A REVIEW OF THE EXPECTED AIR EMISSIONS FOR THE PROPOSED FIBROSHORE 40-MW POWER PLANT TO BE FUELED WITH POULTRY LITTER AND WOOD

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Prepared by:

ARI

Alternative Resources, Inc.
9 Pond Lane
Concord, Massachusetts 01742
(978) 371-2054

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1.0 SUMMARY AND CONCLUSIONS

Summary

The commercial poultry industry in Maryland generates substantial quantities of poultry litter. Poultry litter is comprised of a mixture of poultry manure and poultry bedding material (straw or wood chips). There is a long history in Maryland of beneficially using poultry litter by land applying it as a fertilizer. However, there is mounting concern regarding the environmental impacts on Maryland's surface waters that can result from excessive land-application of animal manure. Accordingly, there is interest in Maryland in finding additional manure management methods that are environmentally and economically acceptable alternatives to land application.

In the case of poultry litter, one promising possibility is to use the poultry litter as a renewable, biomass fuel to generate electric or steam power. Besides alleviating the environmental impacts of excessive land application, using poultry litter as a renewable fuel could reduce dependence on fossil fuels for power generation in Maryland, and could thus reduce greenhouse gas emissions in the State.

A new power plant, to be fueled with poultry litter and clean wood (forestry residue), has been proposed for private development in Maryland by Fibrowatt, LLC. The "FibroShore" plant would be constructed on the Delmarva Peninsula, likely in or near Dorchester County. The proposed facility would be intended to provide the local poultry industry with a reliable, year-round alternative to land application for the management of poultry litter.

The FibroShore facility, as currently proposed, would burn renewable, biomass fuels in a conventional "stoker" boiler to produce steam. The steam would drive a conventional turbine generator to produce a nominal 40 megawatts (MW) of electric power. The plant would process about 300,000 tons of poultry litter annually, and about 100,000 tons per year of forestry residue. Thus, about three-quarters of the plant's fuel requirements would be met with poultry-litter biomass and about one-quarter with clean-wood biomass. The plant would be designed to operate 365 days per year, 24 hours per day, and would be on-line approximately 90% of the hours in a year. Fibrowatt has successfully designed and constructed three similar plants in the United Kingdom which are currently in commercial operation, and all have used poultry litter as their main source of fuel.

To prevent the escape of odors and dust, the FibroShore plant would receive and store the poultry litter fuel, and would conduct all principal process operations within totally enclosed buildings. In addition, stack emission controls would be included, so that the plant would meet all air-related regulatory requirements of the Maryland Department of the Environment (MDE) and U.S. Environmental Protection Agency (US EPA).

This report, solicited by the Maryland Environmental Service (MES), provides a preliminary assessment of air emissions for the proposed, 40 MW FibroShore plant. MES intends this report to serve as a basis for addressing questions from regulators and the public regarding the environmental and public-health implications of the facility's emissions. Accordingly, the report describes the types of emissions expected from the facility and the planned emission control techniques. In addition, the maximum expected emission levels are presented, presuming use of the planned control techniques. To provide perspective, the anticipated air emissions for the

FibroShore plant are compared with emissions from similar-sized power plants that use fossil fuels or all-wood fuel. Finally, this report addresses the effect that the FibroShore plant would have on greenhouse gas emissions. That is, the estimated reduction in greenhouse gas emissions is quantified, that would result from generating 40 MW of electric power using poultry litter and forestry residue as renewable fuels, rather than generating the same power using fossil fuel (coal, oil, or natural gas).

The major points that emerge from this review of air emissions from the proposed FibroShore power plant are as follows:

1. Three Fibrowatt plants, which have been fueled with poultry litter, operate commercially today in the United Kingdom. The newest of these plants operates at a scale similar to the 40 MW size proposed for the FibroShore plant. A substantial amount of air-emissions data exists for these operating plants, resulting from the continuous emissions monitoring and periodic stack testing that has been carried out to date. This air emissions data for actual plant operation provides a sound basis for estimating emission levels expected at the planned FibroShore plant, and for specifying emission control requirements for the plant. Furthermore, there is also useful local emissions data available from emissions testing of the cogeneration plant at the Eastern Correctional Institution, when that plant was being fueled, on a trial basis, with poultry litter.

2. The proposed FibroShore plant would be required to meet stringent, air-emissions permit limits that will be set by the Maryland Department of the Environment (MDE). For most pollutants, MDE will set the emission limits based on requirements for Best Available Control Technology (BACT). But for nitrogen oxides, MDE will set the emission limit based on Lowest Achievable Emissions Rate (LAER) technology. BACT and LAER both require the use of the latest, demonstrated advancements in emissions controls, but LAER is the more stringent. BACT requirements are imposed on a facility for emissions in an area that is in compliance (referred to as in attainment) with National Ambient Air Quality Standards, and the more stringent LAER requirements are imposed in areas not in compliance (nonattainment) with the standards, or where such emissions can impact areas not in attainment.

   Emission controls for nitrogen oxides must meet LAER requirements because Maryland is located in an Ozone Transport Area designated by US EPA. Emissions of nitrogen oxides in the Ozone Transport Area are specially regulated, since such emissions at any given point in the Transport Area can travel long distances downwind, further degrading air quality at downwind locales where the ambient standard for ozone is not currently being met.

3. The Fibrowatt plants operating in the United Kingdom are equipped with modern emissions controls; however, it is anticipated that the FibroShore plant would incorporate more advanced controls to meet expected State and Federal regulatory requirements. Based on a preliminary analysis, it is expected that emissions of nitrogen oxides and acid gases would require such additional control.

4. The maximum emission rates of principal air pollutants anticipated for the FibroShore plant have been compared with emissions for modern power plants that are fueled with

clean wood, or with such fossil fuels as oil and coal. The principal air pollutants of interest are particulate matter, nitrogen oxides, carbon monoxide, and acid gases. The comparison with wood plants is relevant because both wood and poultry litter are solid fuels that are recognized as renewable, biomass fuels. The comparison with oil and coal plants is important because the power generated using poultry litter as the fuel would likely replace power that would otherwise be generated by burning fossil fuels. The maximum emissions from the FibroShore plant of particulate matter, nitrogen oxides, and carbon monoxide would be generally consistent with the maximum emission limits set for the wood, oil, and coal plants that have been permitted recently nationwide (during the 1990's). The emissions of acid gases from the FibroShore facility would fall between the emission levels for wood power plants and coal power plants; i.e., greater than wood, but less than oil and coal.

5. Poultry litter derives directly from the food that the chicken eats; therefore, one would not expect combustion of poultry litter as a fuel to result in significant emissions of heavy metals (e.g., lead, mercury). While this is true, trace levels of heavy metals are ubiquitous in the environment, and are thus present in most solid and liquid fuels, including oil, coal, and biomass fuels (e.g., tree wood, poultry litter, straw, etc.). Accordingly, power plants that use these fuels will have trace emissions of metals. Trace emissions of metals from the FibroShore plant are anticipated to be similar to emissions from a modern power plant fueled with clean wood, based on emissions testing at the Fibrowatt plant in the U.K. The anticipated emission level of mercury, however, is currently in the process of being developed, as is discussed below.

6. The emission level of mercury is more directly related to the level of mercury that is present in the fuel (the local poultry litter) than is the case for the other metals. Most metals are emitted in the form of a particle that can be readily captured by control devices. Mercury, however, will not be emitted entirely as a particle, but also as a vapor. Accordingly, mercury will not be as readily captured in a particulate control device. Therefore, to understand expected mercury emissions from the proposed FibroShore facility, it is more important to understand the level of mercury in the fuel than for other metals. Litter produced in Maryland may have a different background level of mercury than litter produced in the U.K. Thus, the mercury emission level for the FibroShore plant may differ from levels measured at the Fibrowatt plant in the U.K. Accordingly, MES is presently analyzing samples of Maryland poultry litter to determine the background level of mercury that is present in the local litter. That local analytical data will then be used to develop an estimate of the mercury emissions that would be anticipated specifically for the FibroShore plant.

7. Trace emissions of organic compounds such as dioxin can occur with combustion of various fuels (e.g., waste fuels, biomass fuels, fossil fuels). Trace emissions of dioxin for the FibroShore plant would be similar to emissions from a modern power plant fueled with clean wood, and less than the emissions from a coal power plant.

8. The FibroShore plant would have a small emission of ammonia. Although the poultry litter to be used as the fuel inherently contains a substantial amount of ammonia, this would not be the source of the ammonia emission. The small ammonia emission that is anticipated would result from the use of urea or ammonia as a reagent in the emissions

control system for nitrogen oxides. The associated ammonia emission, referred to as "ammonia slip," would be a very small concentration (about 25 parts per million). Regulators usually limit the ammonia slip emission to a small concentration, because emissions at higher concentrations can result in the formation of a visible plume downwind from the emission point.

9. Fossil fuel combustion is the most important source of greenhouse gas emissions that are of concern for global warming. A 40 MW FibroShore plant, by burning poultry litter and forestry residue as renewable biomass fuels instead of burning fossil fuels, could significantly reduce greenhouse gas emissions. Greenhouse gases include carbon dioxide, methane, nitrous oxide, and others. Carbon dioxide (CO_2) is the most common greenhouse gas. For convenience, US EPA expresses the emissions of all these greenhouse gases, in terms of their heat-trapping capacity relative to CO_2. Thus, emissions of all greenhouse gases are expressed in terms of "CO_2 equivalent emissions."

   The FibroShore plant could provide the following, significant reductions in greenhouse gas emissions:

   - 583,000 tons of CO_2 equivalent emissions would be avoided annually, if a FibroShore plant were to replace an equivalent sized power plant fueled with coal. The avoided greenhouse gas emissions annually would be 403,000 tons and 291,000 tons, respectively, if a FibroShore plant were to replace power plants fueled with oil or natural gas.

   - Greenhouse gas emissions of nitrous oxide result from land application of nitrogen-bearing manures as a fertilizer. 53,000 tons of CO_2 equivalent emissions would be avoided each year as a result of using 900 tons per day of poultry litter as a fuel, rather than engaging in excessive land application of the litter. This greenhouse gas advantage is not afforded by most other biomass fuels, including wood.

   - The proposed FibroShore plant would reduce greenhouse gas emissions by an amount equivalent to taking 300,000 cars off Maryland roads.

Conclusions

Several basic conclusions can be drawn from this study regarding the benefits and the environmental permissibility of the FibroShore biomass power plant:

1. Excessive land application of animal manure is believed to be contributing significantly to the environmental degradation of Maryland's surface waters. The FibroShore plant would provide the local poultry industry with a reliable, year-round alternative to land application for the management of poultry litter. In this respect, a FibroShore biomass power plant would represent a practical and environmentally advantageous means to reduce excess land application in Maryland.

2. The Fibroshore plant would produce electric power using renewable, biomass fuels (poultry litter and forestry residue). This would reduce dependence on fossil fuels for power generation in Maryland, resulting in an important reduction in greenhouse gas emissions in the State.

3. By using biomass fuels, the FibroShore plant would potentially reduce Maryland's dependence on imported oil for power generation.

4. The Fibroshore plant, as planned, can reasonably be expected to meet all applicable air regulations of the MDE and US EPA. Thus, the prospects for successful permitting of the plant in Maryland are excellent.

2.0 AIR POLLUTANTS EMITTED

As with any fuel combustion, the air pollutant emissions from a power plant fueled with poultry litter are influenced by the composition of the fuel being combusted. Because the poultry litter fuel consists of about 95% manure and 5% bedding material, the fuel is comprised primarily of what the chicken eats.

The air pollutant emissions of principal interest to regulators for a power plant fueled with poultry litter and forestry residue would be generally similar to those from power plants fueled with wood, oil or coal; i.e., particulate matter, carbon monoxide, nitrogen oxide, and sulfur dioxide. In addition, because of the salt content (sodium chloride) of the poultry feed, combustion of poultry litter produces emissions of hydrogen chloride. There would also be a small emission of ammonia. The ammonia emission results from the use of urea or ammonia as a reagent in the emissions control system.

As a result of food safety practices employed by the poultry industry, the feed and bedding contain no significant levels of toxic materials. Accordingly, the combustion of poultry litter generates only trace amounts of regulated, hazardous air pollutants such as heavy metals. The trace emissions of heavy metals would not constitute a new insertion of heavy metals into the environment. Rather, those emissions would represent a “recirculation” of the metals within the environment. This is because, unlike with fossil fuels, the trace metals in FibroShore’s emissions would already have been present in the environment; i.e., in the poultry feed and bedding. In contrast, the metals emitted when fossil fuel is combusted are a new emission to the environment. This is because the metals had previously been sequestered from the environment underground, until the fossil fuel was extracted from the ground for use.

3.0 EMISSION CONTROL TECHNIQUES

Calcium and ammonia are naturally-occurring constituents of poultry litter. During combustion of the poultry litter as fuel, the calcium and ammonia may act as reagents to reduce somewhat the uncontrolled emissions of sulfur dioxide and nitrogen oxides, respectively. Besides any such inherent emission control, the FibroShore plant would utilize advanced emission control methods. For most pollutants, MDE will set the emission limits based on requirements for Best Available Control Technology (BACT). But for nitrogen oxides, MDE will set the emission limit based on Lowest Achievable Emissions Rate (LAER) technology. LAER applies for nitrogen oxides because Maryland is in an Ozone Transport Area designated by US EPA. Both BACT and LAER require the use of the latest, demonstrated advancements in emissions controls. However, cost-effectiveness can be factored into the determination of BACT, but cannot be considered in determining LAER.

The emission control techniques currently proposed for the FibroShore plant, in order to meet State and US EPA air quality requirements, are as follows:

- Particulate Matter – *Fabric Filter (baghouse).* Fabric filters provide the most stringent level of control for particulate matter.

- Nitrogen Oxides (NOx) – *Selective Noncatalytic Reduction (SNCR) of NOx via urea or ammonia injection into the furnace, or Selective Catalytic Reduction (SCR) of NOx in the flue gas via an add-on control device.* The control efficiency for NOx is dependent on the performance guarantee that can be secured for the specific technique and is anticipated to lie somewhere within the range of 25% to 90%, depending on which control technique is ultimately justified. SCR, if determined to be a technologically demonstrated technology for this specific application, would provide the greatest level of control for NOx. Accordingly, SCR would represent the starting point for determining LAER for NOx control. For the SCR control alternative, preliminary evaluations indicate a maximum theoretical control efficiency of about 90%; however the technical feasibility of applying SCR to a Fibrowatt plant requires further engineering due diligence. This engineering work would be performed to support the assessment of LAER during the permitting effort for the project. Regarding the SNCR control alternative, preliminary review indicates that SNCR is technically feasible for NOx control at the FibroShore plant, and would achieve a control efficiency of 25%, and perhaps could be optimized with further technical efforts up to a control efficiency of about 50%. Determination of the guaranteed, minimum control efficiency with SNCR would also be accomplished during the assessment of LAER for the project.

- Carbon Monoxide and Volatile Organic Compounds – *Good Combustion Practice (GCP);* i.e., maintaining a high combustion efficiency to ensure a "clean burn."

- Sulfur Dioxide – *Spray-Dry Adsorber (scrubber), teamed with the Fabric Filter*. This advanced scrubbing system would provide a high removal efficiency (minimum 80%) for sulfur dioxide.

- Hydrogen Chloride – *Same scrubber system as above*. Would provide a very high removal efficiency (minimum 95%) for hydrogen chloride.

The emission controls currently planned for the FibroShore plant are consistent with recent national determinations of Best Available Control Technology (BACT) for similar power plants that use biomass fuels, fossil fuel, and waste fuels. The currently-proposed emission controls, however, are based on a preliminary assessment and therefore will require further development and engineering review. A formal assessment of emission control requirements for the planned FibroShore facility (BACT and LAER assessments) would be performed during the permitting process. Besides the principal pollutants discussed above, the permitting process will also address how these planned control measures also limit the emissions of trace metals and trace organics (e.g., dioxins).

The newest of Fibrowatt's three, operating plants is located at Thetford in the United Kingdom. The Thetford plant operates with modern emission controls. However, to meet the latest regulatory requirements in the United States, somewhat stricter emission controls will be required for the FibroShore plant in Maryland. The FibroShore plant would use a more sophisticated scrubbing system for control of acid gases (a spray-dry adsorber scrubber) than the Thetford plant uses (dry lime injection). In addition, the FibroShore plant would use add-on controls for nitrogen oxides (SNCR or SCR), whereas the Thetford plant does not utililze such controls. The FibroShore plant would use the same device (a fabric filter) as the Thetford plant to control emissions of particulate matter.

4.0 ESTIMATED MAXIMUM EMISSIONS

Estimates of the maximum emission rates expected from the planned, 40 MW FibroShore plant are presented in Table 4-1. Emissions estimates are given for those air pollutants for which emission levels are anticipated to be limited by permit conditions: particulate matter (PM), nitrogen oxides (NOx), carbon monoxide (CO), sulfur dioxide (SO_2), and hydrogen chloride (HCl).

The maximum projected emission rates were estimated by ARI based on consideration of the following:

- Preliminary emissions projections made by Fibrowatt engineers, based on the actual emissions performance monitored between January 1999 and March 2000 at Fibrowatt's newest plant operating at Thetford in the United Kingdom.

- The additional emission-control measures to be utilized at the FibroShore plant, compared with those used at the Thetford plant. As described above, the additional controls include a more sophisticated acid-gas scrubbing system, plus add-on control measures for nitrogen oxides.

In the table, the estimated, maximum emissions for each pollutant are presented in two ways. First, proposed permit limits are shown, in the units normally adopted for that purpose by regulatory agencies (grains per dry standard cubic foot, pounds per million British Thermal Units, and parts per million dry volume). Then, the maximum emission is given as an emission rate in units of tons per year. These latter emission rates slightly overstate the anticipated actual annual emissions, because they conservatively assume that the plant would operate 100% of the time annually – 24 hours per day, 365 days per year. In reality, the plant would operate 90% to 95% of the time during a year.

Besides the pollutants shown in the table, the FibroShore plant would have a small emission of ammonia. Although the poultry litter to be used as the fuel inherently contains a substantial amount of ammonia, ARI would not expect that to be the source of the anticipated, small emission. ARI believes that the ammonia present in the litter would, during combustion of the litter, convert to elemental nitrogen and/or to nitrogen oxides. This is supported by results of a trial burn of poultry litter as a fuel at the Eastern Correctional Facility cogeneration plant. No ammonia was detected in the stack gases during that trial burn*. As noted previously above, the small ammonia emission that is anticipated would result from the use of urea or ammonia as a reagent in the emissions control system for nitrogen oxides. A small fraction of the reagent input to the emission control system passes through unconsumed, and is emitted from the stack as "ammonia slip." Quantitatively, ARI would anticipate that the "ammonia slip" emission would be approximately 25 parts per million (ppm), which is a very small concentration. Regulators, as well as the facility operator, both desire to limit the ammonia slip emission to a small concentration, because emissions at higher concentrations can result in the formation of a visible plume downwind from the emission point.

*Air Nova, Inc. "Maryland Environmental Service Poultry Litter Test Burn Emission Evaluation Test Program," Table 4: Test Burn Stack Test Results, December 1999.

TABLE 4-1 Rev. 3/8/01

AIR EMISSION RATES AND EMISSION CONTROLS

Compound	Averaging Period	Measurement Basis	ESTIMATED MAXIMUM EMISSIONS		Proposed Emission Controls
			Proposed Limit[1]	Emission Rate (Tons per Year)	
Particulate Matter (PM)	1-hour	Stack Test	0.02 lb/MMBtu (0.01 gr/dscf)	61	Fabric Filter (Baghouse)
Nitrogen Oxides (NOx)	24-hour	Continuous Monitor	Within the range of 0.03[2] to 0.25[3] lb/MMBtu (19 to 142 ppmdv)	--	Feasibility studies under way by Fibrowatt for two, NOx reduction options: (1) Up to 90% control via Selective Catalytic Reduction (SCR)[2] (2) At least 25% control via Selective Noncatalytic Reduction (SNCR)[3]
	30-day	Continuous Monitor	0.03[2] to 0.20[4] lb/MMBtu	Within the range of 94 to 702	
Carbon Monoxide(CO)	1-hour	Continuous Monitor	0.32 lb/MMBtu (302 ppmdv)	--	Good Combustion Practices (GCP); i.e.. maintaining a high combustion efficiency
	24-hour	Continuous Monitor	0.20 lb/MMBtu (193 ppmdv)	583	
Sulfur Dioxide (SO2)	24-hour	Continuous Monitor	0.07 lb/MMBtu (30 ppmdv)	206	Spray-Dry Adsorber (scrubber), and Fabric Filter
Hydrogen Chloride (HCl)	1-hour	Stack Test	0.03 lb/MMBtu (25 ppmdv)	96	Spray-Dry Adsorber (scrubber), and Fabric Filter

[1] All concentrations (gr/dscf and ppmdv) are corrected to 7% O_2.

[2] Assumes NOx control via SCR, with achievement of the maximum, theoretical control efficiency for SCR of 90%. The technical feasibility of applying SCR at the planned FibroShore plant is currently under study by Fibrowatt.

[3] Assumes NOx control via SNCR, which Fibrowatt has determined to be technically feasible technology. Preliminary engineering indicates that at least 25% control of NOx can be guaranteed via SNCR. Final determination of the control efficiency; i.e., whether 25% or greater, would be accomplished during the detailed engineering phase of the project development.

[4] This limit represents the applicable New Source Performance Standard (NSPS) that US EPA imposed on new Industrial Steam Generators.

For the pollutants shown in the table, compliance with emissions limits to be set by MDE will be demonstrated by means of either Continuous Emission Monitors (CEM) or by periodic stack emissions tests. Continuous monitoring will be required for those pollutants for which US EPA has established the reliability of the available CEM technology. Presently, it is anticipated that CEM will be required for nitrogen oxides, sulfur dioxide, carbon monoxide, and opacity (opacity is a reflection of the degree of particulate emissions). Stack testing will be required for all other regulated air pollutants.

5.0 EMISSIONS COMPARISON WITH OTHER POWER PLANTS

5.1 Emissions of Principal Air Pollutants

In Table 5-1, the estimated maximum emission rates of principal air pollutants from the planned FibroShore plant are compared with the permitted maximum emissions for other power plants that are fueled with clean wood, or oil, or coal. The FibroShore plant and the comparison plants use a similar "stoker" type boiler. The comparison plants were permitted during the 1990's, and the permitted emission rates shown in the table were obtained by ARI from a nationwide compilation by US EPA, as referenced in the table footnotes. The comparison of the anticipated FibroShore emissions with the permitted emissions of wood-fueled power plants is relevant, because the fuel in both cases is a renewable, biomass fuel. The comparison with the oil- and coal-fueled power plants is important, because the power generated by a FibroShore plant would most likely replace power that is currently generated by fossil fuel combustion (a similar comparison for natural gas is not made since natural gas is not available, nor is it anticipated to be available in the foreseeable future at the planned, project site).

Poultry litter, like clean wood, can be used to fuel power plants. Both poultry litter and wood are solid fuels; they are both renewable, "biomass" fuels; and the two fuels have similar energy values. In addition, biomass fuels such as poultry litter and wood exhibit greater variability in physical composition and energy content than do fossil fuels such as coal. Accordingly, emissions from a power plant fueled with poultry litter are most appropriately compared with emissions from wood-fueled power plants, particularly with regard to emissions of particulate matter, nitrogen oxides, and carbon monoxide. As is apparent from the table, the expected FibroShore emissions of particulate matter would be similar to emissions from wood power plants, and nitrogen oxide and carbon monoxide emissions for FibroShore would be lower in comparison with wood power plants nationally. In comparison with oil and coal plants, the FibroShore emissions of particulate matter, nitrogen oxides, and carbon monoxide are generally similar.

The planned FibroShore facility would emit acid gases, comprised of sulfur dioxide plus hydrogen chloride. Sulfur dioxide is produced by burning fuels that contain sulfur; for example, fossil fuels such as oil and coal contain sulfur, as do some biomass fuels such as poultry litter. Because of the salt content (sodium chloride) of the poultry feed, the combustion of poultry litter produces hydrogen chloride. An advanced scrubber system is proposed to control acid gas emissions with high efficiency. From Table 5-1, the maximum emissions of acid gases from the FibroShore facility would fall between the emission levels for wood power plants and coal power plants; i.e., greater than wood, but less than oil and coal. Also noteworthy is that the maximum emissions of particulate matter and acid gas from the FibroShore plant would be considerably less than the emission levels allowed for new fossil fuel power plants by latest Federal regulations (NSPS, Subpart Da). Also, if the more stringent NOx control technique (SCR) is determined to be technically feasible and is implemented at FibroShore, then FibroShore's maximum NOx emissions could be significantly below the level allowed by the latest Federal regulations for new fossil fuel power plants.

TABLE 5-1

COMPARISON OF MAXIMUM EMISSIONS OF PRINCIPAL AIR POLLUTANTS
(FIBROSHORE VERSUS WOOD AND FOSSIL-FUEL POWER PLANTS[1])

Power Plant Type	**Particulate Matter (PM_{10})**	**Nitrogen Oxides (NOx)**	**Carbon Monoxide (CO)**	**Acid Gases (Sulfur Dioxide + Hydrogen Chloride)**
Fibroshore Maryland 40 MW Power Plant, Fuel – Poultry Litter and Wood *Estimated Maximum Controlled Emission Rates*	0.02 lb/MMBtu	Range: 0.03 to 0.20 lb/MMBtu (depending on the particular control technique ultimately justified)	0.20 lb/MMBtu	0.10 lb/MMBtu
Wood Fired Boilers (> 100 MMBtu/hr) *US EPA National Survey of Permit Limits 1990-1999[2]*	*Range of Permit Limits:* 0.02 - 0.10 lb/MMBtu *Typical Permit Limit:* 0.02 lb/MMBtu	*Range of Permit Limits:* 0.10 - 0.30 lb/MMBtu *Typical Permit Limit:* 0.30 lb/MMBtu	*Range of Permit Limits:* 0.30 – 2.25 lb/MMBtu *Typical Permit Limit:* 0.35 lb/MMBtu	*Range of Permit Limits:* 0.016 – 0.10 lb/MMBtu *Typical Permit Limit:* 0.023 lb/MMBtu
Oil Fired Boilers, Nos. 2 and 6 Oil[2] (>100 MMBtu/hr) *US EPA National Survey of Permit Limits 1990-1999[2,3]*	*Range of Permit Limits:* 0.005 – 0.08 lb/MMBtu *Typical Permit Limit:* 0.03 lb/MMBtu	*Range of Permit Limits:* 0.08 – 0.4 lb/MMBtu *Typical Permit Limit:* 0.2 lb/MMBtu	*Range of Permit Limits:* 0.02 – 0.17 lb/MMBtu *Typical Permit Limit:* 0.08 lb/MMBtu	*Range of Permit Limits:* 0.05 – 0.53 lb/MMBtu *Typical Permit Limit:* 0.3 lb/MMBtu
Coal Fired Boilers spreader stokers only (100 – 1,000 MMBtu/hr) *US EPA National Survey of Permit Limits 1990-1999[2]*	*Range of Permit Limits:* 0.02 – 0.03 lb/MMBtu *Typical Permit Limit:* 0.02 lb/MMBtu	*Range of Permit Limits:* 0.20 – 0.32 lb/MMBtu *Typical Permit Limit:* 0.25 lb/MMBtu	*Range of Permit Limits:* 0.10 – 0.23 lb/MMBtu *Typical Permit Limit:* 0.20 lb/MMBtu	*Range of Permit Limits:* 0.12 – 1.2 lb/MMBtu *Typical Permit Limit:* 0.13 lb/MMBtu
1998 and 1987 National Standards (NSPS, Subpart Da)	0.1 lb/MMBtu	1.6 lb/MWh (~0.15 lb/MMBtu)	No Limit	1.2 lb/MMBtu

[1] Averaging times for the various emission limits in this table are as follows:

- Fibroshore Maryland: NO_x emission rates are 30-day and 24-hour averages, as indicated in the table.
- Fibroshore Maryland: CO is a 24-hour average; PM is a 1-hour average. "Acid Gases" are a nominal 24-hour average, comprised of SO_2 (24 hour average) plus HCl (1 hour average).
- Wood Boilers, Oil Boilers, and Coal Boilers: The US EPA national survey information does not furnish the averaging times for the indicated permit limits.
- Coal Boilers – National Emission Standards (NSPS, Subpart Da) for NOx (1998) and for SO_2 and PM (1987): the averaging time for NOx and SO_2 is 30 days. The averaging time for PM is 1 hour .

[2] US EPA maintains an ongoing compilation of recent permit limits that represent determinations of Best Available Control Technology and Lowest Achievable Emission Rate , and maintains this information in a database referred to as US EPA's "BACT/LAER Clearinghouse."

[3] The US EPA national survey presents combined, not separate emissions information for fueling with No. 2 (distillate) oil and for fueling with No. 6 (residual) oil.

5.2 Emissions of Metals and Dioxin

Trace levels of heavy metals are ubiquitous in the environment, and are thus present in oil, coal, and biomass fuels (e.g., tree wood, poultry litter, straw, etc.). Accordingly, power plants that use these fuels will have trace emissions of metals. In addition, trace emissions of organic compounds such as dioxin can occur when combusting various fuels such as biomass fuels, fossil fuels, and waste fuels. In Table 5-2**,** the trace emission levels of metals anticipated for the FibroShore plant are compared with emissions levels for power plants fueled with clean wood, distillate oil (No.2), residual oil (No. 6), and coal. The trace dioxin emissions expected from the FibroShore plant are compared with emission levels for power plants fueled with clean wood and with coal (dioxin emission data for oil-fueled power plants were not readily available).

The metals and dioxin emission levels given in the table for the planned Fibroshore plant are based on actual emission levels measured in 1999 and 2000 at the Fibrowatt plant operating at Thetford in the United Kingdom. The metals and dioxin emission levels given for power plants fueled with clean wood, oil, and coal are typical emission factors published by US EPA in 1998 and 1999 for power plants equipped with modern emission controls.

Emissions data are provided in the table for those metals that are typically of greatest concern for combustion facilities: arsenic, cadmium, chromium, lead, mercury, and nickel. Poultry litter derives directly from the food that the chicken eats; therefore, one would not expect combustion of poultry litter as a fuel to result in significant emissions of heavy metals. From the table, the trace emissions of metals from the FibroShore plant are shown to be similar to or less than emission levels for clean wood, and likewise for oil and coal. In the particular case of mercury, however, the anticipated emission level is currently in the process of being developed. The emission level of mercury is more directly related to the level of mercury that is present in the fuel (the local poultry litter) than is the case for the other metals. Most metals are emitted in the form of a particle that can be readily captured by control devices. Mercury, however, will not be emitted entirely as a particle, but also as a vapor. Accordingly, mercury will not be as readily captured in a particulate control device. Therefore, to understand expected mercury emissions from the proposed FibroShore facility, it is more important to understand the level of mercury in the fuel than for other metals. Litter produced in Maryland may have a different background level of mercury than litter produced in the U.K. Thus, the mercury emission level for the FibroShore plant may differ from levels measured at the Fibrowatt plant in the U.K. Accordingly, MES is presently analyzing samples of Maryland poultry litter to determine the background level of mercury that is present in the local litter. That local analytical data will then be used to develop an estimate of the mercury emissions that would be anticipated specifically for the FibroShore plant.

The trace dioxin emissions anticipated for the FibroShore plant are shown in the table to be about the same as typical emissions for power plants fueled with clean wood, and less than emissions for power plants fueled with coal.

TABLE 5-2

EMISSIONS COMPARISON FOR METALS AND DIOXIN
(COMPARISON: TYPICAL EMISSIONS FOR FIBROSHORE VERSUS WOOD AND FOSSIL-FUEL POWER PLANTS)

[Emissions are in units of pounds per million Btu – lb/MMBtu]

Pollutant[(a)]	Fibroshore[(b)]	Wood[(c)]	Coal[(d)]	Oil/No. 2[(e)]	Oil/No. 6[(e)]
Arsenic (As)	0.000002	0.000009	0.00002	0.000004	0.000009
Cadmium (Cd)	0.000002	0.000002	0.000003	0.000003	0.000003
Chromium (Cr)	0.000003	0.00002	0.00001	0.000003	0.000006
Lead (Pb)	0.000003	0.00005	0.00002	0.000009	0.00001
Mercury (Hg)	See Footnote (f)	0.0000006	0.000004	0.000003	0.0000008
Nickel (Ni)	0.00003	0.000008	0.00001	0.000003	0.0006
Dioxins/Furans (Mass Basis)	0.000000002	0.000000005	0.00000001	Not Available	Not Available

(a) The metals are those typically of principal concern with combustion facilities, and regulated by US EPA as Hazardous Air Pollutants.

(b) Metals and dioxin emission rates are based on the averages of 4 to 6 test data points for each pollutant, resulting from stack emissions testing conducted at Fibroshore's reference plant that operates at Thetford in the U.K. The emissions tests were conducted in January and May of 1999, and in March 2000. The dioxin test data were reported in units of International Toxic Equivalents (I-TEQ), and have been converted to mass-basis emissions here using a multiplication factor of 65, based on US EPA data.

(c) US EPA AP-42 Section 1.6 "Wood Waste Combustion in Boilers" February 1999; wood as-received heating value is assumed to be 4,500 Btu/lb.

(d) US EPA AP-42 Section 1.1 "Bituminous and Subbituminous Coal Combustion" September 1998; coal as-received heating value is assumed to be 10,000 Btu/lb. US EPA had based these metals emission rates on combined information for 11 bituminous, 15 subbituminous, and 2 lignite firing plants, each having wet or dry acid-gas scrubbing and modern controls for particulate matter; i.e. either fabric filters or electrostatic precipitators. US EPA gave dioxin/furan emission rates for plants with modern controls; i.e. an acid gas scrubber (spray dryer absorber) and fabric filter.

(e) US EPA AP-42 Section 1.3 "Fuel Oil Combustion" September 1998; No. 2 oil heating value is assumed at 140,000 Btu/gal; No. 6 oil heating value is assumed at 150,000 Btu/gal.

(f) Unlike the other metals, the emission rate of mercury from the FibroShore plant will depend importantly on the background concentration of mercury that is present in the fuel (the poultry litter). The FibroShore emission rate of mercury could differ markedly from the emission rate tested at Fibrowatt's Thetford plant, operating in the U.K. Accordingly, MES is currently sampling local Maryland poultry litter to determine the background mercury level present, and that data will be used to determine a project-specific estimate of the expected mercury emission rate for the FibroShore plant. As a point of information, the mercury emission rate tested at the Thetford plant was variable, ranging from below analytical detection limits to an average detected value of 0.000005 lb/MMBtu.

6.0 GREENHOUSE GAS EMISSIONS

Because of their ability to trap heat in the lower atmosphere, “greenhouse gases” such as carbon dioxide, methane, and nitrous oxide are of concern for global warming. The global warming theory holds that human activity, such as fossil fuel burning, certain agricultural activities, and the landfilling of solid waste, are causing a build-up of greenhouse gases, which in turn is leading to a permanent warming of the planet.

As noted by US EPA[*], the combustion of fossil fuel (coal, oil, natural gas) is generally recognized as the most important source of greenhouse gas emissions. This is because fossil fuel combustion is so pervasive around the world, resulting in a tremendous amount of carbon, in the form of carbon dioxide, being emitted into the environment. Combustion of fossil fuel and any other fuels also produces comparatively minor quantities of other greenhouse gases – nitrous oxide and methane.

US EPA also notes[*] that agricultural application of nitrogen-bearing fertilizers (manures and commercial fertilizers) to the land results in significant emissions worldwide of the greenhouse gas, nitrous oxide. The nitrogen in the land-applied fertilizer is converted to nitrous oxide by natural soil biochemistry. Current manure management practices also produce comparatively minor emissions of carbon dioxide and methane.

While carbon dioxide is by far the most abundant, and thus the most important greenhouse gas, it is not the most potent. Methane, while less abundant, has 21 times the heat-trapping power of carbon dioxide according to US EPA[*], and nitrous oxide is 310 times more potent than carbon dioxide.

As illustrated in Table 6-1, the planned FibroShore plant would provide a substantial greenhouse-gas advantage from two standpoints:

1. The Fibroshore plant would use renewable biomass fuels (poultry litter and forestry residue) to produce 40 megawatts of electric power, instead of using fossil fuel. This would avoid about 583,000, 403,000, and 291,000 tons per year of greenhouse gas emissions, respectively, compared with generating the same power using coal, oil, or natural gas fuels.

   While combustion of renewable biomass fuels (e.g., wood, grains, poultry litter) does produce substantial, actual emissions of carbon dioxide, US EPA does not consider this to constitute a greenhouse gas emission (for references, see table). This is because burning renewable fuels does not put new carbon into the environment; rather, it recycles carbon that is already in the environment. The carbon dioxide emission from the combustion process is essentially equivalent to the carbon dioxide absorbed during the growing of the grain and other vegetation used to make poultry feed and bedding material. When poultry litter is used as a fuel, the carbon it contains had already been present in the poultry feed and poultry bedding material. Poultry litter is thus a

[*] US EPA, “Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1997,” EPA 236-R-99-003, EPA Office of Policy, Washington, D.C., Executive Summary, April, 1999.

TABLE 6-1 (Sheet 1 of 2)

FIBROSHORE – THE GREENHOUSE GAS ADVANTAGE

POWER PLANT (40 MEGAWATT SIZE)	GREENHOUSE GAS EMISSIONS (Tons Per Year)			
	CARBON DIOXIDE (CO_2)	NITROUS OXIDE (N_2O)	METHANE (CH_4)	TOTAL GREENHOUSE GASES ($CO_2 + N_2O + CH_4$, as CO_2)[a]
Fibroshore Power Plant - Poultry Litter and Wood Fueling				**FIBROSHORE - 52,100 (avoided emission)**
Plant Emission Rate	0[b]	+12[c]	+30[c]	
Avoided Emissions[d]	Negligible	- 226 (avoided emission)[d]	Negligible	
CO_2 – Equivalent Emission Rate[a]	0	-52,700	+600	
Wood-Fueled Power Plant				**WOOD +4,900**
Plant Emission Rate[e]	0[b]	+14	+34	
CO_2 – Equivalent Emission Rate	0	+4,200	+700	
Coal-Fueled Power Plant				**COAL +582,500**
Plant Emission Rate[f]	+580,800	+5	+7	
CO_2 – Equivalent Emission Rate	+580,800	+1,500	+200	
Oil-Fueled Power Plant				**OIL +403,000**
Plant Emission Rate[g]	+402,400	+2	+5	
CO_2 – Equivalent Emission Rate	+402,400	+500	+100	
Natural-Gas Fueled Power Plant				**NATURAL GAS +290,500**
Plant Emission Rate[h]	+289,900	+2	+6	
CO_2 – Equivalent Emission Rate	+289,900	+500	+100	

[a-h] Footnotes: See Sheet 2 of this table.

TABLE 6-1 (Sheet 2 of 2)

FIBROSHORE – THE GREENHOUSE GAS ADVANTAGE

[a-h] Footnotes:

[a] Total greenhouse gas emissions is the sum of the emissions of CO_2 + N_2O + CH_4, expressed as CO_2-equivalent emissions. Before summing, the emission of N_2O is weighted by a factor that reflects its greenhouse potency relative to that of CO_2. A similar weighting factor is applied to the emissions of CH_4. Emissions of N_2O and CH_4, respectively, have 310 times and 21 times the greenhouse heat-trapping potential of CO_2 *(US EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1997, " EPA 236-R-99-003, EPA Office of Policy, Washington, D.C., p. ES-9, April, 1999).*

[b] CO_2 emissions for the Fibroshore plant are estimated to be 598,400 tons per year, based on preliminary design engineering. For a wood-fueled plant, CO_2 emissions are estimated to be 677,600 tons per year (see Footnote e, below). While combustion of biomass fuels such as poultry litter and wood produces emissions of CO_2, US EPA does not consider such CO_2 to constitute a greenhouse gas emission *(US EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-1997, " EPA 236-R-99-003, EPA Office of Policy, Washington, D.C., p. ES-12, April, 1999; also, personal communication between David Minott of Alternative Resources, Inc. and Wiley Barbour, greenhouse gas specialist at US EPA, Washington, D.C., December 16, 1999).* EPA's rationale is that the carbon content of biomass fuels was already present in the environment, prior to the biomass being used as a fuel. By contrast, the carbon present in fossil fuels is sequestered from the environment, prior to the fuel's being extracted from the ground.

[c] Emissions from the Fibroshore plant of N_2O and CH_4 were estimated using US EPA emission factors for wood-fueled power plants (see footnote e, below), multiplied by the ratio of the CO_2 emission rate for the 40 MW Fibroshore plant (598,400 TPY; see footnote b, above) to that of a 40 MW wood power plant (677,600 TPY; see footnote e, below). As a point of information, the N_2O and CH_4 emission factors given by US EPA for wood combustion were higher than the emission factors that US EPA gives for fossil fuel combustion.

[d] Avoided emissions: the potential emissions of nitrous oxide from the <u>excess</u> land application of 440,000 tons per year of poultry litter, that are <u>avoided</u> by Fibroshore's using the litter as a fuel instead . Emission rates are calculated using a US EPA emission factor for land application of nitrogen-containing fertilizer *(US EPA "AP-42," Page 14.1-1 and -2, Sep. 1996).* The emission factor used is: N_2O Emissions (tons per year) = Fertilizer Application Rate (tons of nitrogen per year) x 0.0117 x 44/28. The poultry litter is assumed to have has a nitrogen content of 2.8%, on an as-applied basis.

[e] Emissions for wood fueling are calculated using US EPA emission factors for wood power plants *(US EPA "AP-42," Page 1.6-8, Feb. 1999).* The emission factors for CO_2, N_2O and CH_4, respectively, are 2000, 0.04, and 0.1 pounds emitted per ton of wood burned. The calculations presume a higher heating value (HHV) for wood of 4,500 Btu/lb, and a boiler efficiency of 68%, with a plant heat rate of 17,400 Btu/Kw-hr. This yields plant emission rates of 677,600 tons per year of CO_2, and 14 tons per year of N_2O, and 34 tons per year of CH_4.

[f] Emissions for coal power plants are calculated using US EPA emission factors for bituminous coal fueling *(US EPA "AP-42," Page 1.1-40, 41 and 42, Sep. 1998).* The emission factors for CO_2, N_2O and CH_4, respectively, are 4810, 0.04, and 0.06 pounds emitted per ton of coal burned. The calculations presume a higher heating value (HHV) for coal of 10,000 Btu/lb, and a boiler efficiency of 86%, with a plant heat rate of 13,800 Btu/Kw-hr.

[g] Emissions for oil-fueled power plants are calculated using US EPA emission factors for No. 6 oil fueling *(US EPA "AP-42," Page 1.3-14, 20 and 24, Sep. 1998).).* The emission factors for CO_2, N_2O and CH_4, respectively, are 25,000, 0.11, and 0.28 pounds emitted per 1000 gallons of oil burned. The calculations presume a higher heating value (HHV) for oil of 150 MMBtu/1000 gallons, and a boiler efficiency of 86%, with a plant heat rate of 13,800 Btu/Kw-hr.

[h] Emissions for natural-gas-fueled power plants are calculated using US EPA emission factors for natural gas fueling *(US EPA "AP-42," Page 1.4-6, Jul. 1998).).* The emission factors for CO_2, N_2O and CH_4, respectively, are 120,000, 0.64, and 2.3 pounds emitted per million cubic feet of gas burned. The calculations presume a higher heating value (HHV) for gas of 1,000 Btu per cubic foot, and a boiler efficiency of 86%, with a plant heat rate of 13,800 Btu/Kw-hr.

renewable-energy fuel, and as such, carbon dioxide produced from it does not increase the potential for global warming. By contrast, carbon dioxide emitted by fossil-fuel power plants does have the potential to increase global warming. This is because the carbon in coal, oil, and gas that is liberated to the environment during combustion, had previously been sequestered from the environment underground, prior to its being extracted for use as a fuel.

2. The combustion of 900 tons per day of poultry litter as a renewable fuel in the FibroShore plant would avoid the greenhouse gas emission of nitrous oxide that would be produced from excess land application of that amount of poultry manure. The avoided greenhouse gas emission would be about 53,000 tons per year.

As illustrated in the table, wood is a common renewable fuel that offers a similar greenhouse emissions advantage to poultry litter, when compared to fossil fuel combustion. However, use of poultry litter as a biomass fuel offers a slight additional advantage over use of+ wood, by avoiding the emission of the greenhouse gas, nitrous oxide, that would result from excessive land application of the litter.

The White House issued a written statement on January 21, 2000, promoting the generation of energy using renewable, biomass fuels. There, it was stated that lowering greenhouse gas emissions by 100 million tons nationally through biomass power production, would be the same as taking 70 million cars off the road. If the FibroShore biomass plant were assumed to displace power generation at oil-fueled power plants in Maryland, this would reduce greenhouse gas emissions by 400,000 tons per year, the equal of taking about 300,000 cars off Maryland roads.

APPENDIX

COPIES OF GREENHOUSE-GAS REFERENCES CITED IN THIS REPORT