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Lessons on drought and pollution from the forgotten three billion: An Indiana case study on using biomass crops for generating electricity

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Abstract

Although three billion people in the developing world face severe indoor air pollution from domestic incineration of biomass, other nations have not learned from these biomass harms. Instead, scores of developed countries are massively subsidizing biomass crop growing/incineration, touting biomass burning as clean and technologically improved, and claiming it helps address climate change. Are they right? To show why not, this commentary has three objectives. These are (i) to outline the drought/food, air pollution, and water-pollution threats posed by growing/burning biomass, (ii) to answer government/industry defenses of biomass growing/incineration, and (iii) to use a southern Indiana case study to reveal the flawed science in most biomass crop/incineration proposals. For instance, most biomass proposals fail to include a full human-health risk assessment, cost–benefit analysis, and ecological risk assessment. Discussing health-related biomass problems, the commentary uses a case study of a contemporary, state-of-the-art facility to incinerate *Miscanthus giganteus* biomass. It closes with suggestions for improving biomass science/decision-making and reducing biomass threats.

1.1 Background

Biomass incineration of wood, dung, and crop waste is a health scourge in developing nations. At least 3 billion people, almost half the world's population, burn domestic biomass fuel. Consequently, 2 million/year die prematurely from indoor air pollution. More than 1 million die from chronic obstructive respiratory disease. Biomass-caused-particulate air pollution causes approximately 50% of pneumonia deaths among children under the age of 5, mostly in the developing world (WHO, 2011).

Besides biomass incineration risks, developing nations provide at least one other troubling lesson, about droughts and water pollution that reduce access to food/clean water. Drought is the most common reason for food shortages in developing nations, and irrigation is globally the main water user (FAO, 2012). Yet, if developed nations use scarce water for growing biomass crops—like corn/switchgrass/wood/*Miscanthus* that are incinerated for electricity production—later paragraphs show this can induce drought and food shortages/higher food prices/famine in developing nations. Exacerbated by climate change, over-farming, inefficient irrigation, and not growing drought-tolerant crops, drought is deadly. The 1984–1985 drought in the Horn of Africa, for instance, caused a famine that alone killed 750,000 people. Since the 1970s, climate change has doubled the global percentage of severe-drought areas. Future climate-induced drought is predicted to increase developing nations' poverty/ill health by up to 17%/drought (World Bank, 2012).

1.2 Objectives

Given biomass health/drought problems, have developed nations learned from them? To answer this question, this commentary has three objectives. These are (1) to outline biomass taxpayer subsidies, particulate emissions, and water/global food threats; (2) to answer US government/

corporate defenses of biomass crops/subsidies/incineration; and (3) to use an Indiana case study to explain how most biomass proposals use flawed/incomplete science that underestimates biomass risks.

1.3 Discussion

The International Energy Agency says that by 2020, biomass electricity generation will triple globally. Even in the United States, biomass incineration is the largest type of "renewable energy," fulfilling government-mandated, renewable-energy credits (Booth, 2012).

Why is biomass such big business?

1.3.1 Biomass subsidies

Countries like Canada, Denmark, England, Germany, Greece, Ireland, Italy, Japan, Portugal, Spain, Sweden, Turkey, and the United States subsidize biomass/biofuels like *Miscanthus giganteus* for electricity generation. Rather than learning from developing countries, developed nations offer biomass crop, biomass boiler construction, and biomass renewable energy subsidies (Sheehan et al., 2011; DEFRA, 2012; SEA, 2012). For example, US taxpayer biomass subsidies—$3–5 billion/year (federal) + $2–4 billion per plant/year (state)—have promoted 255 existing, and 250 in-progress, US biomass plants (Sheehan et al., 2011).

Based on food security problems, the World Bank/International Monetary Fund/World Trade Organization demands ending biomass crop subsidies (Sheehan et al., 2011). However, developed nations justify subsidies by claiming biomass crops are renewable/promote energy independence. They also say state-of-the-art, electricity-generating biomass facilities are safe, much cleaner than typical indoor stoves in the developing world (TOC, 2010; Booth, 2012).

1.3.2 A typical small, state-of-the-art biomass incinerator

The US Department of Energy likewise says biomass is a "clean" energy source (USDOE, 2012). Is this correct? Consider a typical proposal to burn *Miscanthus giganteus* in a converted coal facility.

Like hundreds of other small, rural towns, Jasper, IN faces prohibitively costly emissions controls for its outdated coal plant—one of roughly 250 closing in the United States. Faced with this nonperforming, dirty "asset," town leaders accepted the Twisted Oak Corporation (TOC) proposal to convert the old coal boiler to combust biomass. TOC's 75-page proposal promises the town lease payments and injecting $200 million locally over 30 years ($6.6 million/year) from the hybrid natural gas/*M. giganteus* incineration facility. Most of the $200 million gross income comes from growing *Miscanthus*. Partnering with Mendel Bioenergy, a seller of bio-engineered *Miscanthus*, TOC would contract with local farmers to grow roughly 100 tons/year of Mendel's cane-like *Miscanthus* (TOC, 2010).

In return for TOC's unspecified amounts of lease payments, Jasper would provide the facility "essential services," including double the water needed by the old coal facility and new electrical lines. However, lease payment amounts were redacted from TOC's proposal, as were lease terms, TOC taxes/financing, costs of water/sewer/new electrical lines/contaminated materials, and safety information about Mendel-bioengineered *Miscanthus*. All redactions were marked "confidential materials" (Sheehan et al., 2011). Although the facility would sell its electricity on the open market, TOC promises minimal health/environmental impacts, given baghouse filters, biomass boiler NOX/CO_2 best available control technology limits, 560 ppm CO limits, and "voluntary" 0.03 lb./million (MM) Btu particulate matter (PM) limits (TOC, 2010; Shaddix, 2011).

1.3.3 Biomass incineration air pollution

How serious are state-of-the-art, biomass-plant, air pollution problems? The main biomass pollutants are CO, hazardous air pollutants such as mercury, nitrogen oxides, PM, and sulphur oxides (SOX). In developed nations, biomass pollutant harms are comparable to, or worse than, those from coal, except that biomass releases less mercury and SOX, whereas biomass CO and, especially, PM emissions are greater. Because PM has no safe dose (Pope et al., 2009), because biomass PM is at least 25 times worse than coal PM, and because PM causes most coal incineration-related deaths, increased biomass PM massively outweighs biomass improvements regarding mercury/SOX emissions (Schneider, 2000; Wiltsee, 2000; Schneider, 2004; Schneider and Banks, 2010; Booth, 2012).

Biomass PM is far worse than that from coal because it is mostly ultrafine, PMUF (<0.1 μm), whereas coal plant PM is mostly PMF (2.5–0.1 μm) (Yinon, 2010). In addition, PMUF is approximately 65 times more hazardous than equal masses of PMF, because PMUF harms are functions of surface area/numbers of particles, not mass concentration (Sager and Castranova, 2009). However, relative PMUF:PMF harms are functions of particle numbers/sizes/surfaces areas, and both PMUF and PMF come in a variety of sizes; exact harms/numbers of fatalities are functions of the specific sizes/numbers/surface areas of the particles in a given volume, which are a function of the specific facility/pollution controls/fuel burned. Consequently, only general coal/biomass harm comparisons are possible. Nevertheless, biomass/biofuel particulate releases, mostly PMUF and carbon black (CBPMUF), cause 60% of global CBPMUF pollutants (Bond, 2007). If leading US government assessors are correct in stating that on average US coal plant particulates (mostly PMF) kill 25 people/year (Schneider and Banks, 2010), and if PMUF is approximately 65 times more hazardous than PMF (Sager and Castranova, 2009), then an average, state-of-the-art, US biomass plant kills far more than 25 people/year, as a coal plant does. Yet, no nation has regulations for the more recently discovered PMUF, despite its far more serious health threat.

What about potential clean water (therefore food) shortages from growing biomass crops? Consider water-related effects of growing *Miscanthus* for the Jasper biomass incinerator.

1.3.4 Biomass crop drought threats

Growing *Miscanthus* and other non-food biomass crops, even in developed nations, can worsen drought/food shortages/global food price increases. Indeed, biomass/biofuels crops are major reasons for rising food prices and resulting global conflicts/riots in 30 countries (Lagi et al., 2011). For the 2 billion people who live on less than $2/day, higher food prices can mean famine/death. For instance, in 2012 the US—the world's largest exporter of corn/soybeans/wheat—had its worst drought in 50 years, since the Dust Bowl. Consequently, the US Department of Agriculture (USDA) slashed its 2012 US corn production estimate by 12%, the largest fall in a quarter century. Drought-induced corn/soybean crop failures in 2012 caused dramatic, 3–5%, global food price increases surpassing the 2007–2008 drought-induced food price increases that caused conflicts/riots in 30 developing nations. Although average US consumers spend only 13% of their income on food, consumers in less-developed nations spend 50% or more. For them, drought elsewhere can be deadly (Norwood, 2012).

USDOE, however, says developed nations mostly subsidize non-food-based cellulosic biomass, such as *Miscanthus*, and therefore are not threatening global food supplies (USDOE, 2012). However, food shortages/price increases arise not only from using cropland for biomass, but also from using scarce water for non-food/biomass crops. Required biomass fertilizers/herbicides/irrigation also threaten clean water, and thus food/health.

Would the Jasper biomass plant worsen drought/food problems? In August 2012, the USDA declared a majority of US counties drought "disaster zones," including drought-prone, southern Indiana counties. Thus, at least seven reasons suggest TOC may err in saying 90,000–100,000 dry tons *Miscanthus*/year, for the biomass facility, could be grown on 8,000–10,000 southern Indiana acres/year.

One problem is that *Miscanthus*' southern Indiana growing season is 7 months, late March through a killing frost, requiring at least 76.2 cm of rain (Heaton et al., 2012). Because southern Indiana rainfall, 109 cm/year, is evenly distributed, only approximately 9.1 cm/month falls (IDNR, 2012). However, 9.1 cm/month rainfall for a 7-month *Miscanthus* growing season yields only 64 cm of the 76.2 cm of rain needed per season. Thus, southern Indiana *Miscanthus* crops would lack approximately 16% of required water, and likely need costly irrigation with scarce water. Such a situation might be minimally workable, except that later paragraphs show climate change will worsen southern Indiana drought. Because the government says recent Indiana summer droughts have been "moderate to extreme" (NOAA, 2012), heat often causes negative precipitation (precipitation minus evaporation, P–E), such as −5.6 cm/month (Charusombat and Niyogi, 2011).

A second biomass/drought problem is that climate scientists predict global drought area doubling, summer/autumn "decreased precipitation," and extreme droughts covering 60% or more of Indiana–Illinois (Mishra et al., 2009). During the last decade, southern Indiana summer drought frequency increased by 33% (Strzepek et al., 2010). Hence, 9.1 cm/month rainfall is unlikely and the *Miscanthus* water deficit is likely greater than 16%.

Third, *Miscanthus* is not drought-tolerant, even for a single season. It has "a lack of adaptation to drought," given water-stressed conditions (Clifton-Brown and Lewandowski, 2000; Lewandowski et al., 2000).

Fourth, without irrigation, *Miscanthus*' yields are variable/low, yet *Miscanthus* irrigation is not cost effective (Clifton-Brown et al., 2001; Walsh, 2008). Thus, given the earlier discussion of drought/food price shortages/dangerous biomass subsidies, if farmers irrigate *Miscanthus*, they could lose money and worsen drought/global food risks. If they do not irrigate, they could lose their crop and their money as well as worsen drought/global food risks. The 1988 drought that affected Indiana cost the country $40 billion—exceeding losses caused by the 1992 Hurricane Andrew, 1993 Mississippi River floods, and 1989 San Francisco earthquake (Riebsame et al., 1991). The 2002 drought that affected Indiana cost the nation $10 billion (Ross and Lott, 2003), and the already mentioned 2012 drought caused 3–5% food price increases (Volpe, 2012).

A fifth *Miscanthus*/drought problem is that *Miscanthus*' deep, penetrating (2.5 m, 8.2 ft), dense, root mat (Werner, 1995) could reduce groundwater availability in already drought-prone southern Indiana (Boelcke et al., 1998), thus worsening drought/global food risks. Even corn root mats are only one-third as deep as *Miscanthus* (NDA, 1997). Soil moisture under *Miscanthus* is also significantly less than under corn or soybeans; after several years, soil moisture under *Miscanthus* is more than 2 in. less than under local food crops (McIsaac et al., 2010).

Sixth, *Miscanthus* is far less likely to survive drought, given its extensive water needs—33% greater than corn, 76.2 cm instead of 55.6 cm/growing season (Purdue eXtension, 2008; Heaton et al., 2012). Because southern Indiana droughts have repeatedly devastated corn crops, they are more likely to devastate *Miscanthus* as well.

Seventh, although many authors (e.g., VanLoocke et al., 2012) report that in midwestern United States, *Miscanthus* has a slightly higher water use efficiency than corn, other authors deny this fact (Dohleman and Long, 2009)—perhaps because such estimates are based on different models/assumptions and different midwestern areas. Nevertheless, growing corn seems preferable to growing *Miscanthus* because of its shorter growing season, its lower water requirements, and its providing food , rather than something to be burned. At a minimum, before growing *Miscanthus*, scientists obviously need to resolve water-efficiency issues for the particular region at issue.

1.3.5 Objections to biomass-induced drought charges

In response, *M. giganteus* supporters say it can tolerate a drought year, then return to normal yields (Khanna et al., 2008) once normal climate returns (Ivanic, 2010). However, "return to normal" relies on false presuppositions. Scientists warn *Miscanthus* is not drought resistant and say climate change means droughts are the "new normal," perhaps persisting forever (IPCC, 2007; Kundzewicz et al., 2008; YinPeng et al., 2009). Besides, only established plants, not starting *Miscanthus* plants, could tolerate even a summer of drought.

Miscanthus proponents also say it decreases groundwater availability only when it covers more than 25% of land (Vanloocke et al., 2010). Because the Jasper biomass plant *Miscanthus* will require only "10,000 acres … over a 35–50-mi radius from the plant," supporters say its land coverage would be <0.5% within a 50-mi radius—and hence pose no drought threat (TOC, 2010).

However, TOC's 50-mi radius claim fails. Why? Suppose someone said dumping toxins would not be harmful, because they would be dumped within a circular area having a 50-mi radius. Obviously, however, without guarantees regarding where, in the circular area, the toxins would be dumped, most could be dumped in one place and thus harm people—just as *Miscanthus* could be grown in one area and thus cause drought there. TOC thus makes the obviously invalid assumption that because *Miscanthus* will be grown within a 50-mi area, it will be completely uniformly distributed there, and not affect the water table adversely. Besides, because TOC's 50-mi growing limit for *Miscanthus* is wholly arbitrary/without legal enforceability, all 10,000 needed acres of *Miscanthus* could easily exceed 25% of some local land area and hence could lower the water table.

Given the preceding considerations, growing *Miscanthus* near Jasper will likely exacerbate drought in a drought-prone region. Besides, TOC's proposal contains no ecological risk assessment (ERA)—and no assessment of hydrology-related consequences. At best, its questionable water-related claims beg the question.

1.3.6 Clean water threats

Other *Miscanthus*-related water threats include local water damage from fertilizers and herbicides needed for growing *Miscanthus*. The Jasper plant biomass input requires fertilizers because TOC says local *Miscanthus* crops will be on less fertile land currently out of cultivation (TOC, 2010). In addition, US government reports say *Miscanthus* always needs fertilization (Wang et al., 2012). Fertilization, however, causes nitrate/nitrogen leaching into water sources (Schroder et al., 2004), a massive problem because midwestern farm nitrogen/nitrates already have caused Mississippi River contamination and a 7,000-mi^2 hypoxia "dead zone" in the Gulf of Mexico; no fish/living creatures can survive in this nitrate/nitrogen-caused, oxygen-depleted zone (Bruckner, 2011).

Because nitrogen/nitrates cause similar oxygen deficiencies in humans, USEPA set nitrogen/nitrate, drinking water limits of 10 mg/L, 10 ppm (USEPA, 2012a). Above 10 ppm, nitrate/nitrogen can cause methemoglobinemia, blue baby syndrome in infants. Because methemoglobinemia reduces the blood's ability to carry oxygen and release it to bodily tissues, it causes tissue hypoxia (Wright et al., 1999; USEPA, 2012b), decreased iodine uptake/thyroid function (Guillette and Edwards, 2005), increased stomach/esophagus cancers (Grosse et al., 2006), and reduced fertility (Guillette and Iguchi, 2012). Even worse, nitrogen/nitrate levels of 5 ppm—half the USEPA limit—cause more-than-double increases in otherwise avoidable thyroid cancer. Yet a minimum of 6-lb. fertilizer/ton *Miscanthus* is required (Heaton et al., 2012)—300 tons nitrogen/year for Jasper.

Most of the 15,000 people in Jasper, and 42,000 in DuBois County (United States Census Bureau, 2010), could be affected by drinking nitrate/nitrogen-contaminated water from *Miscanthus* growing. Moreover, costs of residential, nitrogen/nitrate water treatment systems are $5,000–$21,000/home (IDHEM, 2008). For DuBois County residents, total nitrate/nitrogen treatment costs would be $195–911 million. However, TOC's proposal includes neither a cost–benefit analysis (CBA), nor ERA. It ignores these health harms/costs.

Of course, many crops use fertilizers and cause nitrogen problems. What is troublesome about *Miscanthus* fertilizer problems is that they are created by crops not used for food. In addition, *Miscanthus* fertilizers exacerbate already existing problems with poor nitrogen/nitrate pollution standards, Gulf of Mexico hypoxia, and expensive water purification systems.

Another *Miscanthus* water pollution problem is that TOC plans to use the herbicide atrazine (TOC, 2010; Shaddix, 2011). *Miscanthus* herbicides are always needed, at least during the first three years, to ensure profits (Lewandowski et al., 2000; Anderson et al., 2011). Yet, because atrazine causes runoff of dissolved toxins and lethal, "unpreventable water contamination" (Leonard, 1990; Sass and Colangelo, 2006; Bohn et al., 2011), the European Union—27 nations with a total population double that of the US—banned atrazine a decade ago. Italy and Germany—each producers of millions of tons of corn/year—banned atrazine more than two decades ago (Ackerman, 2007).

Why is atrazine so deadly and thus prohibited in Europe? First, it is slow to break down in water, has a half-life up to 100+ days, and persists/accumulates for years after application (ATSDR, 2003). Second, atrazine causes-cancer in animals (Rusiecki et al., 2004; USEPA, 2012c), has "high potential for groundwater contamination" (USEPA, 2012b), and caused USEPA to set atrazine drinking water limits of 0.0003 mg/L (3 ppb) (USEPA, 2012a). Third, atrazine levels 33 times lower than the allowed 3 ppb can cause human endocrine disruption. Atrazine levels of 0.00009 ppb—500,000 times lower than the current EPA 3ppb limit—delay sexual development and cause hormone-related dysfunctions (Enoch et al., 2007). At far below allowed levels, atrazine causes castration/feminization of male amphibians, similar to what it causes in humans (Hayes et al., 2006), decreased male sperm quality/concentration, inability to conceive (Swan et al., 2003), and sexual differentiation malfunction (Colborn et al., 1993).

A fourth problem is that, even at allowed drinking water levels, atrazine is associated with neurological disease/maldevelopment such as attention deficit hyperactivity disorder (ADHD) and autism (Colborn, 2004; Shelton et al., 2012). Fifth, atrazine also hurts its victims economically. Compared with those without ADHD, adults with ADHD have more than double outpatient health-care costs, double prescription drug costs, and nearly triple total medical costs; employees with ADHD also miss four times more workdays/year than others (Secnik et al., 2005).

A sixth reason to worry about Jasper area atrazine is its concentration within a 50-mi radius that already is drought-ridden, a fact that increases waterborne-atrazine concentrations. Seventh, most US farmers do not use atrazine, so 300 tons/year in Indiana is especially harmful.

Eighth, US government atrazine regulations do not protect citizens because they ignore the US National Academy of Sciences and Institute of Medicine warnings that, because current pesticide/herbicide regulations do not protect children against neurodevelopmental harm, like ADHD and autism, pesticide/herbicide standards/prohibitions should be dramatically strengthened (NRC, 1993).

A ninth problem—that atrazine harms US, not European, citizens—appears close to legalized bribery. Why? Although prohibited in Europe, atrazine is still allowed in the United States, because of its politically powerful, Swiss-based manufacturer, Syngenta. Syngenta spends $500,000–$5 million/year for US election candidates, to promote Syngenta regulatory interests, in addition to undisclosed Syngenta-based funding for Political Action Committees that also provide at least $300,000 each, per year, to US politicians (CRP, 2012; FEC, 2012).

A tenth reason for Jasper concerns about atrazine is that TOC proposes it because it is "cheap" (Shaddix, 2011). Yet, much safer herbicides, such as mesotrione, would cost only approximately 1% more than atrazine (Ackerman, 2007). Because costs of childhood, environmentally induced diseases are approximately $77 billion/year (Trasande and Liu, 2011), it seems unfair for agricultural–biotechnology/biomass companies, such as TOC, to profit at children's expense, instead of paying 1% more for safer herbicides. Of course, the specific health/lives costs of Jasper atrazine use can be calculated based only on case-specific assumptions that are unknown. Nevertheless, preceding atrazine harms are reason enough to question its use.

Another reason for concern about *Miscanthus*-related atrazine use is that there is less justification for contaminating water sources, to produce something to be burned for energy, than to produce food. Given cleaner, safer, cheaper options for producing energy (Shrader-Frechette, 2011), using atrazine on biomass crops is ethically questionable. Of course, atrazine use is a problem only for the TOC and other facilities that use it, and other, less dangerous herbicides could be used for growing *Miscanthus*. However, the fact that TOC chose *Miscanthus* for its facility, because it was cheap, shows that *Miscanthus* economics may be a problem—and perhaps one reason that it has not been grown commercially in the United States.

1.3.7 Biomass proposals as special-interest science

Why have TOC officials written, and Jasper officials accepted, the flawed/incomplete biomass proposal? Two reasons might be officials' wanting income from an outdated, now-closed, coal plant, and TOC's wanting taxpayer biomass subsidies.

TOC's profit-oriented proposal may be biased and incomplete because, despite claims to the contrary, later paragraphs show that TOC provided not science, but special-interest science (SIS), in its proposal. SIS is research whose conclusions are predetermined by profit interests (Shrader-Frechette, 2007). It is performed/funded by industries, special interests, who seek private profits, not public goods like health or unbiased knowledge. Corporations like TOC fund scientists to give them what they want, including incomplete, biased "science." This fact has been repeatedly confirmed for pharmaceutical/medical devices research (Krimsky, 2003), energy-related research (Shrader-Frechette, 2011), and pollution-related research (Michaels, 2008). It explains why so many industries fund SIS, how SIS helped cigarette manufacturers avoid regulations for more than 50 years, and why fossil fuel industry SIS denies anthropogenic climate change.

Evidence of SIS in TOC's lengthy biomass proposal appears through incompleteness/misleading claims. As already noted, the proposal includes (1) no human-health quantitative risk assessment (QRA), (2) no ERA, and (3) no CBA. It also has (4) no PM-related pollution information, despite the fact that, as already shown, most coal deaths arise from PM; each coal plant PM kills, on average 25 people/year; biomass PM pollution is at least 25 times worse than coal plant pollution; and there is no safe dose of PM. Similarly, TOC's proposal includes (5) no drought-related information, despite climate change/worsening southern Indiana droughts. Moreover, even when TOC gives pollution information, it is incomplete/misleading. For instance, TOC says it will use 100 tons *Miscanthus*/year, and release 0.03 lb. PM/million Btu, but gives (6) no *Miscanthus* Btu—needed to calculate total releases of PM/year. Using *Miscanthus* Btu, however, calculations show Jasper biomass facility PM releases 25 tons PM/year. Obviously, TOC covered up the fact that it intended to release 25 tons of PM/year, when it had only 100 tons input, and there is no safe dose of PM. Yet a proposal with such obvious, self-serving omissions/misleading information—such as (1)–(6), suggest SIS. Its authors either deliberately omitted (1)–(6) or had culpable ignorance for doing so.

SIS is widespread/undetected, partly because industries get tax deductions for their research-related expenses, whereas ordinary citizens often have neither time nor the education to challenge SIS that affects their lives. Moreover, most science is funded by special interests. In the United States, the American Association for the Advancement of Science (AAAS) says approximately 75% of all scientific work is industry funded ($300 billion), and 25% (the majority of which is military) is funded by government agencies, e.g., US National Institutes of Health. AAAS also estimates that for every $100 that industry spends on its "science," environmental health interests spend about $1. The result? Even when government decisions affect them, citizens often receive, not the truth, but the best "science" money can buy (Beder, 2002; Shrader-Frechette, 2007).

1.3.8 Suggestions for better biomass decision-making

How can people avoid dangerous biomass crops/incinerators? Because there are no legally required standards for biomass plant proposals, citizens themselves must hold biomass corporations to scientifically accountable proposal standards. At a minimum, and contrary to what most biomass incineration proposals do (Sheehan et al., 2011), all proposals must include CBA/ERA/QRA. Second, because citizens have rights to informed consent to all risks, only legally required proposal redactions should be allowed. Third, biomass proposals must explicitly answer the biomass plant arguments of all medical groups—such as the American Lung Association; the Massachusetts Medical Society says "biomass power plants pose an unacceptable risk to the public's health" (Sheehan et al., 2011). Fourth, all biomass proposals should answer World Bank/International Monetary Fund/World Trade Organization's food security-based and drought/climate-based arguments against biomass crop subsidies.

1.4 Conclusions

If the preceding arguments are correct, biomass incineration causes massive, avoidable death/injury, whereas biomass crops exacerbate drought/clean water problems. Those who assess biomass facilities need to heed the biomass lessons learned from developing countries.

Abbreviations

CBA: cost–benefit assessment; CBPMF: carbon black fine particulate matter; CBPMUF: carbon black ultrafine particulate matter; CO: carbon monoxide; CO_2: carbon dioxide; ERA: ecological risk assessment; µ: micrometers; MM: million; NOX: nitrogen oxides; PM: particulate matter; PMC: particulate matter; PMF: particulate matter; PMUF: particulate matter; QRA: quantitative human-health risk assessment; TOC: Twisted Oak Corporation.

Competing Interests

The authors declare they have no competing financial interests.

Authors' Contributions

Kunycky and Shrader-Frechette did the first three drafts together, and Shrader-Frechette did the final draft. Both co-authors read and approved the final manuscript.

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