating and avoid handling problems.[52]

Fortunately, there is a significant history of co-firing experience upon which a Connecticut project could draw if it elects to proceed along this path. For example, New York State Electric and Gas (NYSEG) and Niagara Mohawk (NiMo) in New York

[49] NOTE: A large, stand alone facility has not been considered due to Connecticut's unfortunate past history with biomass siting and lessons from the more recently attempted 75 MW facility in Minnesota.
[50] Jeffrey Fehrs, "Co-Firing Wood in Coal-Fired Industrial Stoker Boilers: Strategies for Increasing Co-Firing in New York and the Northeast. Prepared for NRBP and NYSERDA. April 1999. P. 1
[51] Barry Lawson. "Co-Firing Wood With Coal in utility Boilers," NRBP Report on Forum of Septmber 27, 1994. November 1994.
[52] op. cit. Fehrs. pp 13-14.

already have direct experience co-firing biomass and coal. Three plants have also been modified to co-fire in Pennsylvania.[53]

A serious disadvantage is that if candidates are confined to existing coal-fired utility plants, the potential is limited to two plants that are currently in service; Bridgeport Harbor #3 and the AES Thames in Montville. However, one of these plants is currently under intense scrutiny by the Legislature as part of the effort to clean up the "Filthy Five".

One potential in-state co-firing target of opportunity is the 181 MW AES Thames coal plant in Montville which is also a cogeneration facility. The CEO of AES is Roger Sant who is an ardent environmentalist and is on the board of World Resources Institute a well-thought of environmental think tank.

This particular plant was the first in the world to use CO_2 offsets when it was being sited and received rave notices in the press. As part of the agreement, AES in conjunction with CARE and others, planted 52 million trees in Guatemala to sequester carbon. If co-firing could further benefit their emissions profile, this one company might buy into it. It would also please the environmental community rather than perpetuating the life of a more dubious plant.

Experts on co-firing emphasize that the following points must be considered:

- A carefully considered resource assessment must be performed to develop location-specific supply curves for biomass feedstock, and to determine their long-term cost and availability relative to other uses of the biomass.

- An effective biomass feedstock production and distribution infrastructure must be developed.

- The economic effects of co-firing should be carefully considered. They should include the potential for slagging, derating of the power capacity, and the potential value of the emissions offsets created . It is estimated that the capital cost to add co-firing technology are in the range of $100- $400/kW for modifications and with an internal rate of return which can approach 30 percent.[54]

[53] op. cit. Fehrs. p. 1.
[54] op. cit. Lawson and Barry Lawson," Report of a One-Day Forum Co-Firing II," NRBP, January 1997.

A table which provides positive and negative factors concerning co-firing and repowering appears on the following page.

Repowering. Repowering is the reuse of the components (boiler, turbine, fuel handling, interconnects, etc.) of a formerly used site. For biomass applications this could take place on any existing steam cycle plant where infrastructure is already in place. Reusing an existing site also eases the siting and permitting problems as well as facilitating transmission interconnections. This lowers the economic cost compared to a greenfield project and is, in a sense "recycling" the equipment. PA 98-28 encourages the use of formerly utilized utility sites such as Connecticut Yankee, which has been considered for conversion to natural gas. If biomass gasification is considered, a co-firing of natural gas with biogas might be investigated.

Repowering could take place either strictly as an advanced low emissions biomass steam plant or the existing steam turbine could be employed as a bottoming cycle coupled to a new gas turbine.

If the owners of an existing plant which is on the "Filthy Five" list could be enlisted as partners in such a project, it would have the added benefit of taking a highly polluting plant out of operation and replacing it with a state-of-the-art plant. Then, if power purchase agreements recognizing a green power price premium could be put in place, the repowered plant might provide a viable economic return to the owners

On the other hand, most candidates for repowering might be so large that the large amounts of biomass required might reduce the economics of the project . However, existing access to the site by rail and/or barge might provide sufficient amounts of material with low enough transportation costs to make even a large project viable .

Positive/Negative Factors for Cofiring/Refiring Strategies

Positive	Negative
Erosion of capacity factor due to new CCGT and increasing O&M costs will cut into revenues making some refiring options look attractive.	From a technical standpoint it may not be possible to refire an 80 MW unit with biomass since it could not be derated enough to meet a lower (~10-25 MW) load without introducing co-firing.
If converted into a base load plant, capacity factor would be higher than for an intermediate load plant.	In a co-firing regime, the unit might still not be able to attain Phase III NO_x requirements and SO_x levels may still be in excess of new source standards.
The price paid for the green electricity would be higher than for "brown" electricity.	The location of the plants may not lend themselves to cost-effective use of biomass due to transportation issues.
Certain federal tax advantages might be available	Announcements of such studies might be used as an excuse for keeping the plants open at current levels

	of pollution longer than is necessary.
Due to the previous four factors, the overall revenues might be higher than continuing to generate with the older plants.	Use of emission offsets from such a project could keep the other polluting plants open leading to environmental opposition to the work of the fund.
Emissions reductions gained through use of biomass may be traded as credits or as offsets for other more polluting plants to reach compliance and lowering overall costs	A report from the NRBP website of 12/31/99 indicates that while gasification seems to be acceptable to enviros for Green-e certification, co-firing remains "“off the table” and refiring with coal and biomass may be treated the same way.
Refiring in this way might relieve continuing legislative and regulatory pressures	
The environmental image of the company would be enhanced which might reflect in overall market performance (Innovest EcoValue ’21 Report)	
Even if refiring does not turn out to be feasible, convert the site into the industrial ecology industrial park with biorefinery etc	

Micro Scale Biomass.

On-site micro scale units (below 1 MW power or small scale biorefineries at ~15 million gallons/year or below) would employ small scale biomass facilities placed in close proximity to the biomass feedstock source to minimize transportation cost, often one of the larger expenses associated with biomass energy. This basic strategy was first proposed by distributive generation guru Carl Weinberg when he noted:

> The trend in energy conversion, however, is towards smaller, more modular less financially risky units. At the much smaller scales needed for biomass, biomass-derived methanol would be cheaper than coal-derived methanol.

More recently in specific reference to biomass electric power Weinberg expounded,

> If you stay with direct combustion you only have big turbines. If you gasify, you only have big gasifiers. What you would like is reasonably priced small gasifiers coupled to small gas turbines.[55]

He believes that the gains which could be made by realizing economies of scope through mass production of small gasifiers and turbines would more than compensate for any economies of scale which larger plants often realize in thermal efficiency but not always in capacity factor.

Additional factors favoring this approach include: [56]

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[55] Personal communication with Carl Weinberg on 12/29/99.
[56] Many of these following points are partially derived from: Howard Brown (ed.) w/Tom Strumolo, Decentralizing Energy Production, (Yale University Press, New Haven, 1978). Fred Gordon, Joe Chaisson

- **Reliability**. Increased reliability and overall risk reduction due to multiplicity of generators and fuel sources. The "dash to gas" in much of the nation to power combined cycle gas turbines will lead to greater subsequent price rises making other fuels more attractive than they are currently. In addition, any constriction of gas supply such as has been experienced in the past will make systems using this fuel more vulnerable. The ability to use biomass decreases vulnerability of the system. In addition, dispersed generators are less liable to all be incapacitated due to natural or man made disasters than are large centralized facilities.

- **Power Quality**. Not only reliability of power but enhanced power quality for sensitive information and manufacturing operations is required whenever computer-related operations are involved since only minor power fluctuations can cause costly glitches. While a glitch may last only a fraction of a second, the harm it could inflict on some operations might take hours to recover from which could be extremely costly for certain businesses.

- **T&D Deferral**. Small biomass may not require any transmission system upgrades. In congested areas, it may also offer a lower cost option than traditional transmission and distribution (T&D) upgrades such as substations or new high voltage lines if the cost is shared with private interests. Since it has been noted that, "Americans' demand for electricity is growing at almost two percent per year. But our power grid is expanding at only half that rate. [57]

- **Reduce System Losses**. Less line losses with generation closer to points of use. When electricity is transported over long distances and in areas where there may not be sufficient line capacity to accommodate increased loads line loses can account for 6-8% typical losses. Distributed technologies such as micro biomass can greatly eliminate these losses.

- **Modularity.** Modularity which does not overbuild/overspend. In the past, in order to realize economies of scale it was necessary to build steam turbines of 1000 MW or more which often entailed billion dollar expenditures and produced overcapacity situations with large rates increases until loads caught up. The modular nature of micro biomass allows for load matching which prevents this.

- **Lead Times**. Shorter lead times meaning less financial uncertainties. Since they are built in the factory rather than on-site, there are less risks associated with lead times which in the case of Millstone III in Connecticut measured 13 years from inception to

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and Dave Andrus, *Helping Distributed Resources Happen*, The Energy Foundation, Dec. 1998. Amory Lovins and Andre' Lehman, *Small is Profitable*, pending publication in 1999.

[57] Charlotte LeGates, "Will WAM-ing Solve the BANANA Problem?" Energy.com, March 02, 1999.

completion. This reduces financial uncertainty and the time differential between when a unit is financed vs. when it begins producing income.

- **Project Scale vs. Technology Risk**. With smaller, distributed technologies there is less risk in placing large amounts of capital in larger or potentially soon-to-be obsolete technologies. [58]

- **Scale of Financial Risk**. There is less financial risk for smaller scale projects in general regardless of technology type. As power projects go, micro biomass projects would be extremely small compared to large generators and the risk to a lender in terms of the scale of the loan would be vastly reduced.

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- **Regulatory Risk**. There is less risk of regulatory changes such as in emission requirements for the short planning and installation cycle of a micro biomass project than for larger, centralized but longer term project. In Connecticut's past, there were several calls for changing the siting criteria for wood energy plants which could have interrupted a long term project.

- **Mobility**. Micro biomass has the flexibility to easily be moved if loads do not develop or decrease over time or a total operation needs to be moved. In addition, they can go to where the biomass feedstock is located reducing transportation cost and utilizing resources which might otherwise be uneconomical.

- **Efficiency**. Being relatively efficient compared to other biomass technologies of the same scale, they will not be as subject to fluctuating biomass feedstock prices as are many less efficient competing options. They will also be able to be placed closer to small biomass sources which might otherwise not be economically recoverable for biomass power use.

- **Operations and Maintenance (O&M) Costs**. Potentially lower operations and maintenance (O&M) costs for micro biomass projects which utilize new, smaller but more efficient gas turbines with less maintenance requirements than steam cycle plants.

One primary advantage to micro biomass would be in providing a solution to domestic bulky and special waste problems that might be otherwise difficult or uneconomic to

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[58] The failure of the proposed 75 MW alfalfa gasification plant in Minnesota provides an example of this large scale technology risk. If continued difficulty is encountered in building new transmission facilities to handle large new plants, this could lead to additional risks associated with transmission congestion.

aggregate in just one or two locations from statewide collection. This might include waste from tree trimming activities from electric utilities and state ad local road crews which are usually left in place.[59] A secondary advantage might come from the ability of such units to enhance Connecticut economic development opportunities if they, or certain of their components, were built within the state. Then they would have the potential to satisfy a second lucrative market through export to less developed nations for village power projects.

Capstone, which produces a 30 kilowatt sized gas turbine with recuperation, claims a 30 percent electrical energy efficiency conversion with natural gas. The company is testing their units with medium BTU gas from landfills and digesters. They are concerned with the quality of gas cleanup including removal of condensate as well as insuring that the gas pressure is sufficient to feed their turbine at the required 70 psig. They have also indicated that they have an interest in wood gasification and are aware of some small-scale gasifiers (e.g. BG Technologies, see Appendix A) which are in the development stage. They feel their unit could make a major contribution when coupled with biomass gasification and expressed an interest in research funding to move this along.[60]

Biorefinery

Biomass electric power, biofuels, and biochemical products are already available in the market and currently meet more than 3 percent of U.S. heat and electric power needs and are increasing by more than 2 percent annually in most regions.[61] Several conditions are contributing to the rapid commercialization of the next generation of biorefineries – the conversion of cellulosic biomass into fuels, chemicals and energy (both thermal and electrical). These conditions include:

1. Presidential and Congressional biomass Initiatives;
2. Scientific and technological advances (including incorporation of fossil-fuel refining technologies);
3. Environmental imperatives including air, water and soil enhancement, and the stabilization of greenhouse gases; and,
4. National and energy security imperatives, including reduced oil and petroleum product imports and improved balance of payments.[62]

The current administration and certain GOP interests see the need to escalate these efforts by tripling the use of bioenergy and bioproducts by 2010.

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[59] Personal communications with Starling Child on 7/10/00.
[60] Personal communication with David McShane of Capstone on 1/4/00 and George Wiltsee on 7/24/00..
[61] "President Clinton and VP Gore: Growing Clean Energy for the 21st Century," Office of the Press Secretary. August 12, 1999.
[62] Personal communications with William Holmberg of Clean Fuels Foundation on 1/25/00.

One major barrier to wider use of bioproducts is lack of integration across the biofuels, biopower, and bioproducts segments of the industry. A biorefinery is one example of an integrated approach that could develop new products and industrial processes in facilities that serve multiple purposes. For instance, an alcohol fuel plant using cellulosic biomass might be able to use the byproduct of the operation as a feedstock for electric generation or other purposes.

Competing technologies for future biorefineries include:

1) Concentrated acid to convert cellulose and hemicellulose into fermentable sugars;
2) Dilute and concentrated acid used in concert;
3) Dilute acids to convert hemicellulose, and enzymes to process the cellulose;
4) Pyrolysis or gasification;
5) Fischer-Tropsch or some similar technology;
6) Other technologies such as the Thermal Depolymerization Process.[63]

A major point in favor of this approach will be that the co-production of ethanol with a higher value product (electricity) may lower the overall cost, providing each of them with a more competitive price position.[64]

This concept currently has significant federal support, including a $2.1 billion tax credit plan proposal in addition to a proposed $243 million budget increase for FY 2001. Although the exact funding amounts are uncertain at best and depend upon continuation of policies of the current administration, they should be accessed if possible. For the CEF, a biorefinery also offers a form of “portfolio diversity” which, while adhering to the legislative mandate of renewable electric energy production, also provides other renewable byproducts not associated with electric production which may have greater market appeal while lowering economic risks for the entire operation.

This option may also open some avenues to economic development since some of the primary components of a biorefinery are tanks of varying sizes for feedstock storage, conversion, fermentation, and product storage. There is the potential that several portions of modular, small scale biorefineries could be manufactured in-state utilizing skills similar to those found in existing aerospace and submarine industries .

Biomass Powered Industrial Park.

A biomass-fired industrial park would combine one or more elements of any of the preceding three strategies. In this way not only would be there be electrical output as a draw to the park but the waste heat component could be used for heating, cooling, and

[63] op. cit. Holmberg
[64] Bioenergy Update, The Economic Feasibility of Converting Lignocellulosic Feedstocks to Etahnol and Higher Value Chemicals,” May 2000. p. 3.

industrial processes. The result would be a far more efficient utilization of the biomass resource than for pure electric production at a tremendous economic advantage to the tenants of the park. They would not only have ecological and inexpensive energy but also, due to the proximity to their own plant, would be assured of a high level of power reliability and quality.

Biomass Powered Industrial Park with Industrial Ecology.

This strategy would encompass all the benefits (and risks) of the biomass-powered industrial park but include the addition of an industrial ecology component to add yet another positive draw to a site. In industrial ecology a waste product from one process becomes the feedstock for the next. In such an industrial park it might be possible to find profitable uses and markets for such products as char, biofuels, calcium acetate (a de-icing chemical made from biomass which does not have the negative aspects of road salt[65]) bricks from sewage sludge and other biomass-based products. A model for such industrial ecology sites is in Kalundborg, Denmark where it was designed with the industrial park based around a coal-fired electric generating station.[66] For example, the steam is cascaded to the pharmaceutical plant and other waste heat used for a fish farming operation. The fly ash was used in cement for roads and the gypsum waste product was used in a wallboard plant. Even wastewater went to the oil refinery for reuse. The power plant also imports some waste products from some of these other industries making it very much a closed loop. One account of this industrial park notes that they saved 19,000 tons of oil, 30,000 tons of coal, and 600,000 cubic meters of water annually. Estimated savings are at $12 to $15 million annually.[67] Design of such an industrial ecology industrial park could be undertaken in partnership with the Yale School of Forestry, which publishes the Journal of Industrial Ecology.

Leverage Points to Advance the Strategies

In order to advance the strategies, a number of leverage points (or tactics) to support the strategies are necessary. In this case, the leverage points are defined as actions which the CCEF might take to advance the technology strategy. Many of them are financial in nature and include such general suggestions as issuance of RFPs to co-fund projects or activities. Others are purely of a capacity building or informational exchange nature but are no less important than other potential leverage points in making the technology viable. While many strategies have certain common requirements, not all will work equally well to advance specific strategies. The matrix on the following page provides an overview of which leverage points might work with the major strategies and provides a

[65] Donald L. Wise and Don Augenstein, "An Evaluation of the Bioconversion of Woody Biomass to Calcium Acetate Deicing Salt," ASES Solar '88 Conference Proceedings. 1988. pp. 36-45.
[66] Technology for a Sustainable Future, Office of Science and technology Policy, 1994. pp. 54-55.
[67] op. cit. Office of Science and Technology Policy,. pp. 54-55.

subjective degree of judgement on the merits (low, medium and high priorities) of each which should undergo further team discussion. [To be inserted from an Excel file.]

Closely tied to the leverage points is a second matrix following the next page which analyzes the strengths, weaknesses, opportunities and threats facing each of the major strategies. [To be inserted from an Excel file.] It is a useful tool to portray the risks involved. If the weaknesses and threats cannot be overcome by enlisting appropriate leverage points, it weakens the potential to move that strategy forward and more favorable strategies should receive attention.

Conclusions

Biomass opportunities for Connecticut can be characterized in the following way:

1. Connecticut does not have, nor has it ever had, any significant biomass power facilities.

2. Within its borders, Connecticut has the capacity to install approximately 100 to 300 MW of biomass energy depending upon the technologies and strategies employed.

3. Biomass has certain large advantages over other renewable forms of energy including the local availability of the resource, ability to be used at any time of day or night, and high availability and reliability. This local availability also eases any requirements for new long distance transmission facilities with their attendant siting problems or, in some scenarios, congestion risks from existing facilities.

4. Biomass has other advantages such as providing viable solutions to what is becoming a critical solid waste problem in Connecticut.

5. As an in-state energy source, it also has the capacity to provide employment opportunities not just at the plant but in the acquisition of the biomass resources and, potentially, in the manufacture of some components used in the biomass conversion technologies. (~ 16,000 jobs per $1 billion invested.)

6. Environmental concerns have had a large effect on the siting of biomass facilities in Connecticut and will continue to do so. Failure to effectively satisfy these requirements and interact with the environmental community may stymie future efforts to site facilities.

7. The technologies which can be used with the biomass resource are on a technological cusp between the older, less efficient steam cycle plants and the newer gasification processes coupled with highly efficient gas turbines. While the existing technology is well-known, it is expensive, of low efficiency, less environmentally friendly than other renewables and may require an effective renewable portfolio standard to make it

viable in the marketplace. The new gasification technologies will be expensive in their developmental stages, more environmentally friendly, highly efficient and more likely to become economically viable without administrative support in the mid to long term.

8. There are a number of strategies which could be employed with either old or new biomass technologies. Some would require the development of a general green power market while others could be tailored for use with limited grid sales applications.

9. While Connecticut does have a Renewable Portfolio Standard, this standard has already been weakened in two successive legislative sessions which has delayed its actual implementation for four years. This may, itself, become a risk factor if perceived by investors as a sign that the State does not have the conviction to aide this market in developing.

Possible Market Development Strategies

Various strategies for biomass development are summarized in Table 1.

Table 1. Biomass Power Development Strategies

Strategy	Outlook
Co-firing. Co-firing involves the direct combustion of solid biomass in existing coal-fired boilers or, if gasified, with coal, natural gas or oil burners.	This has a medium opportunity for implementation. It has advantages of using an existing site and potentially making its environmental impact less but is limited by the number of sites adaptable to it and the risk of keeping marginal plants open.
Repowering. Repowering is the reuse of some of the components (boiler, turbine, fuel handling, interconnects, etc.) which could be adapted to biomass combustion at an existing, but closed power plant.	This has a medium opportunity for implementation and also makes use of a brownfield site to the benefit of the environment. It faces technological challenges in matching scale of existing sites to biomass technologies. It would not, however, keep marginal plants open.
Micro Scale Biomass. On-site micro scale units (below 1 MW) would employ small biomass facilities placed at the biomass source to minimize transportation cost, often the largest expenses associated with biomass energy.	This has a high opportunity for success since it does not depend upon a well-developed green power market to use widely dispersed energy production mostly for internal use. Small scale limits financial risks and it could provide positive manufacturing economic development aspects to the state. Technology risks are

	present.
Biorefinery. A biorefinery is an integrated approach that uses biomass to produce multiple products, including electric power, liquid biofuels and bio-based chemicals	This has a medium opportunity for success since it must have more than a green power market to procure its output. More than one technology would be housed in a single facility and the feedstock requirements would be divided among use by value.
Biomass Powered Industrial Park. A biomass-fired industrial park would combine one or more elements of any of the preceding three strategies but also including combined heat and power (CHP, frequently known as cogeneration).	This has a high opportunity for success since it could use an already existing site and the power produced could mostly be utilized within the facility bypassing the need to market it to an as yet undeveloped green market or develop transmission facilities. CHP as well reliability and power quality aspects would provide extra bonuses.
Biomass Powered Industrial Park with Industrial Ecology. This strategy would encompass all the benefits (and risks) of the biomass-powered industrial park but would also include an "industrial ecology" component in which each of the byproducts of a process is used as the input to another process to provide a zero emissions result.	While appealing, this has a medium to low probability of success due to the extensive planning and lead times required to make it happen. It enjoys all of the positive attributes of the preceding option with the addition of an environmentally excellent use of other resources other than power. It should be kept open as an option if an opportunity presents itself.

CCEF Leverage Points

There is the opportunity for the CCEF to leverage activities of the private sector at several strategic points in the project development path. The leverage points can be tied to economic investment or to less direct, but in many ways no less important, activities which will be required for successful project attraction and completion.

Investment/Financial Activities

- ♦ Issue an RFP for projects which meet the criteria to have a medium to high probability of success

- ♦ As a result of the RFP, become an equity investor in one or more biomass projects which have a medium to high probability of success based upon detailed due diligence.

- Provide non-equity construction financing assistance to project developers involved in biomass projects using advanced technology with a high probability of success based upon due diligence.

- Offer co-funding of site assessments to potential projects

- Issue an RFP in conjunction with the DPUC's Consumer Education Advisory Council to determine baseline attitudes on green energy which may be useful in persuading green project developers to invest in projects in Connecticut

Capacity Building Activities

- **Biomass Resource Assessment.** Issue an RFP for a comprehensive biomass resource assessment to provide potential project developers with reliable information on which to base projects of proper scope and scale.

- **Educational Efforts**. Begin educational efforts on renewable energy in Connecticut and particularly on biomass which has had a "difficult" history. Aside from this potential tie-in, work should commence with several regional and local groups including NESEA, Peoples Action for Clean Energy, the Connecticut Energy Co-operative, CONNECT and possibly others including Connecticut Forest and Parks Association, Sierra Club, Audubon, Toxic Action, ConnPIRG and CCAG

- **Renewable Market Assessment**. Track information in other environmental markets including California and Pennsylvania to determine the total shift away from the standard offer, the degree to which environmental issues have affected such shifts and, where possible, what educational or other programs have been responsible for any environmental shifts.

- **ISO-New England Renewable Energy Market Trading**. Continue to monitor the status of ISO New England to deal with green trading and how this will affect the market.

  In conjunction with ISO-New England, better determine where weaknesses within the transmission grid lie which would prevent the import or export of renewable generation to and from other portions of New England, New York and Canada.

- **Wood Chip Certification**. Insure that a professional forester is involved in the design and implementation of all chip harvesting projects associated with CCEF funding.

- **Gasification Technology Assessment**. Many of the biomass strategies could be expedited in the siting and licensing process if they use environmentally excellent technologies such as gasification. The reports that are currently available provide incomplete information on the operating and environmental characteristics and cost for both large and small gasifiers. Without the latter, there is little basis for any calculation of financial viability. There is the need for additional work to determine this information before any strategies are either selected or eliminated.

- **Develop/Continue Partnerships**. Define partnerships with other agencies or groups having a regulatory or business interest pertaining to biomass. In particular, continue the fruitful dialogue with the Department of Environmental Protection, Waste Management Bureau.

Issues/Questions

1. Determine if it is possible to interface with Connecticut industrial organizations (such as the Manufacturers Alliance of Connecticut, Connecticut Tooling and Machining Association, CBIA, Connecticut Power & Energy Society) to ascertain what biomass energy products or biomass system energy components their members might be able to supply to OEM producers.

2. Determine which energy brokers, power marketers and other entities are poised to enter the Connecticut market, what environmental packages they plan to offer, what they are doing to satisfy their renewable portfolio standard requirements.

3. Determine any interface(s) which may exist between the Connecticut Clean Energy Fund and the Energy Conservation Management Board.

4. Determine the degree of interest by Hartford Steam Boiler and other local insurers in undertaking project due diligence, financing, insurance, or use of the energy generated from renewable energy sources.

5. More thoroughly review the state's legislation pertaining to forest practices, meet with state forestry officials and the environmental community to determine what additional provisions may be required for support of a biomass energy industry.

Appendix A

BIOMASS STAKEHOLDER VIEWS AND CONCERNS: ENVIRONMENTAL GROUPS AND SOME TRADE ASSOCIATIONS

Bioenergy Update
May 2000, p. 8

This exploratory study was conducted by Elizabeth Peele, of the Energy Division, Oak Ridge National Laboratory, and prepared for the Office of Transportation Technologies, Office of Fuels Development, U.S. Department of Energy. This study, which explored the views and concerns of 25 environmental organizations, found high interest and concern about which biomass feedstocks would be used and how these biomass materials would be converted to energy. While all favored renewable energy over fossil or nuclear energy, opinion diverged over whether energy crops, residues, or both should be the primary source of a biomass/ bioenergy fuel cycle. About half of the discussants favored biomass “in general” as a renewable energy source, while the others were distributed about equally over five categories, from favor-with-conditions, uncertain, skeptical, opposed, to “no organizational policy.”

Considerable concern was expressed in the discussions about land use implications of energy crops, especially since increasing land areas for this purpose could affect marginal and ecologically sensitive areas (wetlands, wildlife habitat) and Conservation Reserve Program (CRP) lands. The environmental impacts of developing/growing/ harvesting biomass crops and the collection of residues and wastes for conversion were discussed as well as chemical inputs to crops, and impacts on soil, water, and air. Possible impacts upon national forests and use of forest residues drew much concern, as did use of municipal solid wastes.

Conversion technologies, particularly burning of wood and cofiring of wood or residues with coal, drew great interest and questions. About half of the discussants “had no problem” with burning trees, while others expressed concerns about bad experiences with incineration. Most discussants were full of questions about every aspect of bioenergy fuel cycles and asked for more information. The author found a highly variable information base about biomass and bioenergy, which affected the study design. Discussants asked for comparisons among biomass sources and between biomass and other fuels.

Issues raised most often within the discussion agenda included sustainable agriculture and forestry, sustainable energy systems, and sustainable energy systems, and biodiversity. More issues were volunteered outside of the discussion agenda: land for food vs. energy, subsidies for fossil and nuclear energy vs. equalizing the playing field for renewables, centralized vs. distributed energy systems, how bioenergy fits with utility restructuring, visions of bioenergy futures, who will benefit from biomass programs and subsidies, and scale and size issues. Values and concerns driving these responses appear to be within the context of moving toward an energy future based upon renewable resources. Other driver issues included concern about global warming and the global carbon balance; developing sustainable energy, agricultural and forestry systems; and doing so in ways that enhance (or at least do not further damage) biodiversity. Internal organizational issues and strategies are already impacting these stakeholders' reactions to and interest in bioenergy. For instance, groups working on global warming policy and legislation support development of bioenergy. The Sierra Club's campaign to end logging in the national forests and the several campaigns to upgrade or close old coal power plants probably raise obstacles or deflect policy away from biomass. Concern over effects of global warming on wildlife habitat may push toward acceptance of biomass programs. Sensitive issues and those which raise intense concerns have the potential to slow or stop program development. These may include: municipal solid waste (MSW), genetically modified organisms (GMOs), forest and forest residue use, cofiring as incineration, **cofiring which extends the life of old polluting coal plants**, [Emphasis added] and certain aspects of land use involving marginal and CRP lands.

Most of these stakeholders can be described as waiting hopefully for the promise of bioenergy to be demonstrated, **but a sizeable minority are (influential) skeptics about the prospects**. [Emphasis added] All want to have more information and analysis of the status, progress and prospects of biomass and bioenergy. **The window of receptivity to information and dialogue is open now, but probably not for long**. [Emphasis added]

Recommendations propose research and analysis to produce balanced information on net benefits of bioenergy fuel cycles, tailored outreach to external stakeholders, extended dialogue and involvement of stakeholders including periodic bioenergy/biomass roundtables, and developing the vision of bioenergy futures and various scenarios for achieving these futures.

This report, Biomass Stakeholder Views and Concerns: Environmental Groups and Some Trade Associations, is available electronically from <www.doe.gov/ bridge>. Hard copies are available to the public from U.S Dept. of Commerce, NTIS, 5285 Port Royal Road, Springfield, VA 22161, 1-800-553-6847, 703-487-4639, fax 703-605-6900, email <orders@ntis.fedworld.gov>. Copies are available to DOE employees, DOE contractors, Energy Technology Data Exchange (ETDE) representatives, and International Nuclear Information System (INIS) representatives from Office of Scientific and Technical Information, PO Box 62, Oak Ridge, TN 37831, 865-576-8401, fax 865-576-5728, email <reports@adonis.osti.gov>, web site <http://www.osti.gov/products/sources.html>. Refer to ORNL/TM-1999/271. Date of Issue of the publication is January 2000.

Appendix B

Current Status of Selective Biomass Technologies

1) Power Generation Inc. (PGI) has filed an application with NREL to secure funding to complete testing on their direct combustion, external combustion or biomass fired gas turbine. Also involved in the project is O'Brien energy based in Philadelphia. Because NREL has more funding than was originally bought to do biomass projects, they believe they have a good opportunity to receive funding.[68] PGI originally suggested that the CCCEF "partner" with them on the NREL application (1/26/00) which would provide additional funding for testing but there was not an adequate cost-sharing by the company, the CCCEF was not yet at a point to consider it and no business plan was presented. Since that time, PGI has submitted a business plan and has been back in contact with The Fund. They are currently seeking a meeting in mid-June.

2) William Partanen of BG Technologies noted that they have two units running on chicken litter as well as six in California which are running on wood chips. Under funding from NREL they are looking to couple their gasifier with three ganged Capstone microturbines for a 90 kW unit. They estimate the cost of their gasifiers would be $400 to $600 per kilowatt thermal and $900 to $1200 per kilowatt electric but with increased production the cost could be reduced. They have been in discussions with a firm in New Brunswick on manufacturing it in a 40 kilowatt to 700 kilowatt range. They believe that the average BTUs would be from 125 to 150 Btu/scf although if chicken litter is used that figure may be higher. [69] This technology should be monitored since chicken litter is becoming an increasing problem in Eastern Connecticut.

3) Discussions have also taken place with representatives of Capstone Turbine. James Pfeiffer, the Northeast representative, says that the current price is $1000/kW. The units have a combined total of 250,000 hours of run-time and have done well under multiple cycling tests. Their emissions are rated at 9 ppm NOx at its worst and two parts per million at its best. It is also able to generate 277,000 Btus/hour 520 F. It has operated on digester gas as well as landfill gas with values approximating 600 Btus/scf but can use fuels tested as low as 350 Btus/scf. Yearly maintenance requirements are said to be one-hour or less.[70]

4) Sim Weeks of Future Energy Resources Corp. (FERCO) provided an update on the use of the Battelle gasifier at the McNeil plant in Burlington. He said they were in the operations stage and are now looking at the parametrics to determine certain boundaries. It is operating several times every other week and now has "quite a few hours" operating

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[68] Personal communications with Steven Anderson, President of PGI on 3/10/00.
[69] Personal communications with William Partnaen of BG Technologies on 3/10/00.
[70] Personal communications with James Pfeiffer of Capstone on 3/8/00.

time behind it. He noted that it is expensive to operate since the fuel is specialized and consumes 250 tons per day use. I was led to believe that they have had runs of 24 to 36 hours duration. The firm also has a new CE0 who is actively pursuing commercial projects with a goal to have two under way by the year's end. They have set no restriction on size but units in the 200 to 300 tons per day (approximately 20 MW) is what they are considering. They will match up the size with the availability of the resource. They have not yet matched the gasifier with any particular turbine since they believe it is too early although they have talked with Solar Inc.. There's also the potential to co-fire it with natural gas. They have begun to send out professional looking commercial literature to perspective project developers. In addition, they were recently the recipient of $16 million from the Turner Foundation which is interested in investing in the commercialization of this technology because it fits their conservation and environmental preservation goals. They believe this investment by the foundation will demonstrate to the investment community that they are serious about commercialization and their ability to be a formidable player in the clean energy markets. One press release quotes them as saying that they now have more than 22,000 hours of pilot plant operation behind them.[71]

5) Carl Bielenberg and Barry Burnstein of Better World Energy (BWE) are working with Messersmith Manufacturing located in Michigan on a biomass thermal unit similar to Chiptec's. Chiptec may not be strictly gasification but has been used to heat schools and businesses. The BWE unit is capable of 1 million to 10 million Btus/hour and is projected to sell at $150,000 to $250,000 per unit. They expect to sell three to five units per year. They are also working on a gasification unit for combined heat and power for use with a gas turbine in conjunction with Jack Humphries, a New Zealander who will be coming to spend a year with them on development. It would be a modular design capable of covering the 250 kW to 1 MW range. They envision these being housed in 20 ft. sea freight containers for easy transport. They hope to be able to demonstrate this unit by sometime next year and are open to providing installations. He said they have received $75,000 in grant money from a Washington DC non-profit and support from the State of Vermont. He estimates that the power from the unit will cost $.08-.10/kWh.[72]

6) Kelda Group, which has just acquired the Aquarian water system in Connecticut, has been involved in a 12 MW biomass project in Great Britain utilizing advanced gasification by TPS of Sweden. The American subsidiary of their First Renewables arm is Fiberwatt. While Kevin Bond, who until recently was CE0, was enthusiastic about their biomass endeavors both in Great Britain as well as chicken litter to energy projects in Maryland and Minnesota, he has been recently replaced. Letters of assurance on the continuation of existing policy have been sent out by Kelda representatives so that it appears that there is still the potential to undertake joint projects with this company. Because their involvement with chicken litter in Maryland and Minnesota, there may be

[71] Personal communications with Sim Weeks of FERCO on 3/21/00.
[72] Personal communication with Carl Bielenberg on 3/20/00 and with Barry Burnstein on 5/8/00.

some synergy to develop a similar project in Eastern Connecticut where the chicken litter presents an environmental problem as well is a social nuisance.[73]

[73] Personal communication with Kevein Bond on 4/7/00 and Larry Bingaman and Richard Schmidt on 4/12/00.