From:	EnergyPlan2019@RedwoodEnergy.org
To:	work4peacenow; EnergyPlan2019@RedwoodEnergy.org
Subject:	RE: Biomass is Not Safe
Date:	Thursday, October 3, 2019 9:35:42 AM

Thank you for your comment, Terri. We will include this with the other public comments, and we'll be providing more information in response to the community's questions and concerns.

Best,

Nancy

Nancy Stephenson

Community Strategies Manager | Redwood Coast Energy Authority

(707)269.1700 x 352 | www.RedwoodEnergy.org

From: work4peacenow [redacted]

Sent: Thursday, October 3, 2019 9:24 AM

To: EnergyPlan2019@RedwoodEnergy.org

Subject: Biomass is Not Safe

Dear Redwood Coast Energy:

You are tasked to provide us with CLEAN ENERGY. Biomass is a not a safe or clean method of providing energy for Humboldt County. The plants emit too much CO2, which is adding to the warming of the climate which is leading to melting glaciers, wildfires and more. The American Lung Association, the American Academy of Pediatrics, the American Public Health Association and the National Association of County and City Health Officials oppose biomass due to it's health risks.

Mill waste can, if handled properly, return carbon to the soil with less negative impact on our climate. Composting (with high nitrogen waste, like food) sequesters carbon and avoids emissions from synthetic fertilizer and landfills. Wood chip mulch prevents storm runoff and erosion. Recycled wood products save trees.

We have 10 years to cut pollution in half and heal our planet. Choose solar, wind and battery storage for power. The public is in full support of these CLEAN ALTERNATIVES. We are losing 200 species a day. Extinction is a daily tragedy.

Please do the right thing for our planet.

Please confirm receipt of this letter.

Thank you,

❤ Terri Freedman
Eureka

Thank You for All You Do!

"We need global warming of hearts" -- protester sign at London's Extinction Rebellion die-in, April 21, 2019

The comments to the updated CAPE document below were submitted by RCEA Demand Side Projects Manager Patricia Terry.

Hold Regional Energy Forums. Serve as a forum for addressing countywide energy issues.

Develop Public Displays. Encourage and assist development of educational displays for exemplary renewable energy and distributed energy systems installed throughout Humboldt County. Displays should provide county residents and businesses with information on how the systems work and how well they perform; and should inform county residents about the importance, benefits, and associated impacts of developing local energy resources.

Provide Energy Efficiency Education and Training. Provide community education on energy issues, including the benefits of reduced energy consumption, and increased energy efficiency. Collaborate with schools and colleges for energy-related research, education, and conservation practices.

Integrated Demand Side Management

RCEA will use an Integrated Demand Side Management (IDSM) approach to match customer energy use with intermittent clean and renewable energy supplies. An additional priority will be placed on energy resiliency and independence.

INTEGRATED DEMAND SIDE MANAGEMENT STRATEGIES

Support Member Agency and Local Government Energy Management. Support member agencies in managing their energy consumption. RCEA will support varying activities that reduce and align energy use with available clean and renewable supplies to reduce costs while aligning to performance-based action plans and Greenhouse Gas Emission Reduction goals. Additional activities will be prioritized where they support energy resiliency and independence.

Support Implementation of Codes and Standards. Support the local implementation of Title 24 building energy codes, Title 20 appliance efficiency standards and individual projects that strive to achieve energy efficiencies that exceed state or local requirements. Support the consideration and adoption of above code energy ordinances.

Promote No Regrets Energy Efficiency, Solar and Storage Permitting. Support local ordinances that streamline permitting processes for energy efficiency, solar and storage technologies.

Assist with Facility Benchmarking. Assist local governments with facility benchmarking to evaluate and track the energy performance of non-residential buildings.

Support Zero-Net–Energy Standards. Support the State's goals related to residential and commercial net-zero-energy standards along with other green building standards that align to RCEA's IDSM strategies.

Conduct Community Engagement. Provide community facing information and resources that will support informed decision making as relating to customer energy use.

Support Energy Assessments. Support and encourage full knowledge of the costs and benefits (including product stewardship) of energy efficiency, conservation, generation and storage activities through assessments.

Integrate Distributed Energy Resources. Support, promote and integrate distribution-connected generation, energy storage, energy efficiency, electric vehicle and demand response technologies into new and existing customer facing programs.

Integrate a Distributed Energy Resource Management System. Integrate distributed energy resources into a unified system that can aggregate or automate demand response activities.

Support and Deploy Microgrids. Support and deploy energy microgrids, focusing on critical infrastructure and community facilities, that through onsite generation, energy storage, and advanced control systems provide energy resiliency and emergency-response capabilities as well as ongoing economic and environmental benefits.

Use Advanced Metering Infrastructure. Use advanced metering infrastructure to make informed, data driven program decisions.

ENERGY EFFICIENCY & CONSERVATION

RCEA will support energy efficiency and conservation as core strategies toward achieving the program's environmental, economic, and community goals. Where feasible, energy efficiency technologies will be controllable and integrated as a distributed resource. RCEA will:

Support electrification. Prioritize new programs and alterations to existing services that promote the use of air-source heat pump domestic hot water and space heaters, induction stoves and clothes dryers.

Encourage Energy-Efficient Equipment. Encourage the use of the most energy-efficient equipment for space and water heating, ventilation, lighting, refrigeration, and air conditioning in all buildings and developments, including residential and commercial facilities.

Promote Performance Contracting. Promote residential and commercial performance contracting that is consistent with current best practices for energy efficiency and environmentally sound construction techniques.

Develop and Support Behavioral, Commissioning and Operations (BROs). Develop, promote and support programs that promote conservation, building system commissioning and operational changes that reduce or change the time of energy use.

Replace Plug Loads. Replace existing plug load devices and install line signaling smart technologies that save energy and provide an integrated solution that aligns with demand response and storage measures. Example include internet of things enabled lighting, water and space conditioning, dish and clothes washing and refrigeration.

DEMAND RESPONSE

RCEA will support and prioritize demand response programs that give ratepayers an opportunity to play a role in balancing energy load with renewable energy supply**.** Demand response programs and offerings will, where possible, integrate with distribution connected efficiency, solar and storage measures.

Support Time of Use. Notify, support and enable action from customers who express an interest in load shifting or shaving to reduce evening hour coincident demand**.**

Provide and Support Peak Day Pricing. Notify and support customer energy use changes during summer peak day events.

Enable Automated Demand Response. Install electrification, efficiency, and storage technologies that automatically reduce energy use during demand response events.

Implement Grid Connected Buildings. Implement grid connected buildings that allow for the curtailment of loads

DISTRIBUTED GENERATION & STORAGE

RCEA will support the deployment of distribution connected solar and storage technologies as core strategies toward achieving the program's environmental, economic, and community goals.

Administer and Implement the Public Agency Solar Program. Continue to implement the solar and energy-storage technical assistance program for public agencies; integrate grid-connected resources and microgrids as feasible.

Administer and Implement the Community Solar and Storage Program. Evaluate, design and launch community solar and storage program services that support the increased adoption of grid-connected solar and storage technologies.

Integrate Vehicle to Grid Storage. Integrate vehicle to grid storage solutions

BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF CALIFORNIA

Order Instituting Rulemaking Regarding Policies, Procedures and Rules for the California Solar Initiative, the Self-Generation Incentive Program and Other Distributed Generation Issues.	Rulemaking 12-11-005

COMMENTS OF VOTE SOLAR ON THE PROPOSED DECISION ON THE EQUITY RESILIENCY BUDGET

Susannah Churchill
Ed Smeloff
Vote Solar
360 22nd St, suite 730
Oakland, CA 94612
Telephone: 415 817 5065
Email: susannah@votesolar.org

August 29, 2019

BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF CALIFORNIA

Order Instituting Rulemaking Regarding Policies, Procedures and Rules for the California Solar Initiative, the Self-Generation Incentive Program and Other Distributed Generation Issues.	Rulemaking 12-11-005

COMMENTS OF VOTE SOLAR
ON THE PROPOSED DECISION ON THE EQUITY RESILIENCY BUDGET

I. Introduction

Vote Solar appreciates the opportunity to submit comments on the Proposed Decision (PD) establishing a self-generation incentive program equity resiliency budget, modifying existing budget incentives, approving carry-over of accumulated unspent funds and approving $10 million to support San Joaquin Valley disadvantaged community projects. Vote Solar strongly supports the establishment of an equity resiliency budget in the Self-Generation Incentive Program (SGIP). We also strongly support extending eligibility for non-residential customers to include those who are located in Tier 2 and Tier 3 High Fire-Threat Districts (HFTD) that provide critical facilities or critical infrastructure.

We also agree that disadvantaged communities for SGIP purposes should include all California Indian Country as defined by federal law. Similarly, we support the change to eligibility criteria for SGIP equity budget incentives to include customers who are eligible for the Single Family Affordable Solar Homes (SASH), the SASH for Disadvantaged Communities program, and the Solar on Multifamily Affordable Housing Programs (SOMAH).

Our comments below focus on four issues: 1) the proposed step-down incentive structure for energy storage systems of different durations, 2) the ongoing funding level for the Equity Resiliency budget, 3) the geographic focus for eligibility for incentives from the Equity Resiliency budget and 4) the opportunity to use unused administrative and marketing funds to facilitate local planning to improve the development of critical facility and infrastructure resiliency.

We recommend that the incentive step-down structure be revised to provide greater incentives for longer duration energy storage that will be needed for renewable integration, reliability and resiliency. We recommend that the allocation of unused SGIP incentive funds be flexible and allow for increased allocation to the equity resiliency budget if the demand for critical service or infrastructure facilities is high. We also recommend that customers throughout Tier 2 HFTDs be eligible for Equity Resiliency funds, in addition to those in Tier 3 HFTDs. Finally, we recommend that a portion of the remaining unused administrative funds be made available to local governments and community choice aggregation agencies to plan for future improvement in community resilience including the development of facilities that can provide refuge during long-duration outages or public safety power shutoff (PSPS) events.

II. Longer Duration Energy Storage is Needed for Renewable Integration, Reliability and Resiliency

The PD proposes a step-down incentive that reduces incentives for energy storage projects with discharge durations longer than four hours; storage with a duration of 4-6 hours would receive 25% of the incentive for hours 4-6 and storage longer than 6 hours would receive no incentive for the incremental capacity. While we understand the Commission's desire to use incentive funds efficiently, we believe the proposal should be modified to avoid lost opportunities to develop needed energy storage systems that can be used to improve resiliency, local and system reliability, facilitate the closure of once-through cooling power plants and enable the integration of more carbon-free energy that is needed to meet California's renewable energy and climate goals.

As a preliminary matter, the PD should be modified to make it crystal clear that the incentive stepdown is intended to be applied incrementally. As worded, it is unclear whether an 8-hour battery would receive 100% of the incentive for 4 hours, plus 25% of the incentive for 2 more hours, and no incentive for the last 2 hours. Alternatively, would it receive no incentive because the stepdown does not apply incrementally? The PD implies the first, but greater clarity is needed.

The California Independent System Operator (CAISO) Department of Market Monitoring has expressed concern that increased reliance on the current configuration of shorter-duration battery energy storage systems to meet Resource Adequacy (RA) requirements could increase the potential for market power in CAISO markets and uncompetitive market conditions could become more frequent.[1] Additional battery resources with longer discharge durations could help mitigate the potential for market power during peak conditions by increasing the amount of available RA resources available for the entire evening peak period even if the battery is partially discharged from being used earlier in the day for another service.

Under CPUC rules, a resource must be able to operate for four consecutive hours at its RA value to be able to sell that capacity as resource adequacy. An analysis of the availability of battery storage during August 2018 summer months indicated that many batteries were not able to provide full capacity during the ramping and peak net load hours.[2] Increasing the fleet of longer duration batteries can provide a broad system benefit by lowering the cost of ramping services. Batteries with longer duration storage will be more capable of fulfilling critical reliability needs while also being available for onsite demand management and providing resiliency when called upon during critical situations. Also, as more solar and wind generation are added to the state's resource mix, the system peak is projected to shift to later in the year and later in the day thereby increasing the need for flexible ramping capacity that batteries can provide. Longer duration energy storage is one of the important tools required to further integrate the solar and wind generation that will be needed to meet the state's greenhouse gas reduction goals.

Of immediate concern to policy makers is the impending retirement of once-through-cooling (OTC) fossil power plants at the end of 2020. CPUC staff has projected a need for 2,500 MW of capacity by the summer of 2021 while SCE indicates that the shortfall in capacity may be as high as 5,500 MW. Energy storage systems can be a critical resource in reducing the need for OTC fossil plants to be used to serve the evening peak hours from 4-9 pm. Storage of 5 hours or longer in duration will be valuable for enabling customers to shift their solar energy generated earlier in the day for use during the evening ramp.

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[1] Reply comments of the CAISO Department of Market Monitoring on the Assigned Commissioner and Administrative Law Judge's Ruling Initiating Procurement Track and Seeking Comment on Potential Reliability Issues, R. 16-02-007, August 12, 2019.

[2] Ibid. Pages 12-13

With regard to customers' resiliency needs, critical facilities and medically vulnerable customers could often need their storage system to discharge throughout the night during a long power outage or PSPS event. Protecting vulnerable customers and meeting their critical resiliency needs for extended periods should be a main goal of the PD. Incentivizing customers to install storage of a long enough duration to meet their life-support needs is necessary for the PD to actually achieve that goal.

To leverage all these important values of longer duration storage with the worthy goal of making the incentive dollars available to as many customers as possible, we recommend a step-down structure with 100% of the incentives applying for systems with up to 6 hours of discharge duration, an additional 50% for systems with up to 2 additional hours of discharge capability and an incremental 25% for systems with even longer discharge durations.

Additionally, the size of a storage system that a customer can deploy under SGIP is capped at the customer's maximum historical demand in kW over 12 months. For larger projects that are intended to provide resiliency services to critical facilities, this cap may be too restrictive. We agree with the PD directive that requires project administrators to assure that longer duration storage systems can operate in an islanded mode during an outage to assure that projects can meet the resiliency objectives outlined above. The Commission should consider adjusting the system size cap and the long duration discharge requirement to better address the technical limitations that will otherwise hinder these facilities' ability to achieve true resiliency under a PSPS event.

III. Accumulated Unused SGIP Incentive Funds Should be Allocated in a Flexible Manner to Promote More Equity Resiliency Projects if Demand is High

Vote Solar supports the proposed initial allocation of $100 million for the Equity Resiliency Budget from the accumulated unused generation technology budget. However, we believe that the needs assessment for the use of these funds is still preliminary and uncertain. The potential set of eligible non-residential customers in Tier 2 and Tier 3 HTFDs could be very large and their participation may depend on how well the revised program is marketed. Likewise, it is hard to predict the amount of incentive uptake that will be created by extending the higher incentive to Tier 3 HFTD SASH/DAC-SASH and SOMAH customers.

We know that critical facilities and other customers are flocking to buy fossil backup generators as they anxiously anticipate future disasters and power shutoffs. For example, water agencies have reported renting generators to ensure safe and reliable operations, including one agency spending $400,000 for 29 generators on a 4-month rental period.[3] The San Francisco Chronicle reported that one home services firm received a 1400% increase in generator purchase inquiries in only 3 months. A national generator company reported a 600% increase in demand for generators and equipment from its California-based dealers over that same time period.[4] Solar + storage backup power is a far better solution for protecting public health, avoiding local air emissions and the danger of carbon monoxide poisoning if fossil generators are installed in enclosed spaces. Solar + storage backup power can also provide greater reliability, given that fossil backup generators sometimes fail to start and are dependent on delivery networks or storage for providing fuel.

Providing sufficient funding in the 2020 Equity Resiliency budget will be an essential means of enabling critical facilities and other customers to install cleaner, more reliable backup power soon and minimize reliance on fossil backup generators. It is quite possible that the proposed $100 million for 2020 will be fully subscribed. We are supportive of the directive that SGIP PAs submit Tier 1 advice letters on January 31, 2020 that provides SGIP accounting data for 2019. Based on the data received, the Commission should quickly move to allocate additional funds to the Equity Resiliency Budget as needed.

IV. Customers Located in Tier 2 HFTD areas Should also be Defined as Having Critical Resiliency Needs

The PD defines residential customers with critical resiliency needs as those who are located in Tier 3 HFTD and are: 1) eligible for the equity budget, 2) a medical baseline customer; or 3) a customer who has notified their utility of serious illness or condition that could become life-

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[3] Association of California Water Agencies, Energy Committee Meeting, August 12, 2019

[4] https://www.sfchronicle.com/business/article/Demand-for-generators-lights-up-as-PG-E-power-14054242.php

threatening if electricity is disconnected. It defines non-residential customers as having critical resiliency needs if they are located in a Tier 2 or Tier 3 HFTD, but only if they serve a community that is located in a Tier 3 HFTD.

Tier 3 HFTDs cover a relatively small portion of the state. Utilities have frequently stated that PSPS events could affect large areas particularly if high voltage transmission lines need to be de-energized for safety. During a large fire, residents from a Tier 3 HFTD may need to shelter away from their home in a Tier 2 HFTD area whose critical facilities do not typically serve Tier 3 HTFD areas. We are also concerned that identifying critical facilities that are located in Tier 2 but serve eligible customers in Tier 3 areas will be confusing and administratively burdensome. For all these reasons, we recommend that the same categories of customers throughout Tier 2 HFTD areas be eligible for the Equity Resiliency Budget. If the budget is exhausted quickly with a more expansive geographic area, the Commission could consider expanding Equity Resiliency Budget levels in 2020 and for years beyond 2020.

VI. A Portion of Unused Accumulated Administrative Funds Should be Targeted to Local Government for Improving Local Energy Resiliency Planning

It has been noted by many parties that lack of awareness of the SGIP program has limited customer participation. Changes to the program eligibility criteria in the PD would permit participation from a broad spectrum of critical resiliency need customers including police stations, fire stations, hospitals, skilled nursing facilities, nursing homes, blood banks, dialysis centers, hospice facilities, water, wastewater and flood control facilities, jails, prisons, cooling centers, homeless shelters and facilities that provide assistance during PSPS events. It is very possible that participation will be somewhat haphazard and that facilities with the greatest needs may be overlooked. At the same time, the PD notes at page 78 that approximately $70.3 million remains in accumulated unused administrative funds.

Vote Solar suggests that the Commission establish a pilot program by Program Administrators to help local governments assess the resiliency needs of their local critical facilities and start planning power systems of different configurations that can operate as electrical islands, i.e., microgrids. A microgrid can be entirely on the customer side of the meter at a critical facility, e.g., an individual building, or an entire campus that does not rely on utility services upstream of the point of interconnection, to enable a critical facility such as a hospital or emergency shelter to operate off-grid. A microgrid can also serve a larger community by coordinating the operation of multiple single facilities and utility-side DERs to sustain electric service over one or more distribution circuits on the grid. This effort would seek to accelerate what some California local governments are already doing to plan and implement local microgrid projects (including Oakland, Marin, Calistoga, Humboldt County, and Santa Barbara).[5]

Without integrated planning, there is a danger that local governments and critical facilities will proceed with PSPS planning in isolation from an understanding of local grid capabilities and constraints, and without working in concert with the broader community. For optimal local resilience planning, it makes sense to utilize the largest and most optimal spaces within communities to generate and store energy locally, rewarding property owners as appropriate.

New information resources will be needed to help facilitate this kind of integrated local energy resilience planning. For example, an improved data access framework is needed to enable cities and counties to plan electrification and resilience projects, working in collaboration with third-party DER providers, Community Choice Agencies (CCAs) and distribution utilities to develop projects. It should be possible to protect customers' rights to privacy and control of their own data, while still enabling sufficient data exchange among parties voluntarily collaborating in local energy resilience planning. Program administrators could also create electronic resources highlighting case studies from communities (e.g. as noted above) which have already begun this type of community energy planning efforts, as well as information about the technical aspects of designing critical facility microgrids and other DER-based resilience projects.

V. Conclusion

Vote Solar thanks the Commission for its work to address issues with the SGIP equity budget and resiliency, and appreciates the opportunity to provide comments on the PD.

Respectfully submitted,

[5] See for example https://napavalleyregister.com/community/calistogan/news/calistoga-microgrid-plan-for-backup-power-moves-forward/article_e2eba459-62c0-5ccd-9a48-862373da0631.html

By: */s/ Susannah Churchill*

Susannah Churchill
California Director
Vote Solar
360 22nd St, suite 730
Oakland, CA 94612
Telephone: 415 817 5065
Email: susannah@votesolar.org

From:	EnergyPlan2019@RedwoodEnergy.org
To:	olivia brock; EnergyPlan2019@RedwoodEnergy.org
Subject:	RE: No biomass. Not clean.
Date:	Monday, October 14, 2019 10:09:40 AM

Thank you for your comment, Olivia. We will record it online with the others.
Best,
Nancy

-----Original Message-----
From: olivia brock [redacted]
Sent: Friday, October 11, 2019 4:27 PM
To: EnergyPlan2019@RedwoodEnergy.org
Subject: No biomass. Not clean.

No biomass. Not clean.

Humboldt Redwood™

Redwood Coast Energy Authority
Attention: Richard Engel
633 3rd Street
Eureka, CA 95501

October 11, 2019

RE: Comprehensive Action Plan for Energy

Dear Richard,

Please find attached letters provided by the Humboldt County community recommending continued support of the forest products industry and biomass by the RCEA Community Choice Aggregate program. The letters are primarily from the employees and vendors of Humboldt Redwood Company, LLC and Humboldt Sawmill Company, LLC that earn their living from the forest products industry in Humboldt County.

Best Regards,

Jim Pelkey

Sample forest products industry support letter. Signatures attached.

Redwood Coast Energy Authority
633 3rd Street
Eureka, CA 95501

October 11, 2019

RE: Comprehensive Action Plan for Energy ("CAPE")

Dear Sir/Madam:

I am writing this letter in support of the forest products industry in Humboldt County. As an employee or contractor currently earning a living in the forest products industry in Humboldt County it is important for me to pledge my support for the industry. I am familiar with the Redwood Coast Energy Authority county program and the benefits it offers county residents in terms of an option other than Pacific Gas & Electric, support of renewable energy, and support for the local economy. I would encourage the program to support local biomass energy and the local forest products industry for the long-term given the positive impact it provides to the county in terms of (i) jobs supporting both the residents and the county, and (ii) tax base to support county initiatives.

Please support local biomass energy.

Sincerely,

Employee/Contractor

	Signatures
1	Employee/Contractor
2	
3	Employee/Contractor
4	
5	
6	Randy Murray
7	
8	Sincerely,
9	Tomás Cervantes
10	
11	Sincerely, Employee/Contractor
12	Employee/Contractor
13	
14	
15	
16	Sincerely, Mark Grant
17	Employee/Contractor
18	

19	Valentin Martinez
20	Philip Cramer
21	[illegible]
22	Tracy Denaney wendt Const.
23	[illegible] Wendt Const.
24	[illegible] Wendt Construction
25	[illegible] WENDT Const.
26	Bob [illegible] Wendt Construction
27	Sincerely, [illegible] Wendt Construction
28	[illegible] WendT Cost
29	Sincerely, Jason Harwood Wendt construction
30	Thomas Borges WENDT CONTRUCTION
31	Dave Mungia Wendt const
32	[illegible] Employee/Contractor
33	Michael Austin
34	[illegible]
35	Mike Anaya
36	Brian J. Haman
37	Sincerely, [illegible]
38	John Rolland Yanke Energy, Inc

39	[illegible]
40	Robert Baillie
41	[illegible]
42	[illegible]
43	[illegible]
44	[illegible]
45	[illegible]
46	[illegible]
47	[illegible]
48	[illegible]
49	[illegible]
50	[illegible]
51	[illegible]
52	[illegible]
53	Sincerely, [illegible]
54	[illegible]
55	[illegible]
56	[illegible]
57	Sincerely, [illegible]
58	Ernest Moser Sierra Pacific Industries

59	Casey Ales Ales Trucking
60	Roy T Andrews Redwood Coast Trucking
61	Don Johnson Redwood Coast Trucking
62	Horner Killam F.V. Martin Trucking
63	Stanley Stevens Rock Logging
64	Timothy Burrus Tim Burrus Trucking
65	Larry Turney Philbrick Logging
66	Ramiro Moiseo Ramirez Melecio Trucking
67	Scott W. Smith Steve Wills Trucking and Logging
68	Oustan Perras Leonardo Logging
69	Kenny Hower Hower Hauling
70	Joshua Rogers Northwest log Scalers
71	Murray Armstrong LBA
72	Chad Watson wendt con
73	[illegible] Wendt Construction Co Inc
74	Susan [illegible] Wendt Construction Co Inc
75	[illegible] Wendt const
76	[illegible] Wendt construction
77	[illegible] Wendt const.
78	[illegible] Wendt Const.

79	[illegible] Wendt Const
80	Employee/Contractor [illegible]
81	Sincerely, [illegible] Shultz Construction
82	Sincerely, [illegible] WENDT CONST
83	Sincerely, [illegible]
84	[illegible]
85	Jesse Campbell
86	christian chastain
87	[illegible]
88	[illegible]
89	[illegible]
90	Darnon Eggel
91	[illegible]
92	[illegible]
93	[illegible]
94	[illegible]
95	[illegible]
96	[illegible]
97	[illegible]
98	Randal D Jordan

99	Vern Leaton
100	[illegible signature]
101	[illegible signature]
102	[illegible signature]
103	Matt [illegible]
104	[illegible signature] Employee/Contractor
105	Heater Hernandez
106	[illegible signature]
107	Sincerely, Rodrigo Ruiz
108	Taylor Hutson
109	Alyssa Jorgensen Humboldt Redwood Company
110	[illegible signature] Humboldt Sawmill company
111	[illegible signature] RC Jenkins Trucking
112	[illegible signature] West Coast Logging
113	[illegible signature] Steeve Wills Logging
114	Gustavo Melesio Ford Logging
115	[illegible signature] Steeve Wills Logging
116	[illegible signature] West Coast Trucking
117	[illegible signature] Redwood Coast Trucking
118	Donnie [illegible] Krustosek Trucking

119	[illegible] Employee/Contractor	Paul D Magliano Trucking
120	[illegible] Employee/Contractor	Redwood Coast Trucking
121	[illegible]	Humboldt Redwood Company
122	[illegible]	Humboldt Redwood Company
123	Employee/Contractor [illegible]	Chambers Logging
124	Sincerely, [illegible]	Redwood Coast Trucking
125	Sincerely, [illegible]	West Coast Redwoods
126	Larry Johnson	Redwood Coast Trucking
127	David F Johnson	David F Johnson Trucking
128	[illegible]	Chambers Logging
129	[illegible]	Forg Logging
130	[illegible]	Steeve Wills Trucking and Logging
131	[illegible]	Hank Combs Trucking
132	[illegible]	Babich Trucking
133	[illegible]	Pat Co LLC
134	[illegible]	Leonardo Logging
135	[illegible]	Redwood Coast Trucking
136	[illegible]	GR Sundberg Inc.
137	[illegible]	
138	Michael Richardson	

139	[illegible]
140	[illegible] C.W. Wood Products
141	Danielle Flores
142	[illegible]
143	Mike [illegible]
144	[illegible]
145	Ray [illegible]
146	Sincerely, [illegible]
147	[illegible] Employee/Contractor H.S.
148	[illegible]
149	[illegible]
150	[illegible]
151	[illegible]
152	[illegible]
153	[illegible]
154	[illegible]
155	[illegible] Hunter
156	[illegible]
157	Jordan [illegible]
158	[illegible]

159	[illegible signature]
160	Francisco Sanchez
161	Kim Hunt
162	[illegible signature]
163	James Fox
164	James Meskill
165	[illegible signature] R Bottler
166	[illegible signature]
167	Manuel R. Meras
168	Carlos Urbina
169	[illegible signature] HRC Employee
170	Moises Velasquez Saw Mill
171	[illegible signature] Humboldt company Sawmill
172	[illegible signature] Humboldt Scotia Sawmill Company
173	[illegible signature]
174	[illegible signature] Humboldt Sawmill Company
175	[illegible signature]
176	[illegible signature]
177	Jose [illegible] Humboldt Sawmill Company
178	[illegible signature] Zachary Green

179	Sincerely, [illegible]
180	Gus Sa[illegible]
181	[illegible]
182	[illegible]
183	[illegible]
184	[illegible]
185	[illegible]
186	[illegible]
187	Employee/Contractor [illegible]
188	[illegible]
189	[illegible]
190	[illegible]
191	[illegible]
192	Noah O'Kelly
193	[illegible]
194	[illegible]
195	[illegible]
196	[illegible]
197	[illegible]
198	[illegible]

199	[illegible] millwright
200	[illegible]
201	Eduardo Martinez
202	[illegible]
203	[illegible]
204	[illegible]
205	Robert M Clark
206	Nick Hamilton
207	Devin Stebbins
208	[illegible]
209	[illegible]
210	[illegible]
211	~~Employee~~/Contractor Travis O'Connell
212	[illegible]
213	mark Chancellor
214	[illegible]
215	Kyle Dillon
216	[illegible]
217	Mike Grazioli
218	Please support local biomass energy. Sincerely, [illegible]

219	Paul Marchetti
220	[illegible]
221	[illegible]
222	[illegible]
223	Michael Connich
224	[illegible]
225	[illegible] Watt[illegible]
226	[illegible] Employee/Contractor
227	Sincerely, [illegible]
228	Victor Arregun 10-4-19
229	Robert Dinsmore
230	[illegible] Sheldon
231	Kurt M. Halley
232	[illegible]
233	Brian P Eilers
234	[illegible]
235	[illegible]
236	KEITH LACKEY, AQUATIC BIOLOGIST
237	Mary Bowen Employee/Contractor
238	[illegible]

239	Mark Colozzo
240	Mike Cameron
241	Alex Nicpoth Employee/Contractor
242	[illegible]
243	Mark Freitas
244	Ted Torgerson
245	Ryan P. Rice
246	[illegible]
247	Brad Mauney
248	James Regan
249	Richard Beck Redwood Coast Trucking
250	Mike A. Gardner Humboldt Sawmill Company
251	Sincerely, Michael Johnson Redwood Coast Trucking
252	Kenny Addison Babich Trucking
253	JOHN M. WHITNEY Whitney Trucking
254	Brenda L. Calderas Diamond L. Ranch
255	[illegible] Humboldt Sawmill CO.
256	[illegible]
257	Diane Black
258	[illegible] Sal Chinnici Director, Forest Sciences Mendocino and Humboldt Redwood Companies

259	Michael L. Riddle Chambers Logging
260	Charles E McLaughlin R.B. Browns Trucking
261	Kevin Harrison Boot Leg Trucking
262	Denise Ellen West Babich Trucking
263	Byron Fick H.A. Blankenship Inc.
264	Jerry [illegible] Steve Wills Trucking and Logging
265	Richard Martin G.R. Sundberg Inc
266	Ed Calkins Leonardo Logging
267	David M. Shaffer Redwood Coast Trucking
268	[illegible] Chambers Logging
269	[illegible] Chambers Logging
270	Kenneth Rowe Steve Wills Trucking and Logging
271	William J. Davis Leonardo Logging
272	Employee/Contractor Redwood Coast Trucking
273	Roger Brown Employee/Contractor G.L.J. Construction
274	Kyle Geary Steve Wills Trucking and Logging
275	Trevor Burns Boot Leg Trucking
276	Wes Crambit Lewis Logging
277	Rocky Goodwin Morris Logging
278	[illegible] Redwood Coast Trucking

279	Peter M. Christianson Cameron Cardoza Trucking
280	Martin Jacobsen Redwood Coast Trucking
281	Sam Morris Ace Transport Services Inc.
282	Leo Bader Humboldt Redwood Company
283	[illegible] Humboldt Redwood Company
284	Caleb Aguiar Hooper Trucking
285	Robert Balke Redwood Coast Trucking
286	Wayne [illegible] Morris Logging
287	Don Bernardi Hank Combs Trucking
288	Christopher Hadler R.B. Browns Trucking
289	[illegible] Employee/Contractor Redwood Coast Trucking
290	Chris [illegible] Redwood Coast Trucking
291	Dennis Reeding Employee/Contractor Morris Logging
292	Tim Prauss R.B. Browns Trucking
293	Jeff [illegible] Humboldt Redwood Company
294	Ryan Shepherd [illegible] Hooper Trucking
295	[illegible] HRC - Log Truck Driver
296	[illegible] Tritchler Logging
297	Jobey Tritchler Tritchler logging
298	Manuel Alvarado Leonardo Logging

299	MIKE C. SANFORD Mike Sanford Trucking
300	Brandon moore Parkway Feed
301	Shelly Tyler NWLS
302	Shaun Stoneham Humboldt Redwood Company
303	Chet Starkey TJ Allen Trucking
304	Rick Patrum Sierra Land Management Forestry Professionals
305	Dustin Wantt Wantts Trucking
306	Shane Mintosh Humboldt Sawmill Company
307	Dani Johansen Leonardo Logging
308	Robert Edwards Humboldt Sawmill Company

From:	EnergyPlan2019@RedwoodEnergy.org
To:	Jim Hilton; EnergyPlan2019@RedwoodEnergy.org
Subject:	RE: No Biomass. Not clean.
Date:	Wednesday, October 16, 2019 10:24:32 AM

Thanks for your input, Jim. We'll add this to the public comments on our website. I hope you can make it to our biomass discussion on Friday! https://redwoodenergy.org/services/planning/
Cheers,
Nancy

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

From: Jim Hilton [redacted]
Sent: Wednesday, October 16, 2019 6:54 AM
To: EnergyPlan2019@RedwoodEnergy.org
Subject: No Biomass. Not clean.

Though burning sawmill leftovers makes some economic sense, it's not our responsibility to help them operate. Focus on energy storage with consistent 60 Hertz power. Thanks, Jim Hilton

From: EnergyPlan2019@RedwoodEnergy.org
Sent: Wednesday, October 16, 2019 10:22 AM
To: Parallelepiped; EnergyPlan2019@RedwoodEnergy.org
Subject: RE: Comment on CAPE

Follow Up Flag: Follow up
Flag Status: Flagged

Thank you for your comment, Lance. We will add it to our online collection.
Best,
Nancy

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

From: Parallelepiped [redacted]
Sent: Wednesday, October 16, 2019 12:34 AM
To: EnergyPlan2019@RedwoodEnergy.org
Subject: Comment on CAPE

Dear RCEA,

My name is Lance Nolen and I am a Humboldt County resident.

Please eliminate biomass as a power source within the next 2-3 years. Using this fuel causes air pollution that is harmful to the community. It also increases greenhouse gas emissions from Humboldt County.
Please replace it with solar energy.

Here is a link to a video by William Moomaw listing reasons that biomass is not carbon neutral:
https://www.eubioenergy.com/2015/11/20/bioenergy-is-not-carbon-neutral-says-ipcc-author-william-moomaw/

Regards,
L. Nolen

From:	Walt Paniak
To:	Lori Taketa
Subject:	Additional CAPE comment
Date:	Wednesday, October 16, 2019 10:32:49 AM
Attachments:	biomass FAQ v5.pdf

The attached article from the Center of Biological Diversity presents their argument against Biomass energy as a climate benefit in any reasonable future time frame.
Please add this as a CAPE comment list.

Walt

Frequently Asked Questions About Biomass Energy
Center for Biological Diversity

Q: Doesn't renewable energy, including biomass, reduce fossil fuel emissions?
A: "Renewable" doesn't mean "low-carbon." In fact, burning wood for electricity releases more CO_2 per megawatt of energy than burning coal, and far more CO_2 than burning natural gas. This is because wood is less energy-dense, and contains more moisture, than fossil fuels. Measured at the smokestack, replacing fossil fuels with biomass actually *increases* CO_2 emissions.[1]

Q: But isn't biomass combustion "carbon neutral"?
A: No. The climate can't tell the difference between "biogenic" and fossil CO_2.[2] And CO_2 from combustion of trees remains in the atmosphere—and warms the climate—for decades or even centuries, even if the trees eventually grow back. Multiple studies have shown that it can take a very long time for new biomass growth to recapture the carbon emitted by combustion, even where fossil fuel displacement is assumed, and even where "waste" materials like timber harvest residuals are used for fuel.[3] This is known as the "carbon debt" of bioenergy.

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[1] Typical CO_2 emission rates for facilities:

Gas combined cycle	883 lb CO_2/MWh
Gas steam turbine	1,218 lb CO_2/MWh
Coal steam turbine	2,086 lb/CO_2/MWh
Biomass steam turbine	3,029 lb CO_2/MWh

Sources: EIA, Electric Power Annual, 2009: Carbon Dioxide Uncontrolled Emission Factors. Efficiency values used to calculate emissions from fossil fuel facilities calculated using EIA heat rate data. (http://www.eia.gov/cneaf/electricity/epa/ epat5p4.html); biopower efficiency value is 24%, a standard industry value.

[2] *Center for Biological Diversity, et al. v. EPA*, 722 F.3d 401, 406 (D.C. Cir. 2013) ("In layman's terms, the atmosphere makes no distinction between carbon dioxide emitted by biogenic and fossil-fuel sources"); Science Advisory Board Review of EPA's Accounting Framework for Biogenic CO_2 Emissions from Stationary Sources 7 (Sept. 28, 2012) (hereafter "SAB Panel Report").

[3] *See, e.g.*, Stephen R. Mitchell, et al., *Carbon debt and carbon sequestration parity in forest bioenergy production*, Global Change Biology Bioenergy (2012), doi: 10.1111/j.1757-1707.2012.01173.x; Ernst-Detlef Schulze, et al., *Large-scale bioenergy from additional harvest of forest biomass is neither sustainable nor greenhouse gas neutral*, Global Change Biology Bioenergy (2012), doi: 10.1111/j.1757-1707.2012.01169.x at 1-2; Jon McKechnie, et al., *Forest Bioenergy or Forest Carbon? Assessing Trade-Offs in Greenhouse Gas Mitigation with Wood-Based Fuels*, 45 Environ. Sci. Technol. 789 (2011); Anna Repo, et al., *Indirect Carbon Dioxide Emissions from Producing Bioenergy from Forest Harvest Residues*, Global Change Biology Bioenergy (2010), doi: 10.1111/j.1757-1707.2010.01065.x; Manomet Center for Conservation Sciences, Massachusetts Biomass Sustainability and Carbon Policy Study: Report to the Commonwealth of Massachusetts Department of Energy Resources (2010); Giuliana Zanchi et al., The Upfront Carbon Debt of Bioenergy (Joanneum Research May 2010); M.

Climate scientists agree we need to reduce emissions dramatically in the short term and keep them down. Global greenhouse gas emissions must peak within the next few years and drop sharply thereafter in order to preserve a likely chance of keeping aggregate global warming below 2°C—a level at which serious impacts will still occur.[4] Yet the science shows this is precisely the time period during which bioenergy emissions released today may increase atmospheric CO_2 levels.

Policymakers cannot simply assume that "biogenic" CO_2 emissions have no effect on the climate. Rather, a full and scrupulously accurate life-cycle analysis is essential to understanding the greenhouse gas implications of burning biomass for energy.[5]

Q: Isn't biomass combustion carbon neutral so long as growth rates exceed harvest in the forest?

A: No. Some biomass proponents claim that emissions from harvest and combustion of trees are negated if the forest is growing at a faster rate than it is being harvested; put another way, the claim is that emissions need not be counted if the forest serves as a net carbon sink at the landscape level. The claim is inaccurate for two reasons. First, it ignores the effect of present logging on future carbon stocks. Second, any conclusions of carbon neutrality depend entirely—and even arbitrarily—on the forest area selected for analysis.

Harvest of live trees from the forest doesn't just reduce current standing carbon stocks. It also reduces the forest's future rate of carbon sequestration, and its future carbon storage capacity, by removing trees that otherwise would have continued to grow and remove CO_2 from the atmosphere.[6] Even if harvested biomass is substituted for fossil fuels, it can be decades or centuries before the harvested forest achieves the same CO_2 reductions that

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O'Hare et al, *Proper Accounting for Time Increases Crop-Based Biofuels' Greenhouse Gas Deficit Versus Petroleum*, Envtl. Res. Lett. (2009), doi:10.1088/1748-9326/4/2/024001.

[4] Joeri Rogelj, et al., *Emission Pathways Consistent with a 2° Global Temperature Limit*, 1 Nature Climate Change 413 (2011).

[5] *See generally* Timothy D. Searchinger, et al., *Fixing a Critical Climate Accounting Error*, 326 Science 527 (2009); see also Mitchell 2012, supra note 3 at 9 (concluding that management of forests for maximum carbon sequestration provides straightforward and predictable benefits, while managing forests for bioenergy production requires careful consideration to avoid a net release of carbon to the atmosphere).

[6] Bjart Holtsmark, *The outcome is in the assumptions: analyzing the effects on atmospheric CO_2 levels of increased use of bioenergy from forest biomass*, Global Change Biology Bioenergy (2012), doi: 10.1111/gcbb.12015 ("Taking into account that harvest usually takes place in stands that are still growing, the baseline scenario becomes important. . . . [T]he harvest scenario should be measured against a baseline scenario (with no harvest) in which the trees are still growing, thus capturing CO_2 from the atmosphere.").

could be achieved by leaving the forest unharvested (depending on harvest intensity, frequency, and forest characteristics).[7]

Moreover, because this approach depends entirely on the landscape scale chosen for analysis—that is, what forested "region" is assessed to determine whether it is growing more quickly than it is being cut—its results can be arbitrary, misleading, and easily manipulated. EPA proposed using this approach in its recent draft framework for biomass carbon accounting, but EPA's own case studies showed that the exact same biomass facility could be found to have entirely different atmospheric CO_2 impacts solely as a result of differences in the landscape scale chosen for analysis.[8] Recognizing the potential for arbitrary results and the need to evaluate the relationship between biomass facilities and surrounding forest landscapes in a more sophisticated manner, EPA's science advisors criticized this approach as a "central weakness" of the EPA framework—one lacking a sound scientific basis.[9]

Q: Don't the Intergovernmental Panel on Climate Change (IPCC), EPA, and California Air Resources Board all treat biomass as carbon neutral?
A: No. And declaring something neutral doesn't make it so.

Biomass proponents often assert that IPCC carbon accounting rules treat biomass emissions as carbon neutral, and that EPA has adopted this approach. This assertion is founded on a fundamental misinterpretation of IPCC carbon accounting guidelines.[10] The IPCC guidelines are intended to aid countries in preparing overall national emissions inventories. The guidelines divide each nation's economy into sectors, emissions from which are counted and reported accordingly. Unlike other emissions, bioenergy emissions could show up in either or both of two sectors—in the land use and forestry sector, where harvest takes place, or in the energy sector, where combustion takes place. In order to avoid double-counting these emissions, the IPCC guidelines simply assign them to the land use and forestry sector, and do not count them in the energy sector. But this does not

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[7] *See, e.g.*, Mitchell 2012, *supra* note 3; John L. Campbell, et al., *Can fuel-reduction treatments really increase forest carbon storage in the western US by reducing future fire emissions?* Front. Ecol. Env't (2011), doi:10.1890/110057; Tara Hudiburg, et al., *Regional carbon dioxide implications of forest bioenergy production*, Nature Climate Change (2011), doi: 10.1038/NCLIMATE1264; Searchinger 2009, *supra* note 5 at 528.
[8] EPA concluded that a wood-fired biomass energy facility in New Hampshire would be found to increase atmospheric CO_2 levels based on an assessment of New Hampshire's forests, but would be found to have no net effect on CO_2 levels based on an assessment of forests throughout the Northeast. U.S. EPA, Accounting Framework for Biogenic CO_2 Emissions from Stationary Sources 75 (Sept. 2011).
[9] *See* SAB Panel Report, supra note 2 at 2, 5-6, 17, 20, 27-29, 40.
[10] The scientific literature has repeatedly identified this error in interpreting IPCC guidance. *See, e.g.*, Miguel Brandão , et al., *Key issues and options in accounting for carbon sequestration and temporary storage in life cycle assessment and carbon footprinting*, 18 Int'l J. Life Cycle Assess. 230 (2013), doi:10.1007/s11367-012-0451-6; Repo 2010, *supra* note 3; Searchinger 2009, *supra* note 5.

mean the IPCC regards biomass combustion as carbon neutral. In fact, the IPCC's website specifically explains this is *not* the case.[11]

Nor does EPA share the view that the IPCC guidelines mandate treatment of biomass combustion as carbon neutral. Although statements to this effect appeared in some older versions of EPA's annual greenhouse gas inventory, those statements were removed beginning in 2011. EPA's draft biomass accounting framework, released in September 2011, explains in detail that the IPCC's guidance does not mean that biomass emissions are carbon neutral.[12] EPA's Science Advisory Panel agreed that "[a]pplication of the IPCC accounting approach is not conducive to considering the incremental effect of bioenergy on carbon emissions."[13] And even EPA's recent rule exempting biomass CO_2 emissions from Clean Air Act permitting requirements acknowledges that biogenic CO_2 may not be carbon neutral in all instances.[14] It is, therefore, entirely false to claim that EPA treats biomass as carbon neutral.

The California Air Resources Board ("CARB") has exempted emitters of biogenic CO_2 from compliance obligations under the state's cap-and-trade program for greenhouse gases.[15] CARB's rationale for the exemption seems to have been a preconceived notion—unsupported by any actual analysis—that biomass combustion is preferable to fossil fuels combustion.[16] If CARB does in fact believe that biomass combustion is automatically carbon neutral, its belief contradicts the published scientific literature, the IPCC's guidance, and current thinking at the EPA.

Q: Don't bioenergy power plants reduce greenhouse gases by displacing fossil-fired power plants?

A: Not necessarily. Policymakers often assume "renewable" energy facilities displace fossil fuel facilities on a one-to-one basis. However, studies show this isn't always the case. New "renewable" facilities often just add capacity to the system rather than displacing fossil-fired generation.[17] And although there's some debate in the scientific

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[11] IPCC, Frequently Asked Questions Q1-4-5 and Q2-10, at http://www.ipcc-nggip.iges.or.jp/faq/faq.html (last visited June 12, 2015).

[12] U.S. EPA 2011, *supra* note 8 at 11-12 ("The IPCC also eschewed any statements indicating that its decision to account for biomass CO_2 emissions in the Land-Use Sector rather than the Energy Sector was intended to signal that bioenergy truly has no impact on atmospheric CO_2 concentrations.")

[13] SAB Panel Report, *supra* note 9 at 3; see also id. at 4.

[14] Deferral for CO_2 Emissions from Bioenergy and Other Biogenic Sources Under the Prevention of Significant Deterioration (PSD) and Title V Programs, 76 Fed. Reg. 43,490, 43,498 (July 20, 2011).

[15] Cal. Code Regs., tit. 17, § 95852.2(a).

[16] Cal. Air Res. Bd., California's Cap-and-Trade Program: Final Statement of Reasons 416 (Oct. 2011).

[17] Richard York, *Do alternative energy sources displace fossil fuels?* 2 Nature Climate Change 441 (2012) (finding that non-hydropower renewables, including biomass, typically add capacity rather than displace fossil fuels).

literature about the appropriate "displacement factor" to use in evaluating bioenergy greenhouse gas emissions, an assumption of one-to-one displacement is most likely inaccurate.[18]

Q: What about burning waste wood for energy? Isn't that carbon neutral?
A: No. Calling wood "waste" doesn't tell you what effect burning it has on the atmosphere. "Waste" has no stable definition, and in practice is used to mean anything from slash left over from logging operations, to wood from urban demolition projects, to live, growing trees someone decided should be cut down for some reason.

Determining the atmospheric effect of burning any woody material—including so-called "waste"—requires figuring out what would have happened to the material otherwise. For example, slash and residual wood left over from a logging operation will eventually decompose, releasing at least some of the stored carbon to the atmosphere (though some fraction of the carbon may remain stored for a longer period in the forest soil). Different sizes and kinds of wood decompose at different rates; while smaller branches and stems may decompose in a few years, stumps and other large pieces of wood can take decades to break down.[19] Bioenergy production, in contrast, results in an immediate emission of CO_2 to the atmosphere. Accordingly, even burning this "waste" material incurs a carbon debt for at least the period of time that would have been required for the material to decompose naturally.[20] Recent studies also have shown that intensified removal of logging residues for bioenergy can release vast amounts of carbon stored in forest soils and damage future forest productivity.[21]

Q: Doesn't forest thinning reduce greenhouse gas emissions by preventing catastrophic forest fires, especially when the thinnings are burned for energy?
A: No. Two recently published studies of forests in the western United States suggest that emissions from removal and combustion of forest fuels may exceed emissions from even high-intensity fires, at least for some period of time.

The first study, led by John L. Campbell of Oregon State University, found "little credible evidence" that fuel reduction projects increased forest carbon stock. [22] Campbell identified several reasons for this. For example, the amount of carbon lost through fuels

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[18] Kim Pingoud, et al., *Global warming potential factors and warming payback time as climate indicators of forest biomass use,* Mitig. Adapt. Strateg. Glob. Change (2011), doi:0.1007/s11027-011-9331-9.
[19] Repo 2010, supra note 3.
[20] The SAB Panel Report highlighted the need for consideration of this delay in natural decomposition when accounting for emissions from burning forest-derived "waste" materials. SAB Panel Report, supra note 9 at 5.
[21] David L. Achat, et al., *Forest soil carbon is threatened by intensive biomass harvesting*, SCIENTIFIC REPORTS 5:15991 (2015), doi:10.1038/srep15991; D.L. Achat, et al., *Quantifying consequences of removing harvesting residues on forest soils and tree growth – A meta-analysis*, 348 FOREST ECOLOGY & MGMT. 124 (2015).
[22] Campbell 2011, supra note 7.

reduction projects tends to exceed the amount of carbon those fuel removal projects prevent from being emitted during a fire. This is partly because most fire-related emissions are associated with combustion of fine materials like branches and needles; because these materials tend to burn no matter how hot the fire, the difference in emissions between a high-intensity fire in an untreated stand and a low-intensity fire in a treated stand is not that great. It is not practical to "thin" branches and needles without also removing the trees to which they are attached. Campbell thus concluded that even in a fire-suppressed ponderosa pine forest, protecting one unit of carbon from combustion in a fire required removing three units of carbon in fuels. Moreover, because the probability of a fire on any given acre of forest is relatively low, forest managers must treat many more acres than will actually burn in order to get much of a benefit—again resulting in an increase in carbon removed relative to avoided combustion. Campbell also found that over a succession of disturbance cycles, models predicting forest growth, mortality, decomposition and combustion showed more carbon storage in a low-frequency, high-intensity fire regime than in a high-frequency, low-intensity fire regime. Only where disturbances caused a permanent change in forest productivity did Campbell find fuel treatments to have a profound influence on carbon storage.

Another Oregon State University researcher, Tara Hudiburg, led an investigation of forest carbon responses to three different levels of fuel reduction treatments in 19 West Coast ecoregions containing 80 different forest types and different fire regimes.[23] Hudiburg found that in nearly all forest types, intensive harvest for bioenergy production resulted in net carbon emissions to the atmosphere, at least over the 20-year time frame of the study. Only in forest ecoregions currently functioning as net carbon sources did bioenergy production result in decreased emissions. The positive carbon emissions of bioenergy persisted even in a lighter-touch fire prevention scenario in most ecoregions. The study acknowledged that if forests currently serving as carbon sinks were to become sources in the future, the effect of bioenergy production might be different—but at present, across a wide range of ecosystems, forest bioenergy increases carbon dioxide concentrations, at least in the short term.

Both papers recognize that forest managers may have important reasons for wanting to do certain thinning projects. Both papers also make clear, however, that these projects—whatever their merits from a forest management perspective—may have climatic consequences that should be taken into account.

For more information contact:
Kevin Bundy, Senior Attorney
Center for Biological Diversity
1212 Broadway, Suite 800
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(510) 844-7100 x313
kbundy@biologicaldiversity.org

[23] Hudiburg 2011, supra note 7.

From:	Walt Paniak
To:	Lori Taketa
Subject:	CAPE comment
Date:	Wednesday, October 16, 2019 12:34:29 PM
Attachments:	Letter to the Senate on carbon neutrality of forest biomass Woods Hole Researc 1.pdf

The attached letter speaks to biomass energy at the National level. However, I underlined one note that was significant. It is underlined in red on page 3 (depending on your software.) I will paraphrase , for the same area of land solar panel produce 80 times the energy of biomass power with no CO2. Please add this memo as a CAPE comment.

Walt

Letter to the Senate on carbon neutrality of forest biomass

POSTED ON FEBRUARY 24, 2016

The letter below was sent to 10 U.S. senators who are working on the Energy Policy Modernization Act. The Senate has accepted an amendment to the act which would legally designate forest biomass to be "carbon neutral." This means that U.S. Federal agencies would be required to assume that burning wood (instead of coal) to generate electricity emits no greenhouse gases to the atmosphere, even though this is not the case. As our letter states, it is never good to legislate scientific fact, and especially bad when those facts are wrong.

February 22, 2016

Dear Majority Leader Mitch McConnell, Minority Leader Harry Reid, Chairwoman Lisa Murkowski, and Ranking Member Maria Cantwell:

We are 65 research scientists and practitioners who study energy, soils, forested and wetland ecosystems and climate change. We are writing in our individual capacities to express our concern over the implications of a "forest biomass carbon neutrality" Senate Amendment 3140 to the Energy Policy Modernization Act that was recently accepted by the US Senate.

This well-intentioned legislation, which claims to address climate change, would in fact promote deforestation in the U.S. and elsewhere and make climate change much worse.

The amendment would require all federal departments and agencies to promote consistent policies that "reflect the carbon neutrality of forest bioenergy and recognize biomass as a renewable energy source." Mandating that there are no carbon dioxide emissions from burning wood from forests to produce energy does not make it so in fact.

The consequence of the amendment is to encourage a shift to forest biofuels in the form of pellets and wood chips to replace coal in the generation of electricity. Wood burning power plants are becoming more numerous in the United States and in the European Union. The US Department of Commerce and the US Forest Service are promoting expanded export of American wood pellets for this purpose to Europe and to Asia. Burning any carbon containing substance whether biomass or fossil fuels releases carbon dioxide into the atmosphere. Burning forest biomass to make electricity releases substantially more carbon dioxide per unit of electricity than does coal. Removing the carbon dioxide released from burning wood through new tree growth requires many decades to a century, and not all trees reach maturity because of drought, fire, insects or land use conversion. All the while the added carbon dioxide is in the atmosphere trapping heat. Right now, large areas of American forests including old growth trees are being cleared for pellets that are shipped to Europe and burned to produce electricity that is counted there as zero carbon. There is no requirement in the amendment that trees used for bioenergy be replaced. International obligations require the United States to account for bioenergy emissions from either the energy sector or as land-use change.

While forest biomass energy may be renewable over the long-term, it is not a low-carbon source of energy like solar panels. Using the same amount of land area, solar panels produce up to 80-times as much electricity as wood burning with no emissions at all. Yet with this amendment, both might receive the same subsidy under the Act. Furthermore, fossil fuel emissions associated with producing bioenergy (harvesting, chipping, drying, pelletizing and transporting) are equivalent to 20-25% of direct

emissions, and under this legislation these emissions are unaccounted for.
Forest bioenergy as currently produced also competes with land for other forest products including timber, paper and agriculture. Promoting forest biomass therefore encourages additional deforestation.

Granting carbon amnesty to forest biomass burning for energy could lead to significant depletion of US forests. The potential implications of declaring carbon neutrality for forest biofuels are great because even small quantities of bioenergy require large quantities of wood. The US Energy Information Agency estimates that for each 1% added to current US electricity production from forest biomass an additional 18% increase in US forest harvest is required. This policy would also encourage the destruction of forests in developing countries that would see the US as an export market. This would undermine international attempts to protect tropical forests in these countries through the programs agreed to in Paris.
This amendment puts forest carbon in the atmosphere contributing to climate change instead of keeping it in living, productive forests that provide multiple benefits of water and wetland protection, flood control, soils protection, wildlife habitat, improved air quality and recreational benefits for hunters and all who enjoy being in the great out-of-doors. Legislating scientific facts is never a good idea, but is especially bad when the "facts" are incorrect. We urge you and other members of the Senate to reconsider this well-intentioned legislation and eliminate the misrepresentation that forest bioenergy is carbon-neutral.

We respectfully request an opportunity to inform you and other Senators of the scientific evidence for the appropriate accounting of forest bioenergy emissions. You could perform a great service by proposing and enacting legislation that effectively addresses climate change by enhancing the capacity of forests to reduce the amount of carbon dioxide entering the atmosphere. Any number of us would be willing to testify or to assist you and your staff in meeting the climate challenge with scientifically sound actions.

Sincerely,

Philip B. Duffy, Ph.D. President and Executive Director Woods Hole Research Center pduffy@whrc.org 508-444-1504

Prof. Emeritus William R. Moomaw, Ph.D., Co-Director Global Development and Environment Institute, Tufts University william.moomaw@tufts.edu 617-335-3994

William Schlesinger, Ph.D., President Emeritus, Cary Institute schlesingerw@caryinstitute.org

cc Olivia Kurtz, Senator Collins' Energy legislative Council, James Springer, Senator King's Energy legislative Council, Anne Knapke, Senator Klobuchar's Energy legislative Council and Blaise Sheriden, Senator Franken's Legislative Council

Viney P. Aneja, Ph.D. Professor Air Quality Professor Environmental Technology North Carolina State University

Loretta Battaglia, Ph.D. Secretary General, Society of Wetland Scientists Associate Professor of Wetland Ecology Southern Illinois University

Mary S. Booth, Ph.D. Director Partnership for Policy Integrity

Jonah Busch, Ph.D. Senior Fellow, Center for Global Development Washington, DC.

Ken Caldeira, Ph.D. Senior Scientist Department of Global Ecology Carnegie Institution for Science

Eric Chivian, M.D. Founder and Former Director The Center for Health and the Global Environment Harvard Medical School

James Clark, Ph.D. Nicholas School of the Environment Duke University

Jeffrey Corbin, Ph.D. Associate Professor Union College

Eric A. Davidson, Ph.D. Professor and Director Appalachian Laboratory University of Maryland Center for Environmental Science

Steven J. Davis, Ph.D. Assistant Professor Dept. of Earth System Science University of California, Irvine

Saara J. DeWalt, Ph.D. Associate Professor Clemson University

David Foster, Ph.D. Director, Harvard Forest Harvard University

Peter Frumhoff, Ph.D. Director of Science and Policy Union of Concerned Scientists

James Galloway, Ph.D. Sidman P. Poole Professor Department of Environmental Sciences University of Virginia

Scott Goetz, Ph.D. Deputy Director and Senior Scientist Woods Hole Research Center

Mark E. Harmon, Ph.D. Richardson Chair and Professor Oregon State University

Sarah Hobbie, Ph.D. Professor, Department of Ecology, Evolution and Behavior University of Minnesota

Richard A. Houghton, Ph.D. Senior Scientist and George M. Woodwell Chair for Global Ecology Woods Hole Research Center

Robert M. Hughes, President, International Fisheries Section American Fisheries Society

Deborah Lawrence, Ph.D. Environmental Sciences University of Virginia

Gene E. Likens, Ph.D. Distinguished Research Professor University of Connecticut Special Advisor to the University President on Environmental Affairs Cary Institute of Ecosystem Studies Founding Director and President Emeritus

Richard N. Mack, Ph.D. Professor Emeritus School of Biological Sciences Washington State University

Jerry Melillo, Ph.D. Distinguished Scientist The Ecosystems Center Marine Biological laboratory

Susan Natali, Ph.D. Associate Scientist Woods Hole Research Center

James E. Perry, Ph.D., PWS Immediate Past President, Society of Wetland Scientists Professor of Marine Science Virginia Institute of Marine Science College of William and Mary

Jennifer Powers, Ph.D. Associate Professor Dept. of Ecology, Evolution, and Behavior University of Minnesota

Jonathan Sanderman, Ph.D. Associate Scientist Woods Hole Research Center

Herman H. Shugart, Ph.D. W.W. Corcoran Professor Department of Environmental Sciences University of Virginia

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(https://twitter.com/intent/tweet?source=https://whrc.org/letter-to-the-senate-on-carbon-neutrality/&text=Letter to the Senate on carbon neutrality of forest biomass)

(https://www.facebook.com/sharer/sharer.php?u=https://whrc.org/letter-to-the-senate-on-carbon-neutrality/)

(mailto:?subject=Letter to the Senate on carbon neutrality of forest biomass&body=The letter below was sent to 10 U.S. senators who are working on the Energy Policy Modernization Act. The

The Senate has accepted an amendment to the act which would legally designate forest biomass to be “carbon neutral.” This means that U.S. Federal agencies would be required to assume

that
burning
wood
(instead
of
coal)
to
[…]:https://whrc.org/letter-
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the-
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From: EnergyPlan2019@RedwoodEnergy.org
Sent: Thursday, October 17, 2019 12:57 PM
To: Gary Hughes; EnergyPlan2019@RedwoodEnergy.org
Cc: Estelle Fennell
Subject: RE: Comment for 'Forests, Energy and the Environment' workshop

Follow Up Flag: Follow up
Flag Status: Flagged

Thank you for your comments, Gary. We will include them with our public comments on our website and I will share them with the meeting moderator and presenters for consideration.

Kind regards,
Nancy

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

From: Gary Hughes [redacted]
Sent: Thursday, October 17, 2019 12:15 PM
To: EnergyPlan2019@RedwoodEnergy.org
Cc: Estelle Fennell <efennell@co.humboldt.ca.us>
Subject: Comment for 'Forests, Energy and the Environment' workshop

To whom it may concern:

This message contains comments for inclusion in the Redwood Coast Energy Authority hosted workshop on "Forests, Energy and the Environment."

As the California Policy Monitor with the small international organization Biofuelwatch I offer these comments by email due to my inability to attend the workshop in person tomorrow. It is greatly appreciated that this public workshop is being held to gather important public insight on a critical issue.

Let's start by making sure that forest ecology is front and center to any discussion about biomass energy on the North Coast in saying that Forest Debris Matters.

For the health and recovery of our forests it is not helpful to refer to forest debris as "waste." Forest debris is not waste, it is an essential part of restoring nutrient cycles to an industrially depleted forest.

The fact on the ground is that North Coast forests have been severely depleted by many decades of industrial economic activity. Seeing our forests as "feed stock" for industrial activity is at the heart of the cultural sickness that is resulting in the intensifying ecological degradation crisis we are confronting.

Sustainability remains elusive, as the Forest Stewardship Council certification is controversial world wide, including in the forests of Humboldt County, due to the evidenced failings of the standard to protect forests and the communities that depend on them. There are severe doubts as to the objectivity of the certifying body in reviewing and assessing the FSC model on the North Coast. FSC as a standard of sustainability is increasingly doubted in the eyes of the public.

Thus, because of the widespread reliance on the no longer trusted FSC brand, any assumptions about "sustainable forest management" on the North Coast must be questioned. In no way can it be assumed that mill waste and other coveted biomass material from industrial forestry operations is at all sustainably sourced, raising doubts about the sustainability of the biomass energy operations that rely on this mill waste and forest debris.

Unfortunately, biomass energy is classified as a "clean' and "renewable" source of energy. It is included in the California state Renewable Portfolio Standard, leading the Redwood Coast Energy Authority and PG&E to promote to their consumers the benefits of "renewable biomass energy."

Yet the hard evidence shows how wood-fired power plants are neither "clean" nor "carbon neutral" within a time frame relevant to responding effectively to climate change.

At the smoke stack, biomass-fueled power plants emit far more CO_2 per megawatt hour than fossil fueled plants.

Burning biomass for energy can increase atmospheric CO_2 concentrations for many decades, even if it displaces fossil fuels.

Intensive forest management for bioenergy represents a significant new demand that threatens forest resources, at a local level, a state level, a national level and increasingly at a global level.

Biomass-fueled power plants also emit conventional air pollutants that harm public health, including particulate matter. volatile organic compounds and nitrogen oxides, at levels comparable to fossil fuels.

Recognition of any potential emissions reductions associated with biomass always relies on accounting for activities not applied at and largely not under the control of that combustion source -- as in reality any claimed "reduction" in emissions from burning biomass depends on being offset by future forest regrowth, and such regrowth can take decades if not centuries, if it is that it ever occurs.

The science is clear: the utility-scale expansion of burning wood for electricity threatens our forests, our climate, and the health of communities. Discussions about how Humboldt County will be impacted by proposed utility-scale energy development must take these factual realities about dirty biomass energy into account.

Just because an energy source is called renewable does not actually mean it is harmless, or even sustainable.

Please take this information into account.

Our organization will continue to engage on these matters.

Thank you.

For our forests,
Gary

--
Gary Graham Hughes, M.Sc.
California Policy Monitor - Biofuelwatch
Email: [redacted]
Mobile: [redacted]
Twitter: [redacted]

From:	Information
To:	Trisha Lee; Information
Subject:	RE: Comments in regards to renewal energy sources
Date:	Thursday, October 17, 2019 9:44:13 AM

Thank you for your comment, Trisha. We will add it to our public comment collection.

For more information on the solar microgrid project we are building at the airport with Schatz Energy Research Center (it will be the largest solar array in Humboldt County), and other information about our projects and programs, please visit our website: https://redwoodenergy.org/community-choice-energy/about-community-choice/power-sources/airport-solar-microgrid/

Warm regards,
Nancy

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

From: Trisha Lee [redacted]
Sent: Thursday, October 17, 2019 1:07 AM
To: Information <info@redwoodenergy.org>
Subject: Comments in regards to renewal energy sources

General Manager:

In regards to the upcoming meeting regarding types of energy, I wanted to submit my brief comments:

Wood by-products are not sustainable. The Wind Energy program is going to cause a lot of destruction, difficulty shipping in blades, and after 20 years it will be obsolete, and we will be left with the mess.

Solar is the key, where people have sun. This invention below by Schatz Energy Research Center could be huge for us.

PGE lines need to all be put underground, starting in areas prone to fires.

See below for a new invention, I believe you should incorporate into our current energy system as a back up when electricity is shut down, and perhaps it can be expanded.

Sincerely,

Trisha Lotus

Microgrid Developed by Schatz Energy Research Center Saved Lives During Recent Power Outage

October 14, 2019 Kym Kemp 9 comments
http://kymkemp.com/2019/10/14/microgrid-developed-by-schatz-energy-research-center-saved-lives-during-recent-power-outage/

Cars wait in long gas line at Blue Lake Rancheria during the recent power outage. [Screenshot from video below]

Information from Humboldt State University:

> A groundbreaking microgrid developed to provide renewable power and energy resiliency for the Blue Lake Rancheria was put to the test during the recent statewide outage
>
> The Blue Lake Rancheria Tribe's main campus remained up and running when Humboldt County went dark, thanks to its fully integrated solar+storage microgrid developed by the Schatz Energy Research Center at Humboldt State. The Rancheria's gas station also stayed operational, running on a backup diesel generator that will be replaced later this fall by a second solar+ microgrid. Schatz played a leading role in the design and development of both microgrids, working in collaboration with the Rancheria and other project partners.
>
> The microgrid provided a safe, warm environment for local families to study and play, charge cell phones, and access the internet; supported a mobile office for Humboldt's daily newspaper, the Times-Standard; charged electric vehicles; and gave an electrical boost to municipal water and sewage systems. The gas station delivered fuel and other services for emergency response vehicles, government agencies, the Mad River Fish Hatchery, and thousands of community members.
>
> One of the greatest concerns during power outages is impacts on people whose medical needs require ongoing access to electricity. During the power shutoff, the Rancheria also housed eight people with acute medical needs in its hotel, by request of the County Department of Health and Human Services (DHHS). DHHS credited the Rancheria with saving their lives, due to their critical needs for power. Emergency diesel was also provided to United Indian Health Services to power the backup generators that keep perishable medicines cold.
>
> The Schatz Center's current microgrid projects include installation of final components, testing, and commissioning of the solar+ system at the Blue Lake Rancheria's gas station — which will be operational this fall — and development of the Redwood Coast Airport microgrid for deployment in 2021.

“As we prepare to deploy new microgrids currently under development for the North Coast and beyond, it’s good to see our first commissioned microgrid successfully delivering critical services for our region,” says Schatz Outreach Coordinator Maia Cheli.

From: Walter Paniak
To: Lori Taketa
Subject: CAPE comment regarding Environmental Health
Date: Thursday, October 17, 2019 1:08:30 PM
Attachments: ijerph-12-08542.pdf
ijerph-12-08542.pdf

The attached article discusses environmental health at biomass plants. The elementary school in Scotia is about 850 to 900 feet away. I feel that the negative effects of the various pollutants would harm small children. Except for planned maintenance these plants run 24/7.

--

Walt Paniak

Int. J. Environ. Res. Public Health **2015**, *12*, 8542-8605; doi:10.3390/ijerph120708542

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Review

Potential Occupational Exposures and Health Risks Associated with Biomass-Based Power Generation

Annette C. Rohr [1,*], Sharan L. Campleman [2], Christopher M. Long [3], Michael K. Peterson [3], Susan Weatherstone [4], Will Quick [4] and Ari Lewis [3]

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Academic Editor: Paul B. Tchounwou

Received: 1 April 2015 / Accepted: 14 July 2015 / Published: 22 July 2015

Abstract: Biomass is increasingly being used for power generation; however, assessment of potential occupational health and safety (OH&S) concerns related to usage of biomass fuels in combustion-based generation remains limited. We reviewed the available literature on known and potential OH&S issues associated with biomass-based fuel usage for electricity generation at the utility scale. We considered three potential exposure scenarios—pre-combustion exposure to material associated with the fuel, exposure to combustion products, and post-combustion exposure to ash and residues. Testing of dust, fungal and bacterial levels at two power stations was also undertaken. Results indicated that dust concentrations within biomass plants can be extremely variable, with peak levels in some areas exceeding occupational exposure limits for wood dust and general inhalable dust. Fungal spore types, identified as common environmental species, were higher than in outdoor air. Our review suggests that pre-combustion risks, including bioaerosols and biogenic organics, should be considered further. Combustion and post-combustion risks appear similar to current fossil-based combustion. In light of limited available information, additional studies at power plants utilizing a variety of technologies and biomass fuels are recommended.

Keywords: biomass; occupational health; bioaerosols; particles; combustion

---

1. Introduction

Biomass-fueled power generation will contribute to reaching international targets for renewable production of electricity and related greenhouse gas emissions reductions through new construction or re-powering of existing coal-fired units [1]. Biomass combustors, common in small scale, industrial boiler, or cogeneration (heat/power) applications, have now been developed for electricity generation at a larger utility scale (over 50 megawatts (MW) thermal input) [2]. As with other solid fuel power plants, facilities using biomass as the primary combustion source can provide a reliable source for base load, cycling, and on-demand situations. However, as with any emerging or scaled-up technology, evaluation of environmental and occupational health impacts requires an understanding of the properties and characteristics of the fuel, as well as consideration of plant design, fuel processing, handling and storage [3].

In the case of occupational health and safety (OH&S), biomass combustion may result in several unique worker exposures relative to petroleum or coal-based fuels. These differences may be due both to the combustion process itself and the introduction of new occupational tasks related to biomass handling, storage and processing. Though extensive data from utility-scale operations are limited, occupational information can be gleaned from small-scale biomass technologies or related industries, such as waste handling and forestry [4,5]. This review focuses on the potential for occupational exposure and related health risks specific to biomass-based electricity generation, primarily for direct-fired, stand-alone technologies. It should, however, be noted that other biomass energy conversion processes, such as co-firing with coal, gasification, pyrolysis and anaerobic digestion have similar OH&S issues around biomass handling and, where available, experiences from these systems have been drawn upon. This review does not discuss the potential for health effects at the population level due to ambient emissions, or residential in-home exposures due to wood or other biomass burning (see [6] for a good review of this topic).

For the most part, it is possible to separate processes at power plants into three groups: pre-combustion (handling, storage, fuel preparation), combustion (including flue gas treatment), and post-combustion (ash and by-product handling). Each of these groups has its own inherent OH&S issues and hence this review follows a similar categorization. Following a discussion of the literature, testing results for dust, fungal and bacterial levels at two power stations are presented.

2. Summary of Available Technologies and Fuel Types

Combustion technologies used (or proposed) for modern biomass-fueled, direct-fired power plants vary by design, fuel flexibility, and environmental considerations. As such, the degree and type of emissions control technologies required to meet any required emission limits for pollutants of regulatory concern also influence OH&S issues. Biomass varies substantially in composition and fuel characteristics, so some combustion technologies may be more suitable than others for a particular biomass feedstock, depending on factors such as availability, composition and moisture content. The combination of fuel and boiler type chosen establishes the relative combustion efficiency, temperature range, and other combustion characteristics that influence the quantities, types and chemical composition of the solid waste to be handled post-combustion (ash and air pollution control residues). These factors, along with influences such as local pollution control regulations, also govern the choice of control technologies and ultimately the relative risks associated with worker exposure to potentially hazardous substances from combustion and post-combustion handling processes [2,3,7,8]. In direct-fired, 100% biomass combustion for power generation, combustion within a given boiler produces high-pressure steam for driving a turbine [9]. Table 1 provides a summary of the major types of stand-alone, direct-fired biomass technologies; the two most common combustion boiler types for dedicated biomass combustion are generally of a stoker (grate) or fluidized bed design. Table 2 provides a summary of available emission control technologies and related environmental exposures of potential concern for these two common designs; it should be noted, however, that not all technologies can be used with all biomass fuels.

In addition to these stand-alone technologies, a number of large (up to 660 MWe) pulverized coal units in Europe have recently been converted to combust 100% biomass, although this type of boiler is not generally considered the most suitable for a new build biomass plant due to the high level of biomass pre-processing required (such as drying and pelletizing).

A wide variety of biomass fuels are in current use for electricity generation. These include agricultural residues, such as straw, olive cake, and palm kernels, wood chip and wood residues, and specially grown "energy crops" such as miscanthus and switchgrass. The choice of the fuel (or mixture of fuels) used in a particular boiler depends on a number of factors, including availability of sufficient quantities (taking into account seasonality), fuel quality, potential negative impacts on the boiler, and price. In some countries, the definition of biomass also includes waste materials such as sewage sludge and post-consumer wood (including panel products such as particleboard). Levels of contaminants such as heavy metals can be significantly higher in these waste materials than for "clean" biomass types (e.g., see the Phyllis2 database [10]. As a result, their use is often subject to tighter regulatory controls. For example, the EU's Industrial Emissions Directive includes emission limits for biomass combustion in the same section as fossil fuels, but plants using demolition wood must meet the stricter waste incineration limits [11].

Table 1. Summary of available large-scale, standalone biomass combustion technologies for electricity generation.

Direct Fired Technology	Common Fuel Types	Biomass Feed Size (cm)	Moisture Content (%)	Generation Capacity (MW)
Pile burners	Wood or agricultural residues (excl. wood flour)	Limited by grate size and feed opening	<65	4 to 110
- with underfire stoker	Sawdust, select bark (“non-stringy”), shavings, chips, “hog” fuel	0.6–5	10–30	4 to 110
Stoker grate boilers	Sawdust, select bark (“non-stringy”), shavings, end cuts, chips, “hog” fuel, sander dust	0.6–5	10–50	4 to 300
Suspension boilers				
- Cyclonic	Sawdust, select bark (“non-stringy”), shavings, wood flour, sander dust	<0.6	<15	<30
- Air spreader-stoker	Wood flour, sander dust, processed sawdust, shavings	0.1–0.15	<20	1.5 to 30
Fluidized-bed combustor	Low alkali fuels: wood residues or peat	<5	<60	Up to 300
- with underfire stoker	Sawdust, select bark (“non-stringy”), shavings, chips, “hog” fuel	0.6–5	10–30	4 to 110
- with underfire stoker	Sawdust, select bark (“non-stringy”), shavings, chips, “hog” fuel			

Summarized from [2] and [12].

Table 2. Substances of significance for health and corresponding emission control options for stoker or fluidized bed boilers.

Air Pollution Control or Environmental Target	Emission Control Options	
	Stoker Boiler	**Fluidized Bed Boiler**
Typical post-combustion air pollution control	PM—Cyclones, ESP, FF NOx—SNCR, SCR (only applicable for low alkali fuels) CO—oxidation catalysis SOx/HCl—IDSIS, SDA, DS (with FF), FGDw	PM—ESP and FF NOx—SNCR, SCR (only applicable for low alkali fuels) CO—generally absent SOx/HCl—In furnace injection, IDSIS, SDA, DS, FGDd (with FF)
Low sulfur oxide (SOx) combustion	Not possible (in furnace)	Some reduction possible through limestone addition to bed material
Low NOx combustion	Air staging	Generally low inherent NOx (due to lower temperature), air staging, flue gas recirculation
Low CO formation	Difficult (lower combustion efficiency)	Generally low due to higher combustion efficiency

Summarized from: [2,7,8,13]; CO = Carbon Monoxide; DS = Dry sorbent; ESP = Electrostatic Precipitator; FF = Fabric Filter or Baghouse; FGDd = Dry Flue Gas Desulfurization; FGDw = Wet Flue Gas Desulfurization; HCl = Hydrogen Chloride; IDSIS = In Duct Sorbent Injection System; NOx = Nitrogen Oxides; PM = Particulate Matter; SCR = Selective Catalytic Reduction; SDA = Spray Dryer Absorber; SNCR = Selective Non-Catalytic Reduction; SOx = Sulfur dioxide.

3. Potential Occupational Exposures

Evaluating potential occupational exposures at biomass-fueled power generation facilities is complicated not only by the wide variety (and mixtures) of fuel types, but also by the variety of facility designs and lack of detailed exposure monitoring data reported in the literature. The focus of this section is on exposures associated with fuels used at these facilities (pre-combustion, stack emissions, and post-combustion), as opposed to other secondary occupational exposures (*i.e.*, forklift/truck traffic, diesel generators, *etc.*). Evaluation of a biomass feedstock generally includes analyses for energy content, fuel properties (including moisture and ash content), and major fuel elements (carbon, hydrogen, nitrogen, sulfur, chlorine) [14], as well as more minor components capable of influencing plant operations, including the main mineral components of the ash and levels of heavy metals [15,16]. These physiochemical properties also influence the type of emissions (air, water and solids), environmental impacts, and plant control requirements. Just as the availability and type of the source fuel(s) influences the ability to design, site, and operate a large-scale biomass combustion plant [17], it also determines the nature of the operational waste streams and the associated potential for worker exposure. As with other combustion-based power plants, biomass-fueled facilities produces emissions to air and water, as well as solid byproducts such as ash and pollution control residues.

Due to the limited data regarding occupational biomass exposures in the power generation sector, potential worker exposures—particularly those unique to biomass *versus* other fuels—are described from similar occupational exposures as needed, such as wood pellet or other biomass waste management. Exposed populations of interest are identified, and relevant exposure sources and routes are discussed. The section also identifies substances of significance to health (SSHs) at these facilities, and further discuss SSHs that may have different exposure profiles than at traditional fossil fuel power generation facilities.

3.1. Overview of Exposure Sources and Routes

In general, three primary sources of exposure should be considered for an occupational risk assessment of a biomass-fueled generation facility: the biomass fuel itself (pre-combustion), biomass combustion emissions (usually associated with the boiler or stack), and exposure to the resulting ash residue (post-combustion). Some exposures may be common to multiple stages. For example, workers may be exposed to gaseous pollutants and particulate matter (PM) generated from biomass handling, transport, storage, and agitation, as well as from post-combustion ash. Numbers of workers and their typical tasks vary between installations, but a basic overview is provided in Table 3.

The inherent physiochemical characteristics, including the amount of cellulose, hemicelluloses, and volatile organics, in common biomass sources such as straw, wood pellets and chips, may be expected to influence pre-combustion exposures. As well as dust from the material itself, biomass may contain an inhalable bioaerosol component, comprised of microorganisms and endotoxins [18]; these materials may be released during industrial handling [19–21]. In general, exposure levels in wood handling industries differ substantially by the type and size of biomass, by temperature and humidity, and by the specific task (e.g., transport, shredding, agitation) [20]. Primary exposure routes are likely to be through inhalation of particulate, bioaerosols and volatile compounds and dermal contact, although there is also the risk of mechanical irritation of the eyes. Ingestion is a less likely route of exposure, although contamination of welfare areas with biomass may be an issue in some cases where controls are inadequate.

For onsite personnel, the primary exposure route is likely to be associated with the pre-combustion release of PM, bioaerosols, and volatile organics from the biomass during storage and handling operations. Although combustion of biomass produces pollutant gases and PM, exposure to these is considered to be a risk mainly at the very small scale (such as in domestic heating and cooking); at the utility scale, plant design and control should minimize the risk of worker exposure to combustion products.

For some plant workers, there is also the potential for exposure to post combustion products, particularly ash. Different combustion technologies produce ash with differing characteristics, which are further modified by emissions control systems. At the utility scale, it is usual for different ashes to be handled separately, with streams labeled as "bottom ash" and "fly ash" most commonplace. The bottom ash, removed from the bottom of the boiler, is primarily composed of relatively unreactive, high melting point materials such as aluminosilicates; with fluidized bed boilers there is also a contribution from the bed material (often sand), as well as any limestone used for acid gas control. In contrast, the fly ash consists of those inorganic components that have volatilized in the furnace before condensing as the gas cools, as well as fine non-volatile ash that has become entrained in the flue gas before being collected in control devices such as filters and electrostatic precipitators (ESPs). Many of the volatile trace elements contained in the fuel are concentrated in this fly ash. Where dry sorbents are added to the flue gas for pollutant control (e.g., lime for acid gas abatement or activated carbon for heavy metal control), these are also removed with the fly ash. Some plants may have multiple ash capture stages to reduce the proportion of the ash contaminated with air pollution control sorbents.

Although it may be assumed that the highest risk of exposure to ash is among those personnel involved in its handling and storage, there are other groups of workers who may also be at risk. Where ash handling systems are not fully enclosed, airborne ash releases may affect all personnel, while those workers working on repair and maintenance within the boiler are likely to be exposed to ash in the form of furnace deposits. It should be noted that these boiler deposits could have different chemical characteristics to the bulk ash; for example, they could be enriched in those metals that preferentially condense into the deposit at particular furnace temperatures [22]. While potential exposure to ash should be limited by process controls (such as enclosure of handling systems) wherever possible, with Personal Protective Equipment (PPE) used by workers to reduce any residual risk, the efficiency of these controls can vary widely. The effectiveness of PPE in particular is heavily influenced by factors including training, proper fit (a particular issue with respiratory protection), safety culture, management enforcement, and workers' own perception of risk. Exposure routes of interest for ash include inhalation and dermal contact during transfer and transport processes, with incidental ingestion of ash or dust comparatively less important. Biomass ash can also be highly alkaline, presenting a risk of irritation and corrosiveness due to pH alone, particularly in contact with skin and eyes.

3.2. Substances of Significance to Health

3.2.1. Pre-Combustion Exposures

Pre-combustion exposure to biomass materials is influenced by the unique physiochemical properties of the fuel. A limited number of European studies have reported ambient PM concentrations within facilities associated with biomass combustion, processing or handling; these have often focused on bioaerosols, including bacteria, fungi, endotoxin, and other related markers [4,5,23–25]. There has also been significant interest in exposure to gaseous species, mainly carbon monoxide (following a number of fatal incidents during transport and storage of wood pellets), but also volatile organics [26–30]. In general, these studies have focused on area monitoring or overall personnel exposure assessment, with minimal or no worker task specification. Table 4 summarizes the SSHs identified from the literature for biomass handling, processing (e.g., wood pellets), and storage at either biomass power facilities or related industries such as wood pellet production.

3.2.2. Combustion-Related Exposures

The major combustion SSHs emitted from biomass-fueled power generation facilities are similar to those from traditional fossil fuel generation facilities. Concentrations of these substances in the flue gas can be influenced by factors such as fuel chemical composition, boiler design, pollutant control systems, and combustion conditions, and so can vary considerably between different facilities. In addition to criteria pollutants such as PM, carbon monoxide (CO), sulfur oxides (SOx), and nitrogen oxides (NOx), a number of different volatile organic compounds (acrolein, aldehydes) and some associated persistent semi-volatile compounds (PAHs, dioxins/furans) may also be present, although data regarding their presence—and more especially their concentrations—in the flue gas are often limited. Emitted PM also contains mineral and metal species. The US EPA AP-42 guidance does provide emission factors for a large number of organic species from wood residue combustion in boilers; these factors were last updated in 2001 [31]. The boilers which have provided the data used to generate these factors are generally industrial-scale rather than utility-scale units, being primarily used to utilize residues from wood processing facilities and pulp mills. In many cases, emission factors presented are derived from only one or two measurements. Where there are multiple measurements available, the range of values often spans several orders of magnitude. As a result, these factors may not reflect current practice at the utility scale, particularly in terms of boiler design (most tests were undertaken on stoker or Dutch Oven-type boilers) and flue gas clean up. Non-woody biomass fuels are not considered in AP-42, with the exception of a limited amount of data provided for bagasse use in sugar mills. It should be noted that as the size of the installation increases, there is greater scope for optimization of the combustion system, improving efficiency and reducing air emissions associated with poor combustion. In many countries, there are also legally mandated emission limits on major pollutants to air for plants over a specified thermal input, and these limits often decrease as plant size increases (see for example [11]). The controls required to meet the limits for major pollutants often also provide a co-benefit removal of minor species (for example, systems for sulfur oxide reduction can also reduce other acidic gases) [13]. Emission rates (per unit of output) for large-scale generation plants can therefore be significantly lower than for smaller industrial units. Table 5 provides a summary of the types of substances that may be of interest to occupational health in this industry; however, it should be noted that many of these substances are associated with combustion processes in general, not biomass combustion specifically.

Although few quantitative data on SSHs at biomass combustion facilities exist, a number of studies provide information on the relative stack emissions at biomass facilities compared to traditional fossil-fueled facilities. For example, biomass fuels generally have lower levels of mercury and sulfur than coal, and thus mass emissions of SOx and mercury from these facilities would likely be lower (assuming similar control technologies) [32]. Chlorine levels in biomass are more variable, but for wood (the most common biomass fuel used for large-scale generation) chlorine content is typically very low, which may lead to low emissions of chlorinated dioxins and furans. However, on the other hand, the heterogeneous nature of biofuels (as compared to coal) might lead to less efficient combustion and possibly the formation of proportionately more of these chemicals for the same chlorine content in the two fuels [32–34]. Emissions of PM and NOx depends on the levels of ash and nitrogen in the fuel, the combustion system, and the emissions control technologies used. At the utility scale it could be expected that PM and NOx emissions would be lower than for coal combustion (except for those coal plants fitted with selective catalytic reduction systems for NO_x), but higher than for light oil or natural gas combustion [5,36].

While the types of SSHs emitted are fairly well understood, there are very few data on concentrations that might be relevant to assessing occupational risks *versus* concentrations related to ambient releases. The design and operation of modern biofuel plant is such that the probability of release of flue gas into the plant itself should be low, and therefore assessment of risk of worker exposure to combustion products based on composition of stack emissions is likely to overestimate risk.

3.2.3. Post-Combustion Related Exposures

The majority of inorganic material associated with the biomass fuel is recovered from the boiler as ash. As the composition of mineral matter in different biomass fuel varies, so does the ash, with additional variability introduced by the use of non-fuel materials, such as sand or other minerals, as the bed material in fluidized bed boilers, along with the use of sorbents for flue gas treatment. In large-scale boilers, multiple ash streams are often produced with different chemical properties. For example, in fluidized bed boilers the bottom, or bed, ash consists of a mixture of fuel ash, bed material, and coarse contaminants of biomass (such as stones). Certain volatile elements, including sulfur, chlorine, alkali metals, and some heavy metals, are depleted in the bottom ash, as the temperatures in the boiler are sufficient to vaporize them and they exit the boiler in the flue gas. In contrast, the fly ash (or filter ash) consists of material fine enough to be carried by the flue gas and can be enriched in the volatile elements as they condense out onto the ash as the flue gas cools.

Table 3. Typical power plant tasks and exposures.

Job Type	Tasks	Potential Exposures
Trucker	Transport of biomass to site (road/rail) Loading and discharge of material Transport of ash	Biomass dust and bioaerosols generated during biomass loading and discharge Ash dust generated during loading and discharge Diesel exhaust from vehicles
Fuel Handling Plant operative	Transport of biomass through the site Storage of biomass Fuel preparation (milling *etc.*)	Biomass dust and bioaerosols generated during biomass handling and milling Off-gases from storage Direct contact with moldy biomass
Cleaner	Removal of dust deposits from plant	Generation of airborne biomass dust, bioaerosols and ash through disturbance of deposits Potential for direct contact with moldy biomass
Maintenance engineer	Maintenance of plant equipment during normal operation	Generation of airborne biomass dust, bioaerosols and ash through disturbance of deposits Potential for exposure to combustion gases
Outage contractor	Repair of plant items during shutdown periods (particularly within the boiler)	Generation of airborne biomass dust, bioaerosols and ash through disturbance of deposits Direct contact with ash deposits within the boiler (often confined spaces)
Ash handling plant operative	Removal of ash from the boiler Transport to storage	Direct contact with ash
Other plant personnel	Various	Fugitive dusts from fuel and ash handling plants Combustion gases

Table 4. Identified substances of significance to health (SSHs): pre-combustion.

SSH Class	COI	Source	Industry	Reference(s)
Particulate Matter	Wood dust	Raw or processed material Straw, wood chips, pellets	Forestry Wood pellet production Biomass generation Biomass laboratory	[25,37–40]
Bioaerosols	Microbial (Fungi/Bacteria)	Component of PM Wood chips or pellets	Biomass power generation Fuel processing and handling	[23,40–43]
	Endotoxin	Component of PM Straw, grain, hay, organic waste	Biomass power generation	[21]
Volatile Organics (VOCs)	Aldehydes Total VOCs	Off gassing from sawdust Auto-oxidation of unsaturated fatty acids	Wood pellet production	[5,26]
Organics	Monoterpenes Resin acids	Components of PM, off gassing from sawdust	Wood pellet production Forestry, milling	[5,26,44]
Inorganic Gases	Carbon monoxide	Off gassing from raw materials	Wood pellet production, transport, storage	[28–30]

Table 5. Identified substances of significance for health (SSHs) and potential health effects: combustion and post-combustion.

SSH Class	SSH	Source	Refs	Health Effects Associated with Exposure Route		Refs
				Inhalation	Dermal/Eye	
Inorganic Gases	Carbon monoxide	Combustion	[45]	CNS; Miscarriage; Carboxylhemoglobinemia		[45,46]
	Nitrogen oxides	Combustion	[45]	URT and LRT	Irritation (Skin and Eye)	[45,48]
	Sulfur oxides	Combustion	[46]	Pulmonary function; LRT		[45,49]
	Acid aerosols (e.g., H_2SO_4)	Combustion	[47]	Pulmonary function	Irritation (Skin and Eye)	[45,49]
Hydrocarbons	1,3-Butadiene	Combustion	[45]	CNS; Stomach, Respiratory and Hematolymphopoietic Cancers		[45,50]
	n-Hexane	Combustion	[45]	CNS; Peripheral Neuropathy	Irritation (Eye)	[45]
	PAHs [a]	Combustion, Ash	[45,48,49]	Lung Cancer	Skin Cancer *	[51]
	Benzene	Combustion	[45]	Leukemia; Anemia; CNS		[45,52]
	Styrene	Combustion	[45]	CNS		[45]
Oxygenated organics	Acrolein	Combustion	[45]	URT; Pulmonary edema; Pulmonary emphysema	Irritation (Skin and Eye)	[45]
	Formaldehyde	Combustion	[45]	URT; Nose Cancer *	Irritation (Skin and Eye)	[45,53]
	Methanol	Combustion	[45]	CNS; URT	Eye Damage	[45,54]
	Acetic acid	Combustion	[45]	URT; Pulmonary function	Irritation (Eye)	[45]
	Catechol	Combustion	[45]	URT	Dermatitis; Irritation (Eye)	[45]
	Cresol (methylphenols)	Combustion	[45]	URT; Kidney; Liver	Skin Damage	[45,55]
	Hydroquinone	Combustion	[45]	CNS	Irritation (Eye)	[45,56]
	Fluorenone	Combustion	[45]	URT	Irritation (Eye)	[57]
	Anthraquinone	Combustion	[45]	Respiratory	Irritation (Skin and Eye)	[58]
Chlorinated organics [b]	Methylene chloride	Combustion	[45]	CNS; Peripheral Neuropathy; Liver and Lung Cancer *	Irritation (Skin and Eye)	[59,60]
	Methyl chloride	Combustion	[45]	CNS; Liver; Kidney; CNS *; Testicular *; Teratogenic *		[45,61]
	Dioxins/furans	Combustion	[45,48]	URT; Chloracne; Liver; Glucose metabolism	Chloracne	[62,63]
Particulate matter (PM)	PM_{10}	Combustion/ Condensation	[45]	Pulmonary function; URT	Irritation (Eye)	[64]
	$PM_{2.5}$	Combustion/ Condensation	[45]	Pulmonary function; URT	Irritation (Eye)	[22]
Inorganics	Aluminum (Al) [c]	Combustion	[45]	Pneumoconiosis; LRT		[45,66]
	Arsenic (As) [e]	Ash	[48,49]	URT and LRT; Lung Cancer		[45,67]
	Beryllium (Be) [d]	Ash	[48]	Beryllium disease;	Irritation (Skin)	[45,68, 69]
	Cobalt (Co) [d,e]	Ash	[48]	Pulmonary function; Myocardial effects		[45,70]

Table 5. *Cont.*

SSH Class	SSH	Source	Refs	Health Effects Associated with Exposure Route		Refs
				Inhalation	Dermal/Eye	
	Magnesium (Mg) [d]	Combustion	[45]	URT; Pulmonary function; Metal fume fever	Irritation (Eye)	[71]
	Iron (Fe) [d]	Combustion	[45,49]	Pneumoconiosis; URT	Irritation (Skin and Eye)	[45,72]
	Manganese (Mn) [f]	Combustion	[45]	Neurobehavioral		[73,74]
	Zinc (Zn) [h]	Combustion	[45,49]	Metal fume fever; LRT and URT	Irritation (Skin and Eye)	[45,75,76]
	Nickel (Ni) [d]	Combustion, Ash	[45,48, 49]	Pneumoconiosis; Nasal and Lung Cancer	Dermatitis	[45,77,78]
	Copper (Cu) [d]	Combustion	[45,49]	URT; Metal fume fever	Irritation (Eye)	[45,79]
	Lead (Pb) [f,g,h,i]	Combustion	[45,49]	CNS and PNS; Hematologic; Nephropathy		[45,80]
	Mercury (Hg) [d,f]	Ash	[48]	CNS and PNS; Kidney		[45,81]
	Chromium (Cr) [d]	Combustion, Ash	[45,48, 49]	Pulmonary function; Lung Cancer	Irritation (Skin)	[45,82]
	Cadmium (Cd) [d,i]	Combustion	[45]	Pulmonary function; Kidney		[45,83,84]
	Quartz	Ash	[48]	Pulmonary fibrosis; Chronic silicosis; Lung cancer *		[45,85]

CNS—central nervous system; LRT—lower respiratory tract; PNS—peripheral nervous system; URT—upper respiratory tract; * Endpoints derived from animal studies; [a] Oral exposure—Animal bioassays positive for reproductive/developmental effects and stomach cancer; [b] Assumes chlorine in fuel; [c] Oral exposure—Animal bioassay positive neurotoxicity; [d] Oral exposure—Human gastrointestinal toxic effects observed for Be, Co, Mg, Fe, Ni, Cu, Hg, Cr, Cd; [e] Oral exposure—Human skin toxicity observed for As (and cancer) and Co; [f] Oral exposure—Human CNS effects observed for Mn and Pb; [g] Oral exposure—Human PNS effects observed for Pb; [h] Oral exposure—Human hematologic effects observed for Zn and Pb; [i] Oral exposure—Human kidney toxicity observed for Pb and Cd.

Two studies provide information on levels of SSHs in biomass boiler room dust (likely to consist of a mixture of pre-combustion and post-combustion material), and others have reported qualitative aspects of exposure. Cohn *et al.* [23] reported levels of PAHs and selected trace metals in three dust samples collected from the boiler room at a straw-burning biomass generation facility in Denmark (Table 6). Madsen and Sharma [18] performed an analysis on a single sample of dust collected in the boiler room of a straw-fueled biomass plant and found that the primary inorganic elements present were potassium, calcium, and sodium. Other elements included aluminum, magnesium, iron, manganese, phosphorus, zinc, nickel, copper, lead, chromium, and cadmium (Table 6). Although different analytes were targeted in each study, the overlapping analyzed components were roughly similar with respect to concentration, with the exception of nickel, which was higher in the Madsen and Sharma study than the Cohn *et al.* study. It should be noted that the number of samples was extremely low in both studies, limiting interpretability of the findings.

Table 6. SSHs in biomass power generation boiler room dust.

SSH	Madsen *et al.* [18] $N = 1$ Concentration (ppm)	Cohn *et al.* [23] $N = 3$ Concentration Range (ppm)
K	303,154	−
Ca	53,061	−
Na	44,266	−
Al	6789	−
Mg	5892	−
Fe	16,434	8100–28,000
Mn	361	−
P	1890	−
Zn	1770	1050–15,700
Ni	568	30–125
Cu	530	300–525
Pb	127	115–150
Cr	38	20–50
Cd	5	−
Li	−	4.8–15
As	−	5–15
PAH	−	145–880

− not analyzed.

4. Potential Occupational Risks

The potential occupational health impacts of biomass combustion in power generation remain poorly defined, and as a result, there is limited guidance available to inform monitoring and health surveillance best practice guidance. The following section classifies potential occupational risks related to biomass into pre-combustion, combustion, and post-combustion categories. Because of the limited availability of sector-specific studies, information from related industries, uncontrolled combustion, or ambient-focused studies is utilized. Unfortunately, these studies cannot be relied upon to provide specific information related to occupational scenarios using controlled generation technologies, but can serve as a guide for future worker health and safety research.

4.1. Pre-Combustion Risks

In combination with the sparse information regarding exposures of biomass-based generation workers, a lack of epidemiologic studies limits the ability to establish potential associations or speculate on the role of biomass in any potential adverse health effects in workers. However, ancillary data from related industries can help to define constituents of potential concern for future study.

4.1.1. Bioaerosols

A number of case studies have associated occupational health effects with exposure to microorganisms in wood chip dust. Exposure to fungi from stored chipped wood used for heating has been linked to respiratory allergies and hypersensitivity pneumonitis [41–43,86]. In the wood-processing industry, dose-response relationships have been reported between endotoxin levels and respiratory symptoms [87], with significantly higher prevalence of respiratory symptoms such as cough and chronic bronchitis among woodworkers than in the control group. However, the microbial content of fuel biomass used in large-scale power generation has not been extensively reported, making it difficult to extrapolate to potential exposure levels of concern. Cases of extrinsic allergic alveolitis (EAA) have been identified in connection with the use of wood chips for heating. van Assendelft *et al.* [42] reported that EAA was associated with endotoxins for *Penicillium* in two farmers, the first of whom used green pine and alder chips, and the second who used birch, osier, and alder woods. Both cases reported respiratory symptoms and malaise after handling wood chips. Furthermore, in the second case levels of molds, including *Penicillium* and *Aspergillus*, were high on the surface of the wood chip, despite the storage area being cleaned and no visible signs of mold growth in the material. EEA was also diagnosed in the case of a maintenance worker in a sawmill which processed spruce and Douglas fir woods [88]. Immunological testing suggested sensitization of the worker to *Trichoderma konigii*, exposure to which was believed to be associated with the use of damp logs in the sawmill.

Ławniezek-Wałczyk *et al.* [89] reported the results of bioaerosol sampling at a coal-fired power plant that was also co-firing sunflower seed pellets and wood chips. Analysis of samples collected from nine plant locations plus an outdoor reference location with MAS ($N = 4$ per location) and Andersen six-stage ($N = 20$) impactors showed that both bacterial and fungal spore levels were significantly higher within the plant than the reference case (all t-test p values < 0.05). Levels of airborne bacterial spores varied from 5.1×10^2 cfu/m^3 to 2.0×10^4 cfu/m^3 while fungal spore levels varied between 2.2×10^2 cfu/m^3 and 2.3×10^4 cfu/m^3. Levels were highest in the areas around the conveyor system, particularly where the biomass was in free-fall, such as during conveyor loading and transfer. Species analysis showed that fungal types included *Aspergillus* species (including *A. fumigatus*), *Mucor* spp., *Penicillium* spp., *Rhizopus stolnifer*, and a number of yeasts. Gram-negative rods identified included *Citrobacter* spp., *Pseudomonas* spp. (including *P. aeruginosa*, which can cause severe lung and urinary tract infections), and *Rahnella aquatilis*, while various Gram-positive *Bacillus*, *Micrococcus* and *Staphylococcus* species and thermophilic and mesophilic actinomycetes were also identified. The Polish Ministry of Health [90] classifies nine of the species identified as a "group 2" infection risk. Analysis of fresh samples of the biomass types used at the plant showed a similar mix of genus types, although the number of species identified was smaller.

Madsen *et al.* [25] examined the levels of different microbial indicators, including bacteria, actinomycetes, fungi, lipopolysaccharide, endotoxin, and muramic acid for various biomass stock (straw, wood chips, wood pellets, and wood briquettes) handling on a small pilot scale (particulate generated via rotating drum). Both the microbial content and overall "dustiness" varied by fuel type, analytical method, and biochemical indicator. Overall, straw generated more respirable particles (both by number and mass), total bacteria, and endotoxin *versus* wood chips, pellets or briquettes. Not unexpectedly, moisture content influenced particle generation, with higher moisture decreasing overall particle release. However, wood chips generated as much or more respirable PM than straw during initial handling (e.g., early generation rate in rotating drum test). By comparison, wood pellets and briquettes (both processed biomass stock) generated the lowest amount of microbial components, potentially indicating that non-microbial particles may be a greater concern for this type of biofuel. The densification process usually requires heat, and sometimes steam, decreasing the inherent microbial content of the material, while the low moisture content of the product (<10% is typical; higher moisture levels cause pellets to swell and break up into dust and so are avoided) limits its suitability as a growth medium for opportunistic microorganisms. However, these fuels may be prone to break-up during transport and handling, particularly if this involves multiple stages as in the case in large-scale supply, potentially releasing fine dust.

A follow-up study measured fungi, bacteria, actinomycetes, endotoxin, and *n*-acetyl-beta-D-glucoaminidase at five Danish biomass-fueled plants (straw and/or wood chips) at different seasonal time points [20]. Both personal worker and stationary area monitors were utilized to determine inhalable bioaerosols for an approximately 5- to 7-h window in fuel areas (e.g., storage), non-fuel areas (e.g., offices), and outdoors (e.g., local background). In total, 32 personal exposure measurements and 108 area samples were taken across the five plants over four days of monitoring (two in spring, two in autumn). Personal levels were converted to a time-weighted average (TWA). In summary, the authors considered levels of endotoxin (median personal exposure 55 EU/m^3), bacteria (4.8×10^5 cells/m^3) thermophilic actinomycetes (1.3×10^4 cfu/m^3), and fungi (2.1×10^5 spores/m^3) to be high at all five biomass-fueled plants. As with the laboratory tests, the highest levels of endotoxin exposure were associated with straw (although *Aspergillus fumigatus* levels were highest at the wood chip plant). Work related to the straw shredder produced levels up to 119,000 EU·m^{-3}. For perspective, this is orders of magnitude higher than the levels reported by Zock *et al.* [91] to affect lung function in potato processing workers (53 EU·m^{-3}). In these Danish plants, 34% of workers handling straw or wood chips had exposure levels above 150 EU·m^{-3}, and the overall median personal exposure of 55 EU·m^{-3} was higher than that observed by Rongo *et al.* [92] in small-scale wood industries. Levels of bacteria and fungi were also high in this study. For example, in 81% of study workers, personal exposures to mesophilic fungi were higher than levels previously reported to be associated with eye, nose and respiratory irritation (>10^4 colony forming units (cfu) per m^3) [93]. These levels are higher than previously reported in the wood processing [87] and milling [4] industries.

In further work, levels of fungal and bacterial components in PM_1 were analyzed in samples taken from 14 Danish biofuel plants principally utilizing straw [95]. *N*-acetyl-β-D-glucosaminidase and (1→3)-β-D-glucans, both associated with fungi, were found in all PM_1 samples ($N = 29$) at higher concentrations than in total dust, while cultivatable fungal spores were present in 6 of the samples and thermophilic actinomycetes in 23. Some research suggests a relationship between (1→3)-β-D-glucan and airway inflammation [96]. Few occupational exposure limits exist for bioaerosols, although the Dutch Expert Committee on Occupational Safety has recommended a health-based limit for endotoxin of 90 EU/m^3 [97]. Recommended reference values of 1.0×10^5 cfu/m^3 for bacteria and 5×10^4 cfu/m^3 for fungi in industrial settings where organic dusts are present have also been proposed [89]. Eduard [93] identified a lowest observed effect level (LOEL) for diverse fungal species of 10^5 spores/m^3 in non-sensitized populations; however, for asthmatic patients with pre-existing allergy to *Penicillium* sp. or *Alternaria alternate*, LOELs to the sensitizing agent of 1×10^4 spores/m^3 and 2×10^4 spores/m^3 respectively were identified for reduced airway conductance.

Wouters *et al.* [98] reported on results from personal monitoring of workers for exposure to dust, endotoxin, and (1→3)-β-D-glucan in both waste management and power generation industries. Four power plants were studied; one was a dedicated wood pellet boiler, while the other three co-fired a number of different biomass types with coal. A wood pellet manufacturer was also included in the study.

Large variations in exposure were observed both between and within worker tasks. The highest average exposures to inhalable dust, (1→3)-β-D-glucan, and endotoxin occurred during wood pellet production (9.6 mg/m^3 inhalable dust, 12.07 μg/m^3 glucan and 200 EU/m^3), but exposures of up to 2104 EU/m^3 and 290.9 μg/m^3 glucan were seen in the power plants. Average levels of endotoxin and glucan were lower in the co-firing plants than in the dedicated biomass plant (26.1 EU/m^3 *vs.* 32 EU/m^3 and 2.1 μg/m^3 *vs.* 8.4 μg/m^3 glucan) but inhalable dust levels were higher (1.3 mg/m^3 *vs.* 0.48 mg/m^3).

Madsen *et al.* [99] reported a significant inflammatory response among mice exposed to airborne dust collected from either a combined straw-feeding/boiler room (termed the "boiler room") or a combined straw-receiving/storage hall (termed the "straw storage hall"). Mice were exposed via intratracheal instillation to either a single dose of dust (18 or 54 μg) from either the boiler room or straw storage hall, or four doses (each 54 μg) on consecutive days. The greatest inflammatory responses were observed in the mice exposed to dust from the straw storage hall, including 30 to 60-fold elevations in mRNA expression in lung tissue for interleukin-6 (IL-6), monocyte chemoattractant protein-1 (MCP-1), and macrophage inflammatory protein-2 (MIP-2) compared to controls. Levels of mRNA for these cytokines were increased about 10-fold in mice exposed to dust from the boiler room. The study authors hypothesized that the inflammatory response was linked with microbial components in the dust, which were generally present at higher concentrations in the dust from the straw storage hall than from the boiler room. Importantly, the study reported a lack of significant increases in DNA strand breaks in bronchoalveolar lavage (BAL) samples, and thus no evidence of DNA damage, for either dust type. Madsen *et al.* [99] cautioned that "more data are needed for an understanding of how the data should be interpreted in a comprehensive risk assessment of exposure at biofuel plants."

Cohn *et al.* [23] characterized PM components from source biomass (straw and wood pellets), including microbial components and mutagenic activity, from area-level particle samples at the same Danish plant. PM generated via agitation from the source material (pre-combustion) was larger in diameter than PM collected within the facility from the straw storage hall and the boiler room, the latter of which likely included post-combustion ash. Particle diameter ranged from 3.5–5 μm for pure straw biomass, 5.0–7.5 μm for wood pellet samples, and 0.77–0.97 μm for samples from the area of the biomass facility. A large portion of the biomass facility PM was of respirable size, but less so for the raw samples (30%–58% *vs.* 98%). A number of different factors were identified as potential contributors to this difference, including the greater distance from source to measurement in the biomass plant allowing the larger particles to sediment and the presence of combustion PM from biomass and vehicle emissions. PM generated from the raw biomass differed from facility biomass in terms of composition, reactivity (generation of reactive oxygen species), and mutagenicity (Salmonella mutagenicity assay). Specifically, biomass facility PM samples were higher in metal content, polyaromatic hydrocarbons, reactivity potential, thermophilic bacteria (actinomycetes), fungi (*A. fumigatus*) and mutagenic activity, as compared to source-specific biomass generated PM. However, facility samples were collected using a high throughput area sampler potentially contaminated with additional exposure sources (e.g., diesel fumes or other vehicular emissions, welding fumes, *etc.*). As reported by Madsen [20], facility area samples related to straw handling or storage did have high levels of fungal spores and endotoxin, again raising concerns that high pre-combustion exposure may put workers at risk for irritation or inflammatory responses [100,101].

A recent published report from Denmark [102] investigated bioaerosol exposure levels in relation to respiratory symptom and asthma prevalence at a straw and wood chip-fueled power plant. The worker population was compared to a similar occupational group at a more conventional fuel facility. No increased prevalence of pneumonitis symptoms was observed among the biomass facility workers; however, higher asthma symptoms were reported among non-smokers exposed to straw (OR 7.6, 95% C.I. 1.4–12.8) and to lesser extent wood chips. A logistical data analysis reported increased asthma symptoms and work-related respiratory symptoms related to increased endotoxin exposure (OR 1.5, 95% C.I. 1.1–44.4). No statistical associations with endotoxin exposure were observed for rhinitis, conjunctivitis, current asthma, coughing, flu-like symptoms, or diarrhea. Similar associations appeared to be related to fungal exposure. No associations were found between lung function indices and bioaerosol exposure indicators. Albeit a cross-sectional study which lacks the ability to demonstrate causality, this first study adds to the knowledge of exposure methodology, measured levels of bioaerosols, and respiratory symptoms in an industry-specific cohort.

4.1.2. Wood Dust

Wood dust has been recognized as an irritant, sensitizer, respiratory toxicant, and, for a limited number of species, a potential carcinogen [103,104]. The UK Government's Health and Safety Executive (UK HSE) has also issued guidance on the health risks associated with particular species, as shown in Table 7 [105]; this information was targeted primarily at the wood-working industry and so contains a large number of "unusual" woods, but some species also have relevance in the biomass power generation industry. Mandatory or recommended OELs have been established in a number of regions, including Europe, Canada, and the United States, based on either total inhalable or respirable wood dust, with some authorities specifying lower limits for some wood groups, based on their carcinogenic or allergenic potential, as shown in Table 8 [106,107]. Although the current European Union OEL for hardwood dust is 5 mg/m^3 of inhalable dust, the EU's Scientific Committee for OELs has reported that exposure to wood dust at levels of 0.5 mg/m^3 can induce measurable health effects in the human respiratory system [108]. In a small Swedish study, worker exposure to wood dust ranged from 0.16 to 19 mg/m^3 (total dust) in a wood pelleting facility, with levels varying across the processing facility [26]. Many of the levels observed were higher than the concurrent Swedish OEL and some studies in other Swedish woodworking industries [103,109]. In a more detailed follow up study by Hagstrom *et al.* [5,24], 35% of inhalable dust samples were above the Swedish OEL. Additionally, larger variation existed between shifts *versus* between workers, indicating that day-to-day temporal variation was higher than inter-individual worker variability.

Table 7. Reported health effects associated with wood species (adapted from [105]). Species in bold are known to be in current use as biomass fuels.

Wood Name	Classification	Reported Health Effects
Abura/bahia	Hardwood	vomiting
Afrormosia	Hardwood	skin irritation, splinters go septic, nervous system effects
Afzelia/doussie	Hardwood	dermatitis, sneezing
Agba/tola	Hardwood	skin irritation
Alder	Hardwood	dermatitis, rhinitis, bronchial effects
Andiroba/crabwood	Hardwood	sneezing, eye irritation
Ash	Hardwood	decrease in lung function
Avodire	Hardwood	dermatitis, nose bleeds
Ayan/movingui	Hardwood	dermatitis
Basralocus/angelique	Hardwood	general unspecific effects
Beech	Hardwood	dermatitis, decrease in lung function, eye irritation (possibly from bark lichens)
Birch	Hardwood	dermatitis on sawing lumber
Bubinga	Hardwood	dermatitis, skin lesions possible
Cedar of Lebanon	Softwood	respiratory disorders, rhinitis
Cedar (Cent/S American)	Hardwood	allergic contact dermatitis
Cedar (Western Red)	Softwood	asthma, rhinitis, dermatitis, mucous membrane irritation, central nervous system effects
Chestnut (sweet)	Hardwood	dermatitis (possibly from bark lichens)
Douglas fir	Softwood	dermatitis, splinters go septic, rhinitis, bronchial effects
Ebony	Hardwood	mucous membrane irritation, dermatitis, possibly a skin sensitizer
Freijo/cordia	Hardwood	possibly a skin sensitizer
Gaboon/okoume	Hardwood	asthma, cough, eye irritation, dermal effects (hands, eyelids)
Gedu nohor/edinam	Hardwood	dermatitis (rare)
Greenheart	Hardwood	splinters go septic, cardiac and intestinal disorders, severe throat irritation
Guarea	Hardwood	skin and mucous membrane irritation
Gum (southern blue)	Hardwood	dermatitis
Hemlock (western)	Softwood	bronchial effects, rhinitis
Idigbo	Hardwood	possible irritant
Iroko	Hardwood	asthma, dermatitis, nettle rash
Larch	Softwood	nettle rash, dermatitis (possibly from bark lichens)
Limba	Hardwood	splinters go septic, nettle rash, nose and gum bleeding, decrease in lung function
Mahogany	Hardwood	dermatitis, respiratory disorders, mucous membrane irritation
Makore	Softwood	dermatitis, mucous membrane and respiratory tract irritation, central nervous system and blood effects
Mansonia	Hardwood	splinters go septic, skin sensitization, irritation, respiratory disorders, nose bleeds, headache, cardiac disorders
Maple	Hardwood	decrease in lung function
Meranti/lauan (various)	Softwood	skin irritation
Oak (various)	Hardwood	asthma, sneezing, eye irritation
Obeche	Softwood	skin and respiratory tract irritation, nettle rash, dermatitis (handling articles), feverish, sneezing, wheezing

Table 7. *Cont.*

Wood Name	Classification	Reported Health Effects
Opepe	Hardwood	dermatitis, mucous membrane irritation, central nervous system effects (e.g., giddiness, visual effects), nose bleeds and blood spitting
Padauk	Hardwood	species-dependent: itching, eye irritation, vomiting, swelling (e.g., eyelids)
Peroba	Hardwood	skin and mucous membrane irritation, systemic effects (e.g., headache, nausea, stomach cramp, weakness), blisters
Pine (many species)	Softwood	skin irritation (may cause photosensitization) decrease in lung function
Poplar	Hardwood	sneezing, eye irritation, may cause blisters
Ramin	Hardwood	dermatitis (possibly from bark)
Rosewood (many species)	Hardwood	dermatitis, respiratory disorders. Effects may arise from handling wood
Sapele	Hardwood	skin irritation
Spruce (several species)	Softwood	respiratory disorders, possible photosensitization
Teak	Hardwood	dermatitis (potent, even after seasoning), nettle rash, respiratory disorders
Utile	Hardwood	skin irritation
Walnut (not African)	Hardwood	sneezing, rhinitis, dermatitis from nut shells and roots
Wenge	Hardwood	splinters go septic, dermatitis, central nervous system effects (e.g., giddiness, drowsiness, visual disturbance), abdominal cramps
Whitewood (American)	Hardwood	dermatitis

The link between wood dust exposure and nasal cancer has been explored in a number of studies, led by Macbeth [110] and Acheson *et al.* [111], with a number of studies in the 1980s and 1990s providing evidence of a relationship between wood dust and sinonasal adenocarcinoma (e.g., [112–117]). In 1995, IARC issued guidance that “there is sufficient evidence in humans for the carcinogenicity of wood dust”, with a clear association between adenocarcinoma of the nasal cavities and paranasal sinuses and exposure to hardwood dust [104]. A link with softwood dust is less clear. Identification of specific wood species implicated is problematic, since most of the research has been based on the lumber and furniture making industries, where exposure to a variety of tree species is likely. In Germany, dusts from beech and oak have been classified as carcinogenic since 1985 [118]. Links between wood dust exposure and other cancers are less conclusive, although studies have also indicated higher rates of lung, nasal cavity, nasopharynx, larynx, and prostate cancers with exposure to wood dust, particularly hardwood dusts [117,119–121].

Table 8. Occupational exposure limits (legal and recommended) for biomass-relevant substances in various countries.

Country/Region	**Dust Type**	**Limits mg/m^3**	**Additional comments**	**Health Endpoint/Comments**
		Short-term (15 min)	**Long-term (8 h. Time Weighted Average)**	
		Wood dusts		
US (OSHA)	Particulate not otherwise regulated (includes wood dust)—inhalable—respirable		15 5	Throat, skin, eye irritation, upper respiratory problems
US (NIOSH recommended)	Wood dust		1	Pulmonary Function, Carcinogen
European Union (applies to all member countries)	Hardwood (inhalable fraction)		5	Carcinogenic, sensitizer
UK	Softwood (inhalable fraction)		5	Sensitizer
Australia	Hardwood		1	
Australia	Softwood		5	
Ontario, Canada	Certain hardwoods such as beech and oak		1	
Ontario, Canada	Softwood	10	5	
Sweden	Inhalable non-impregnated wood dust		2	Carcinogen
Sweden	Impregnated wood		0.05	Applies if levels of impregnating substances (with their own OELs) are unknown
Australia	Softwood	10	5	Sensitizer
Australia	Certain hardwoods such as beech and oak		1	Sensitizer
Germany	Respirable wood dust		2	Selected species identified as carcinogenic and/or sensitizing

Table 8. *Cont.*

Country/Region	**Dust Type**	**Limits mg/m³ Short-term (15 min)**	**Additional comments Long-term (8 h. Time Weighted Average)**	**Health Endpoint/Comments**
Russia	Wood dust		6	Maximum allowable concentration, sensitizer, fibrogenic action
US (OSHA/California)	Wood dust, all soft and hard woods except Western red cedar	10	5	
US (OSHA/California)	Wood dust, Western red cedar		2.5	
		Other biomass dusts		
US (OSHA)	Grain dust (oat, wheat, barley)		10	
UK	Grain dust (inhalable fraction)		10	Sensitizer
		Trace metals in biomass ash		
UK	Cadmium and Cadmium compounds (as Cd)		0.025	Carcinogenic (selected compounds)
UK	Cobalt and Cobalt compounds (as Co)		0.1	Carcinogenic (selected compounds), sensitizer
UK	Manganese and inorganic manganese compounds (as Mn)		0.5	
US (OSHA)	Cadmium dust	0.5	0.2	
US (OSHA)	Cobalt metal, dust, and fume (as Co)		0.1	
US (OSHA/California)	Cadmium		0.005	
US (California)	Manganese and compounds, as Mn		0.2	
US (OSHA/California)	Cobalt metal, dust, and fume (as Co)		0.02	

The association between exposure to wood dust and asthma symptoms was reported in the 1940s [122] and has repeatedly been identified since (e.g., [123–126]). A meta-analysis of the data by Pérez-Rios *et al.* [127] suggested that exposure to wood dust could increase the risk of work-related asthma by 50%. In a number of these studies, sensitization to specific wood species has been identified. In the De Zotti and Gubian study [123], bronchial provocation tests identified obeche, chestnut, acacia, and iroko woods as being likely to cause asthma symptoms in four cases, while oak, beech, and pine woods triggered rhinitis in three cases. Positive responses to respiratory provocation and skin challenge tests and specific IgE antibodies to ash wood were found by Fernández-Rivas [124] in the case of a furniture factory worker suffering rhinitis and asthma symptoms. In the UK, physicians report cases of occupational asthma to the SWORD database [128], with estimates given for the number of diagnoses linked to different potential causative agents. Between 1998 and 2012, wood dust was ranked as the third most common causative agent in terms of the average number of cases of occupational asthma linked to exposure reported each year (15 cases), behind isocyanates (49 cases) and flour (29 cases). Note that incidence rates are not reported for individual causative agents. As these data rely on both a positive diagnosis of occupational asthma and identification of the causative agent by a respiratory specialist, these figures may be underestimated.

4.1.3. Volatile Organic Compounds (VOCs)

Monoterpenes, such as α-pinene, β-pinene, and Δ^3-carene, are derived from biomass and may be of concern due to their ability to irritate eyes, skin, and mucous membranes [26,109]. The previously mentioned small study among Swedish wood pellet workers (5) reported personal exposures to monoterpenes in the range of 0.64 to 28 mg/m^3, below the Swedish occupational exposure limit of 150 mg/m^3 (total or individual monoterpene, 8-h TWA. However, intercompany variation appeared to be substantial, potentially due to variable moisture content or wood type. The correlation between wood dust and monoterpenes was moderate (0.44). A related concern has been raised regarding oxidization of monoterpenes to form both particle- and gas-phase reaction products that may induce respiratory effects [129].

In the Swedish wood pellet production study [5] measurements also included resin acids, α-pinene, and total VOCs. Resin acids ranged from <0.33–10 μg/m3 and α-pinene from <0.23–25 mg/m3 (β-pinene and Δ3-carene were below detection limits for the majority of samples). Workers were exposed to multiple resin acids; although no OELs exist for these compounds, exposure in other industries to colophony (a resin-containing compound also known as rosin, and used in soldering flux, adhesives, and polishes among other products) has been associated with occupational asthma and contact dermatitis [130]. The correlation between total dust and resin acids was moderate. Monoterpene levels varied by location and relative age of the raw material, with newer raw material associated with higher measurements. The VOC analysis identified a range of compounds including terpenes, C6-C11 aldehydes (e.g., hexanal, heptanal and nonanal), and other hydrocarbons (e.g., ethylacetate, propionic acid, 1-pentanol, and 2-butanone), all of which have been identified as irritant chemicals [131].

Svedberg et al. [28] investigated levels of a number of organic gases during storage at three pellet production plants, both in warehouses containing pellets and in domestic storage rooms. The principle organic compounds identified at two of the warehouses were aldehydes (50%–60% w/w), acetone (30%–40% w/w), and methanol (10% w/w) (the third warehouse had an ambient temperature of −10 °C and levels were below detection limits). In one warehouse, a peak aldehyde reading of 457 mg/m3 was recorded at the surface of the pellet pile, with hexanal (70%–80%wt) and pentanal (10%–15%wt) predominating. Auto-oxidation of fatty acids in the wood was proposed as the mechanism of formation of these compounds, the rate of which increases with temperature. Hexanal and carbon monoxide were also present in the emissions from pine lumber drying at these plants. Human exposure studies indicate that hexanal concentrations of 10 ppm are sufficient to invoke symptoms of mild irritation [132].

4.1.4. Carbon Monoxide (CO)

Carbon monoxide exposure, such as that which could occur in confined or enclosed spaces where wood pellets are stored or transported, has resulted in accidents and fatalities [28,133]. In the Hagstorm *et al.* study [5], all CO levels remained below 1.6 mg/m^3. In an earlier Swedish report, air sampling in one warehouse containing freshly produced wood pellets showed CO levels of 54 mg/m^3 at the ceiling [28]. In 2012, Gauthier *et al.* reviewed the deaths of two people, one in Germany in 2010 and the other in Switzerland in 2011, both of which were linked to CO exposure in storage rooms of multi-household wood pellet heating systems [30]. These systems consist of an airtight storage room (filled pneumatically from the outside) which feeds a boiler supplying hot water to the surrounding houses. In normal operation, the storage room is not entered—both casualties were investigating faults in the pellet handling system at the time. In the Swiss case, CO measurements of 7500 ppm were recorded several days after the event, with 2 h of ventilation only reducing this to 2000 ppm (note the system guidelines recommended 15 min of ventilation prior to accessing the storage area). Subsequent experiments confirmed that the CO was likely generated from the wood pellets rather than a fault in the combustion system, and that the area was also likely to be oxygen deficient. A third fatality was reported in Ireland after a householder entered his 7-ton capacity pellet storage room [134]. Two deaths in different wood pellet silos have been reported in Finland [30]. Ship holds appear to be particularly susceptible to the buildup of lethal levels of CO, coupled with oxygen depletion, with six deaths during wood pellet transport and at least three during transport of other woody materials reported since 2002 [27–30,135]. This is most likely due to the gradual decomposition of biomass and release of CO and CO_2 [136]. High oxygen and temperature can accelerate this process [27].

Emissions from off-gassing have also been recorded during storage of non-pelletized wood material. He et al. [137] stored logging residues in sealed containers at 15 °C and 35 °C. At 35 °C, after 10 days, oxygen levels in the headspace of the containers had decreased to near-zero, while CO2 was present at 13.8%, CO at 0.16%, and CH4 at 0.15%. Also detected in the headspace were numerous volatile organic compounds (total concentration 85 ppm), including alcohols, aldehydes, acids, acetone, benzene, ethers, esters, and terpenes. High product turnover, good ventilation and high oxygen levels may be expected to decrease the likelihood of off gassing [27]; however, at biomass-fueled generation facilities a number of different storage systems are in use, and so the effectiveness of these cannot be guaranteed. Biomass may also be stored for significant periods of time, e.g., during an unplanned shutdown, which increases the risk of off-gas accumulation.

4.2. Combustion-Associated Risks

Occupational studies focusing on the potential health risks posed by exposures to biomass combustion products at large scale biomass power plants are lacking, with minimal data on potential SSHs and their exposure levels relative to facility, worker tasks, working environment, and biofuel stock. Because there remains uncertainty regarding the specific components, concentrations, and related nature of the health risks posed by specific biomass combustion products from modern power plants, this section must rely on identifying the potential for adverse OH&S effects based on data from other biomass exposures scenarios, including poorly- or uncontrolled biomass combustion such as wildfires. However, given the greater degree of control over both combustion quality and specific pollutants as well as the high level of dispersion from the stacks of utility scale power plants, data from these less-controlled sources should be considered worst-case. Although occupational exposure of power plant workers to combustion gases is expected to be low during normal operation, self-heating and spontaneous combustion of stored biomass (due to biological and chemical oxidation reactions) is a recognized issue in many industries, including the power sector [9]. Under these situations, there is a risk of worker exposure to products from incomplete biomass combustion and smoldering. However, the frequency of such exposures is expected to be low and the size of the affected population limited.

4.2.1. Health Effect Studies of Relevance and Uncertainties in the Available Studies

A wide range of literature exists on exposure to smoke from residential wood burning, prescribed burning, and wildfires, as well as resultant health effects (see reviews by e.g., [6,138,139]). Therefore, this section relies on data from these alternate combustion technologies (e.g., small domestic woodburning appliances such as woodstoves, wood log boilers, and fireplaces, and also forest and brush fires) to explore the potential health risks posed by the occupational exposure to biomass combustion products within commercial biomass power plants.

It is important to emphasize the large uncertainties associated with the consideration of health effects data from these studies. Major factors leading to differences in occupational exposures at power plants *versus* uncontrolled ambient exposures include variability in the composition and physicochemical properties of the combustion gases from biomass, and thus the potential toxicity of the mixture, based on biomass fuel type and properties, boiler type, and combustion conditions. In particular, the completeness of the combustion process is a key determinant of the levels and composition of biomass emissions [140]. In general, concentrations of CO, VOCs such as acrolein, formaldehyde, and benzene, gaseous and particulate PAHs, and other organic species are enriched in emissions from incomplete biomass combustion [141]. With incomplete combustion, particle emissions are dominated by condensable organic particles, soot, and char [33]. In contrast, large-scale boilers, representative of a modern biomass-fueled power plants, generally operate under more controlled and stable combustion conditions that favor quasi-complete combustion [33,138]. Under such optimal combustion conditions, organic carbon content of particle emissions can be negligible, and inorganic ash can dominate particle emissions [33,140]. Combustion conditions are more variable in domestic wood-burning appliances such as woodstoves and fireplaces, typically yielding emissions rich in both soot and organic carbon particles and containing lesser amounts of inorganic ash [140]. Incomplete combustion, and thus emissions dominated by organic carbon particles and hydrocarbons, appear more prevalent for prescribed burning and wildfire events where low temperatures and smoldering conditions prevail [140,142].

Another source of information on the impact of biomass combustion on health is research on household biomass combustion for heating and cooking purposes in developing countries. These studies illustrate the significant public health burden of indoor biomass combustion in these populations, including an estimated 1 to 2 million premature deaths per year due to chronic obstructive pulmonary disease (COPD), acute and chronic respiratory disease, tuberculosis, and lung cancer [6]. Given that unvented stoves continue to have widespread usage in developing countries, often discharging emissions directly into the living space, such exposures and related health risks for these biomass combustion scenarios are unlikely to reflect occupational exposure at electricity-generating biofuel power plants. Therefore, particularly large uncertainties exist regarding the relevance of health effects findings from studies either based on wildfires or prescribed agricultural or wild land burning or from studies of the effects of indoor household combustion relative to biomass combustion sources favoring more efficient and complete combustion, such as modern biofuel plants. Nonetheless, despite these uncertainties, findings from such epidemiologic studies do have the statistical power to detect possible biomass combustion product-related health outcomes.

Finally, given the scarcity of relevant studies, both on health effects and exposure data specific to occupational environments at biofuel plants, it is not feasible to quantify biomass-specific risks posed to workers. Instead, assessments of potential adverse occupational effects are currently limited to qualitative extrapolation of findings from controlled exposure studies and epidemiologic studies in populations exposed to uncontrolled biomass smoke. Furthermore, while experimental animal data exist describing the toxicity of various types of biomass combustion products (as reviewed by [6, 139]), until better sector-specific occupational exposure characterization becomes available for biofuels of concern, these data are of limited quantitative value.

4.2.2. Studies of Occupational Exposures and Potential Health Risks at a Large-Scale Danish Biofuel Plant

To date, only the research group based at the Danish National Research Centre for the Working Environment has reported on potential occupational exposures and related toxicities at a large-scale biofuel plant, specifically a straw-fueled 8.3 MW electricity-generating facility in Zealand, Denmark [23,25]. Studies have addressed pre-combustion emissions such as organic dust and bioaerosols (e.g., [20,25,95]), with more recent limited data related to combustion-related PM [23].

As discussed earlier, Cohn *et al.* [23] investigated the mutagenicity and generation of highly reactive oxygen species (hROS) of respirable PM samples collected from the boiler room of a Danish biofuel facility (as well as PM samples reflecting pre-combustion materials from the straw storage hall at the same facility, as well as test samples of biomass-derived PM obtained by placing straw (n = 9) and wood pellets (n = 1) in a rotating drum). Using a *Salmonella* mutagenicity assay, they reported evidence of mutagenicity for the majority of the PM samples collected from the boiler room. In addition, they observed higher hROS generation in a cell-free chemical assay for the boiler room PM samples than for the biomass stock-derived PM samples. As discussed by the study authors, these findings suggest greater biological activity of biomass-combustion PM *versus* biomass-derived PM (e.g., pre-combustion biomass fuel), although they note that boiler room PM likely consists of a complex combustion mixture of both biomass and vehicular emissions (e.g., trucks and diesel-powered forklifts), thereby limiting the biomass-specific apportionment of both exposure and risk. Overall, these findings provide limited evidence of the potential toxicity of biomass combustion PM from a modern biofuel facility, primarily using straw-based stock fuel. Additionally, the limited number of sites sampled indicates the potential difficulty in apportioning the portion of combustion PM due to biomass stock or other facility sources.

4.2.3. Controlled Human Exposure Studies of Small-Scale Biomass Combustion

Controlled exposure studies, or chamber studies, are considered to provide some of the more useful data for assessing the potential health risks of inhaled pollutants due to the use of human subjects, well-defined exposure concentrations and durations, and precise measures of biological responses [143]. As summarized in Table 9, a number of controlled exposure studies have utilized biomass smoke generated from domestic wood burning appliances, including woodstoves and wood pellet boiler systems. These small combustion appliances are less efficient and more poorly controlled than large boilers in biomass fueled power plants, thereby contributing to differences in emissions (e.g., higher organic carbon and soot content) relative to biofuel plants, as discussed previously. As a result, these results are only briefly discussed and reference is made to the source material cited for further details of the testing undertaken.

Despite the use of highly elevated exposure levels of biomass smoke, as reflected by $PM_{2.5}$ concentrations in the range of 150 to >600 μg/m^3, these studies have generally reported evidence of fairly mild and readily reversible biological responses (Table 9). Observed effects include relatively small increases in some biomarkers of lung and systemic inflammation, airway oxidative response, blood coagulation response, or lipid peroxidation, including changes in several biological markers achieving statistical significance. As shown in Table 9, many of these studies reported inconsistent findings for some types of biological responses, or a greater number of negative findings (*i.e.*, no changes compared to control) than statistically significant positive findings.

Human controlled exposure studies of healthy adult volunteers thus provide some evidence of statistically significant, but generally mild, biological responses to elevated smoke exposures from uncontrolled biomass combustion, in particular lung and systemic inflammation and an airway oxidative response. While the physiological significance of some of the observed responses is ambiguous, they provide evidence of potential respiratory and cardiovascular health risks from elevated exposures to biomass smoke. However, it is again important to emphasize the uncertainties regarding the relevance of these findings to the biomass combustion gas at modern biofuel plants.

4.2.4. Epidemiologic Investigations of Uncontrolled Ambient Biomass Smoke

Epidemiologic studies of populations affected by biomass smoke are more numerous than human controlled exposure studies. None are currently available for workers or communities impacted by biomass combustion emissions from a modern biofuel plant, and findings from the available studies of wildfires and prescribed burning are of uncertain relevance to occupationally exposed workers at modern biofuel plants due to potential differences in combustion conditions and the properties of combustion emissions (as discussed earlier). In addition, it is important to note that epidemiologic studies have a variety of other general limitations and uncertainties that contribute to the difficulty in making causal conclusions based on this type of health effects evidence only, including model selection and specification, treatment of co-pollutants, control of potential confounders (e.g., smoking, seasonal effects), and exposure misclassification. A particular advantage of epidemiological studies compared to human controlled exposure studies, however, involves their frequent study of large populations and thus increased statistical power to detect rare health outcomes.

Overall, epidemiological findings regarding smoke from uncontrolled biomass combustion are mixed. Table 10 summarizes the epidemiologic literature related to short-term studies of exposures to biomass smoke in areas impacted by large-scale biomass combustion events. These studies show a range of outcomes, from increased emergency department visits to mortality. There is now a consistent body of epidemiologic evidence linking elevated short-term exposure to biomass smoke with increased risk of a variety of respiratory-related health impacts. Despite a growing number of studies, there is little epidemiologic evidence linking biomass smoke exposure to either cardiovascular-related health outcomes or mortality. In addition, the epidemiologic evidence linking biomass smoke exposure and cardiovascular health outcomes is significantly weaker than that linking urban $PM_{2.5}$ with cardiovascular morbidity and mortality [144].

4.2.5. Regulatory Consideration of Biomass Combustion Emissions and Cancer Risk

IARC [145] has classified indoor emissions from household biomass combustion (primarily wood) as "probably carcinogenic to humans" (Group 2A). In its report, IARC cited limited evidence in humans and experimental animals for the carcinogenicity of household biomass combustion emissions, but sufficient experimental evidence in animals for the carcinogenicity of wood smoke extracts. Indeed, the mutagenic potential of biomass smoke PM extracts is well documented in both bacterial systems and human and animal cell lines [6,140,146]. Study findings suggest relationships between mutagenic activity and a number of factors, including combustion combustions, type of wood-burning device, fuel type and origin, and PAH content [6,140,147]. In particular, Klippel and Nussbaumer [147] reported greater evidence of chromosome aberrations in a micronucleus test of a Chinese hamster lung fibroblast cell line for particles generated during incomplete combustion conditions than for more complete combustion conditions, where the number of chromosome defects was below the limit of detection. Mixed evidence of the carcinogenicity of wood smoke is available from laboratory animal studies [6].

Epidemiologic studies investigating the health impacts of long-term exposures to biomass combustion emissions in developed countries are limited, and thus large uncertainty exists regarding cancer risk posed by combustion product mixtures relevant to modern biofuel plants. Some studies have reported significant associations between ambient fine PM ($PM_{2.5}$) and increased cancer risk, in particular lung cancer (e.g., [148]). However, biomass combustion emissions are generally a relatively minor contributor to ambient $PM_{2.5}$ in the urban locations included in these studies compared to other $PM_{2.5}$ sources such as traffic emissions and coal-fired power plant emissions, and these findings are thus of uncertain relevance to specific PM types such as wood smoke PM.

4.2.6. Conclusions Regarding the Evidence for Biomass Combustion Product Health Risks at Large-Scale Modern Biofuel Facilities

Although the specific magnitude of any potential human health risk is a function of a variety of factors, multiple lines of evidence suggest that short-term exposure to elevated levels of biomass combustion products could increase the risk of respiratory-related health impacts. There is large uncertainty associated with potential long term effects. However, the probability of such exposure among workers at biofuel plants is expected to be low). Furthermore, there are significant compositional differences between emissions from modern biofuel plants and the biomass combustion sources that have been the focus of the bulk of the health effects research (*i.e.*, woodstoves, fireplaces, forest and brush fires). Combustion of biomass produces a complex mixture, and there is significant toxicological information on many of the individual constituents, including criteria pollutants, several different classes of VOCs (e.g., acrolein, aldehydes) and some associated persistent semi-volatile compounds (e.g., PAHs, dioxins/furans). However, it must be emphasized that in the absence of reliable monitoring and exposure estimates, it is uncertain if these constituents would be present at levels within biomass plants that could cause health effects in workers.

There is even more uncertainty associated with cardiovascular health impacts and mortality. As mentioned previously, numerous epidemiological studies have reported associations between cardiovascular morbidity and mortality and ambient $PM_{2.5}$. Moreover, there is accumulating evidence on the role played by specific PM components in adverse health effects, with some indication that carbonaceous PM (*i.e.*, elemental and organic carbon) may play a larger role than other constituents (e.g., [149,150]), and others suggesting the importance of certain trace metals and other components [151,152]. However, despite some similarities in composition compared with other types of combustion emissions, PM from biomass combustion can have very different composition and physicochemical properties, and thus potentially differing toxicity [6,140,153,154]. Some studies (e.g., [147,155,156]) suggest that biomass combustion PM, and in particular that associated with quasi-complete combustion in well-operated boilers, is of lesser toxicity than other types of combustion emissions. In contrast, other studies (e.g., [142,157]) reported findings indicating that biomass combustion products, in particular those from forest fires and prescribed fires, are of similar—if not greater—toxicity than other types of combustion emissions.

Another area of uncertainty relates to discrepancies between environmental and occupational epidemiology studies of PM exposure. In contrast to the number of epidemiologic studies that have reported statistically significant associations between ambient $PM_{2.5}$ and increased risk of mortality in the general population, many large occupational epidemiologic studies (e.g., [158–160]) have failed to observe increased mortality risk among worker populations with highly elevated PM exposures, including workers in the carbon black industry who are routinely exposed to combustion emissions.

4.3. Post-Combustion Risks

Studies of health effects in workers exposed to biomass ash in power generation facilities are limited. From studies in workers that handle coal ash, however, it is known that key hazards for conventional ash exposure relate to the potential inhalation of PM and trace inorganic compounds (e.g., arsenic, chromium, cadmium) [161]. Also of potential concern are free respirable quartz [162, 163] and radiological exposures [163]. It should be noted, however, that even if these properties of coal ash pose a potential concern, evidence from epidemiological, animal, and *in vitro* studies, albeit limited, supports the conclusion that coal ash exposure is not associated with silicosis [162,164]. Concerns related to potential exposures to organic compounds (e.g., dioxin, PAHs) in coal ash have also been raised, but these levels have been repeatedly shown to be close to detection limits [165,166] Potential routes of exposure to biomass-derived ash are expected to mimic those of coal ash, with inhalation of PM and associated compounds being the primary concern. Additional exposure could occur via dermal contact or ingestion if hygiene measures are inadequate to prevent contamination of welfare areas.

4.3.1. Ash and Inorganic Compounds

To understand potential health risks from exposure to biomass ash it may be informative to compare the ash generated by coal and biomass combustion. Ash from solid fuel combustion consists of a mixture of the inorganic components of the fuel and unburnt carbon. It may also contain materials added to assist in the combustion process, such as the bed material (typically sand) used in fluidized bed combustion, or materials to control pollutant emissions (e.g., limestone for acid gas control). At the industrial scale, the amount of unburnt carbon in the ash is minimized, so the major component of the ash is the mineral matter contained in the fuel. While both biomass and coal can vary considerably, most biomass is lower in ash than most coal. The mineral composition of the ash also varies significantly by fuel source and combustion process [167]. Van Loo and Koppejan [9] reported that ash levels varied from about 0.5 wt% to 12% (on a dry basis), with hardwood, straw, and wood contaminated with inorganic impurities on the higher end of the range. Nonetheless, despite the lower ash content of these fuels, ash is a major contributor to overall dust loads at biomass power generation facilities and thus can constitute risk related to PM inhalation. In addition, although the total ash content of biomass is usually less than coal, the water-soluble fraction (including compounds of alkali and alkali earth metals) can be higher [9]. Chemical analyses of different fly ash size fractions at biomass-fired plants have shown that these alkali metal compounds form fine particles in the flue gas [168]. The health implications of this are not well studied, but by implication, the levels of these alkali metals in the fuel could affect the emission rate of respirable ash particles.

Under Europe's Registration, Evaluation and Authorization and Restriction of Chemicals (REACH) regulations, biomass ash has been registered as a UVCB substance (unknown or variable composition, complex reaction product or biological origin), with identified components including oxides of calcium, sodium, potassium, silicon, iron, manganese, magnesium, aluminum, phosphorous, titanium and sulfur [69]. The associated chemical safety assessment concluded that biomass ash did not require hazardous classification under REACH. A significant amount of work has been undertaken to characterize "clean" biomass ash, primarily from wood-fired boilers in Scandinavia, where the use of such ash as a forestry fertilizer is permitted (see for example [170]). Various studies and databases have complied data on the macro and trace element composition of biomass ash. Data from a number of sources are presented in Table 11 and are compared to these same trace metals measured in coal ash and soil. Someshwar [171] compiled information on the trace metal content of wood ash collected from a variety of sources (26 ash samples in all). Most of the ashes were from pulp mill bark boilers, although ash samples from other types of large capacity wood boilers are represented. In addition to the Someshwar analysis, the International Energy Agency has collected information on the trace metal content of biomass ash produced from different processes and fuels. The database currently includes 560 ash samples from biomass burning facilities with capacities from 400 kWth to 6.3 MWth in six different countries, although many of these samples were only analyzed for a limited number of elements. In Europe, data on wood ash composition have been collated by the Swedish University of Agricultural Sciences [170] and The Energy Centre of the Netherlands [10], although much of the data are shared between these databases. In general, the data in Table 11 reflect biomass boilers of different types, sizes and fuels; this is reflected in the wide range of values for most of the trace elements. It is unclear how representative some of these data are for ash from large-scale commercial boilers, although much of the data in the SLU and ECN databases were obtained from dedicated biomass generation plants. For metals in particular, there is a relationship between levels in the fuel and levels in the ash. However, most large boilers have multiple ash streams (e.g., bottom and fly ash), and, as is the case with coal, some metals preferentially condense into certain ash products, resulting in different concentrations in each stream [172]. This is evident in the data from the ECN database, where many of the elements are enriched in the fly ash compared to the bottom ash.

The metal content of ash derived from various fuel sources differs. In general, ash from the burning of straw, cereal, and grasses is lower in metals compared to ash from woody material and bark [9]. As shown in Table 11, average trace metal concentrations in ash from the burning of waste wood (regularly used as a fuel for electricity generation in Europe) are considerably higher than levels in clean wood ash. Compared to coal ash, clean wood ash generally contains lower levels of arsenic, chromium, and nickel. Biomass ash, however, does appear to be enriched in manganese, cobalt, cadmium, and zinc compared to coal ash and soil. However, even when summed they constitute less than 2% of the total ash composition, and so, provided occupational exposure limits for general dust are complied with, exposure to these metals is unlikely to reach the limit values for individual metals.

One experimental study (reported in [173]) involved exposure of rats via inhalation to fine (*i.e.*, equivalent to emitted) fly ash from coal, biomass, and coal/biomass co-firing. No significant impact on lung inflammation was seen with the biomass-derived fly ash compared to titanium oxide control, while coal and coal/biomass ash elicited significant effects, e.g., increases in IL-8 and PMNs. The magnitude of these effects was lower than the effects of carbon black, the positive control. The authors theorized that this may be a result of the higher percentage of soluble salts in the biomass ash; while all the ash samples were of a similar size (mean mass aerodynamic diameter 1.5–3 μm), resulting in similar deposition rates in the lungs, biomass ash could dissolve and be eliminated from the lungs, while the less soluble coal ash remained.

4.3.2. Polycyclic Aromatic hydrocarbons (PAHs)

PAHs form from the incomplete combustion of organic material. Consequently, the combustion of biomass has the potential to generate PAHs, which can adsorb to ash particles and thus become available for oral, dermal, and inhalation exposures; however, bioavailability can be modified by a number of factors [174]. PAH generation is diminished with complete burning (low carbon in ash levels), which would be more characteristic of large commercial biomass boilers used to generate electricity. Interestingly, some of the technologies that reduce NO_x emissions in large commercial boilers, such as staged combustion, may also cause PAH formation in ash to increase [175]. Data on the PAH content of biomass ash, including benzo(a)pyrene (often used as a marker for total PAH levels), are limited. The available data show that, in general, the PAHs found in wood ash are two and three-ring compounds, as opposed to the more toxic 4-and 5- ring compounds; naphthalene is the most abundant PAH [171]. Data from some larger scale facilities are presented in Table 12. With the exception of filter fly ash from bark combustion, these PAH levels are within the range of levels found in background urban soils [176]. Like metals, the highest level is associated with the filter fly ash. In conclusion, because high-capacity commercial boilers favor complete combustion conditions, it is unlikely PAHs in ash would be of toxicological concern for utility workers.

4.3.3. Dioxins/Furans

There is substantial information on dioxin levels of biomass ash, but the information mainly comes from small-scale combustion units or uncontrolled burning. Despite the limited information from large-scale facilities, some general principles can be garnered from the available information. Generation of dioxins and furans is favored under conditions where the fuel stock contains higher levels of chlorine. In addition, incomplete combustion is associated with higher levels of dioxins and furans (*i.e.*, higher ash levels are correlated with higher dioxin content). In general, herbaceous materials (straw, cereal) have higher chlorine content compared to wood and bark, and consequently the ash generated is associated with higher levels of dioxin/furans [9]. As with PAHs, while dioxin should be considered as part of a thorough risk evaluation, the concentrations of dioxins and furans in biomass ash (expressed as toxic equivalents of TCDD) are generally within levels found in background soils and below health-screening levels]. Pitman [167] reviewed several available datasets and concluded that the PCDD/F contents of both "domestic" grate ash and "commercial" wood boiler ash are "negligible". This is especially true of clean wood burned in commercial boilers. However, as reviewed in Someshwar [171], salt-laden wood can generate significantly higher levels, which may be important for fuel harvested from more coastal regions. In addition, the burning of waste wood or residual wood can produce higher levels of PCDD/F in ash than the combustion of clean wood fuel [9] Due to the potential variability in levels of dioxins and furans, biomass combustion facilities would need to undertake ash analysis to understand the potential range of PCDD/F in the ash produced by their boiler/fuel combination to use as the basis of a risk-based assessment.

Table 9. Human controlled exposure studies of inhaled woodsmoke biological effects.

Reference	Exposed Population	Combustion Source	Dominating Particle Types	$PM_{2.5}$ Exposure Levels [1]	Key Statistically Significant Acute Biological Responses [2]	Key Negative Findings [2]
[177–180]	13 healthy adults	Small cast iron wood stove Fuel: Standardized mixture (50/50) of hardwood/softwood (birch/spruce), dried for 1 yr (moisture content 15%–18%) Exposure: 4 h	Organic carbon/soot	240–280 μg/m^3	↑ Serum amyloid A; ↑ Plasma factor VIII; ↑ Factor VIII/von Willebrand factor ratio; ↑ Urinary excretion of free 8-iso-prostaglandin$_{2\alpha}$; ↑ Malondialdehyde in breath condensate; ↑ Serum Clara cell protein; ↑ $FENO_{270}$ and calculated alveolar NO ↓ PBMC levels of DNA strand breaks; ↑ mRNA levels of hOGG1	"Weak" subjective symptoms; No significant increases in serum C-reactive protein (CRP), fibrinogen, IL-6, or TNF-α levels; No significant changes in RBC, Hb, Hct, leukocytes, or platelets; No significant change $FENO_{50}$ or NO influx; No significant increase in urinary Clara cell protein No significant changes to FPG sites, hOGG1 activity, or PBMC expression of hNUDT1 or HO-1; No significant changes in urinary excretion of 8-oxodG or 8-oxoGua
[181]	10 healthy adults	Electric element in a woodstove Fuel: Red oak wood Exposure: 2 h	Organic carbon/soot	485 ± 84 μg/m^3	↑ Percentage and absolute numbers of neutrophils in blood, BL, and BAL; ↑ IL-1β in blood; ↑ blood LDH c	No significant changes in symptom prevalence or lung function; No significant changes blood or BAL cytokine concentrations (IL-6, IL-8, TNF-α); No significant changes white blood cell counts, blood coagulation (e.g., von Willebrand's factor, plasminogen activators) or total proteins and albumin; Minimal changes in cardiac endpoints

Table 9. *Cont.*

Reference	Exposed Population	Combustion Source	Dominating Particle Types	$PM_{2.5}$ Exposure Levels [1]	Key Statistically Significant Acute Biological Responses [2]	Key Negative Findings [2]
[182]	26 healthy adults	Standard woodstove Fuel: Dried pine wood with UV aging woodsmoke Exposure: 3 h	Organic carbon/soot	150–200 μg/m^3	None	No significant changes in vascular function measured by reactive hyperemia-peripheral arterial tonometry (RH-PAT)
[183]	20 healthy adults	Standard woodstove (operated "optimal conditions") Fuel: Dried beech Exposure: 3 h	Combination of alkali salts, soot, and organic matter	165–662 μg/m^3	↑ Self-reported subjective symptoms (significant changes for 5 of 6 indices): "environmental perception" "irritative body perceptions" "psychological/neurological effects" "weak inflammatory" ↑ Self-reported general mucosa irritation	No increase in the index for "lower respiratory effects"
[184]	19 healthy adults	Adjustable wood pellet boiler system (operated under incomplete combustion) Fuel: Moist softwood pellet/sawdust mixture from pine and spruce (18% moisture)	Organic carbon/soot	224 ± 22 μg/m^3	↑ Glutathione in BAL; ↑ Upper airway symptoms (nose and throat irritation)	No significant changes in lung function (VC, FVC, FEV_1) or exhaled NO (FE_{NO}); No significant changes peripheral blood counts; No significant changes GSH in BW or endobronchial biopsy tissue; No significant changes in lung inflammatory parameters (e.g., MPO, MMP-9), levels of other antioxidants (GSSG, vitamin C, and urate), or enzymes indicative of oxidative stress (HO-1, GST) in BAL, BW, and endobronchial biopsy tissue

Notes: (1) Exposures are for whole woodsmoke and thus reflect exposures to not only particulate matter (PM) but also gaseous constituents including NO_x, CO and a number of gaseous hydrocarbons. The PM concentration is an indicator of the level of exposure; (2) Significant effects reflect significant differences between woodsmoke and clean air exposures; BAL = bronchoalveolar lavage; BL = bronchial lavage; BW = bronchial wash; $FENO_{50}$ = fraction of exhaled NO at a flow rate of 50 mL/s; FENO270 = fraction of exhaled NO at a flow rate of 270 mL/s; FEV_1 = forced expiratory capacity in one second; FPG = formamidopyrimidine-DNA-glycosylase; FVC = forced vital capacity; GSH = glutathione; GSSG = glutathione disulfide;GST = glutathione transferase; Hb = hemoglobin; Hct = hemocrit; hNUDT1 = nucleoside diphosphate linked moiety X-type motif 1; HO-1 = heme oxygenase 1; hOGG1 = oxoguanine glycosylase 1; IL = interleukin; LDH = lactate dehydrogenase; MMP-9 = matrixmetalloproteinase 9; MPO = myeloperoxidase; NO = nitric oxide; 8-oxoGua = 8-oxo-7,8-dihydro-oxoguanine; 8-oxodG = 8-oxo-7,8-dihydro-2 –deoxyguanosine; PBMC = peripheral blood mononuclear cells; RBC = red blood cells; TNF = tumor necrosis factor; UV = ultraviolet; VC = vital capacity.

Table 10. Health outcomes linked with biomass smoke exposure in epidemiologic studies.

Health Outcome	Example Reference(s)
Emergency department (ED) visits for respiratory diseases, including asthma	[185–188]
Respiratory hospital admissions	[189–194]
Respiratory physician outpatient visits	[194–197]
Respiratory symptoms	[198–201]
Lung function	[202–205]
Pulmonary and systemic inflammation	[202,206,207]
Cardiovascular-related health outcomes	Vascular function- 207; ED visits for cardiovascular diseases-208 [a]
Mortality	[209,210] [b]

Notes: [a] In general, the epidemiological evidence linking biomass smoke exposure with cardiovascular-related health outcomes is weak and inconsistent, with most pertinent studies failing to observe statistically significant associations [155,188,192–194, 197,211–215]; [b] Most other studies have reported no evidence of an association between biomass smoke and mortality, including [155,193,195,214,216].

Table 11. Trace elements measured in biomass ash (number of samples).

	As	Cd	Cr	Pb	Hg	Co	Cu	Mn	Ni	Zn
					Median (mg/kg)					
Wood Ash [a]	10	3.6	30.8	61.5	0	9	68.2	3485	16.4	329
All Fuels-All Ash fractions [b]	9	17	107.5	36	9.5	16	146	14,350	55	1659.5
Wood Chips-All Ash fractions [b]	8	19	132	39	10	14.5	180	14,366	55	350
Wood Ash—all boiler types [c]	7.98 (558)	8.4 (619)	66.4 (567)	54 (607)	0.11 (549)	10.2 (543)	101 (659)	8200 (551)	33 (563)	1438.5 (656)
Waste Wood-fly ash [d]	104	456	404	50,000	<0.5	11	422	na	74	164,000
Coal Ash-Fly Ash [e]	71	1.07	133	49	0.1075	7.9	140	189	102	152
Coal Ash-Bottom Ash [e]	7.2	<5.5	191	20	0.018	na	73	262	123	59
Soil [e]	5.8	0.2	50	15	0.05	7	20	300	15	50
All Wood ash—all ash fractions [f]	13 (89)	6.5 (109)	57.2 (128)	59 (127)	0.4 (87)	9.1 (123)	97.7 (128)	7350 (122)	30 (127)	1595 (128)
Clean wood bottom ash [f]	<3 (32)	<0.51 (31)	49 (37)	15.5 (36)	<0.045 (28)	7.3 (37)	59 (37)	4900 (36)	20.5 (36)	400 (37)
Clean wood fly ash [f]	9.1 (26)	17 (30)	54 (31)	75 (31)	0.3 (28)	10 (26)	120 (31)	10850 (26)	31 (31)	3310 (31)

Notes: [a] [171]; [b] [217]; [c] [170] [d] [9]; [e] [218] ; [f] [10].

Table 12. Other components, including persistent organics, measured in biomass ash.

Ash Fraction	$C_{org.}$ (wt% (d.b.))	Cl (wt% (d.b.))	PCDD/F (ng TE/kg d.b.)	PAH (mg/kg d.b.)	B[a]P (µg/kg d.b.)
			Bark combustion		
Bottom ash	0.2–0.9	<0.06	0.3–11.7	1.4–1.8	1.4–39.7
Cyclone fly-ash	0.4–1.1	0.1–0.4	2.2–12.0	2.0–5.9	4.7–8.4
Filter fly-ash	0.6–4.6	0.6–6.0	7.7–12.7	137.0–195.0	900.0–4900.0
			Wood chips combustion		
Bottom ash	0.2–1.9	<0.01	2.4–33.5	1.3–1.7	0.0–5.4
Cyclone fly-ash	0.3–3.1	0.1–0.5	16.3–23.3	27.6–61.0	188.0–880.0
Filter fly-ash	–	–	–	–	–
Pulverized Wood [a] Fly Ash				156	1500
			Sawdust combustion		
Bottom ash	0.2–3.4	<0.1	1.3–2.1	14.7–21.1	21.0–40.5
Cyclone fly-ash	3.2–15.3	0.1–0.6	1.5–3.7	11.2–150.9	180.0–670.0
Filter fly-ash	–	–	–	–	–
			Straw combustion		
Bottom ash	9.0	1.1	2.3	0.1	0.0
Cyclone fly-ash	16.6	13.6	70.8	15.8	17.0
Filter fly-ash	16.1	35.1	353.0	26.0	320.0
			Cereal combustion		
Bottom ash	9.4	1.3	22.0	0.3	0.0
Cyclone fly-ash	9.9	5.2	12.2	0.5	0.0
Filter fly-ash	4.9	19.0	56.0	7.3	210.0

Notes: [a] data from [175]; all other data from [9]; B[a]P = benzo[a]pyrene; C_{org} = Organic carbon; Cl = chlorine; d.b.= dry ash basis; PCDD/F = polychlorinated dibenzodioxin/furan; TE = Toxic equivalents standardized to toxicity of 2,3,7,8- tetrachlorodibenzo-*ρ*-dioxin (TCDD).

4.3.4. Respirable Silica

Most biomass materials contain silica among the ash-forming material; the extent to which this silica can cause health effects via inhalation depends on the particle form and the fraction of the material that is respirable. Respirable free crystalline silica (*i.e.*, quartz) is associated with silicosis (a nodular pulmonary fibrosis), lung cancer, pulmonary tuberculosis, and other airway disorders [219]. Elevated risks are associated with occupations exposed to dust from rocks, including any activity involving sand blasting, brick cutting, rock drilling or blasting, *etc.* [219]. Exposure to coal ash results in exposure to respirable free silica, but no well-designed epidemiological study has established an association between silica exposure from this source and adverse health effects [162]. Some research has demonstrated that the lack of health effects may be because the free quartz in combusted material is vitrified and unable to interact with biological targets [163]. The tendency for silica in biomass ash to fuse has also been observed [9]. This feature, in conjunction with the understanding that in general biomass has a lower silica content than conventional solid fuel, indicates that the silica in ash is unlikely to pose an occupational health concern. In addition, some fluidized bed boilers use sand as a bed material; this material is removed with the ash (primarily the bottom ash) when degraded; levels of respirable quartz in this material are not clear. A study presented at the 2011 World of Coal Ash conference found that ash produced during the co-firing of biomass and coal had low levels of respirable quartz, which were not biologically available [163]. While the low silica content of biomass ash may be a general feature, an exception may be rice husks, which have particularly high quartz content [9]. From this perspective, the silica risk from the utilization of risk husks may be considered to be a potential concern for occupational exposures, but it is unlikely that other biomass ash would be a significant occupational concern. Still, more research to characterize the respirable quartz fraction of different biomass ash (and fuels) is warranted.

4.3.5. Radioactivity

Concerns over the potential radioactivity of biomass ash stems from the expectation that natural or manufactured radioactivity present in plant material can become concentrated in ash upon combustion. Overall the concern has been less for natural radiation (which is generally considered to be negligible), and more for anthropogenic radionuclides that may be present at higher levels in plants and soils in areas that have experienced nuclear fall-out [167]. Principal radionuclides of concern are cesium-137, with a half-life (time taken for radioactivity to decay to 50% of the original levels) of 30.17 years and strontium-90 (half-life 28.8 years); the half-lives of these isotopes result in contamination remaining for many decades after the original event, and significant quantities of both were released from the Chernobyl and Fukushima accidents [220]. A limited number of studies have examined potential occupational radiation risk from biomass fuel. After an exposure assessment that included on-site monitoring of airborne dust, aerial radon, and ambient gamma dose-rate measurements, a study conducted at a peat-fired power station in Ireland concluded that workers involved in various plant activities did not experience a radiation dose above the level of concern established by the Irish government (calculated dose of 0.3 mSv per year against an action level of 1 mSv per year) [221]. Potential radiation exposures to workers have also been investigated in areas where the fuel stock is contaminated with radioactivity associated with the fall-out from Chernobyl.

5. Field Testing at Two Power Stations

5.1. Experience with Biomass Handling at UK Power Plant

Co-firing of biomass in coal-fired power plants started in the UK in around 2003 following the introduction of government requirements for renewable generation. Although co-firing ratios in most cases have been relatively low (<5% of thermal input), since most UK coal stations consist of 2 to 6 units rated between 330 and 660 MWe (with 4 × 500 MWe being the most common configuration), even at these low rates the quantities of biomass involved are significant. This has given these stations some experience with large-scale handling of biomass, with the storage and handling systems often subject to improvement from the initial design as experience increased. The biomass used in these projects has mainly been derived from agricultural residues such as palm kernel expeller, straw and olive cake, although energy crops including willow and miscanthus have also been used. In more recent years, regulatory support for biomass has moved towards high percentage (>50%) co-firing or dedicated biomass plants, through either "small"-scale new build stations (<50 MWe) using local biomass (often waste wood) or conversion of existing coal units to use biomass, with wood pellets the principal fuel used in these. These conversion projects, and similar conversions in continental Europe, represent the largest use of biomass in power generation globally. Most notably, Drax Power Station has recently completed conversion of two of its six 660 MWe units to 100% biomass firing, and is in the process of converting a further unit. When this project is completed, an estimated seven million tons of wood pellets will be required annually; this is compared to total global wood pellet production of 14 million tons per year in 2010 [222]. As a result of this and similar projects, the occupational health aspects of using biomass are becoming increasingly important, both at the power stations themselves as well as further upstream in the pellet production plants, ports and transport chains.

5.2. Testing and Analysis of Power Station Exposures

5.2.1. Site Descriptions

In support of this review, testing of dust, fungal, and bacterial levels within two power stations was undertaken. Plant A is a 44MWe dedicated biomass CHP plant firing a mixture of fresh forestry chip (predominantly Northern European pine and spruce species), sawmill residues (derived from the same sources as the forestry chip), and reclaimed waste wood. The waste wood portion is source separated, so although the fuel includes particleboard as well as laminated, varnished, and painted material, wood treated with heavy metal-containing preservatives and chlorinated pesticides is specifically excluded. The boiler is a bubbling fluidized bed combustor with flue gas clean-up via activated carbon and lime injection into a bag filter (required due to EU regulations around the use of waste wood). The plant was visited on two occasions, in autumn and spring.

The fuel handling system at Plant A is relatively simple. The fuel is stored within a single "A-Frame" building capable of holding up to 5 days' worth of fuel. Fuel is fed into the store by a central conveyor from the adjacent fuel supplier, which discharges at the roof-level of the store onto a shuttle conveyor, running approximately east-west, which distributes the fuel evenly across the stockpile below. Reclaim of the stock is via two screw reclaimers, each running along one side of the store, which discharge onto a common conveyor up to two "day silos" (each holding ~30 min of fuel) which feed the boiler. During plant operation there is no access along the conveyors from the store to the day silo, so sampling focused within the store, although at the autumn visit samples were also taken in the boiler house (Figure 1).

Plant B is a 2 GWe coal fired power station that has been co-firing various biomass types at levels of up to 15% for approximately 10 years. The plant consists of four pulverized coal units, all of which use cold-side electrostatic precipitators for dust control, while two units also have wet limestone flue gas desulfurization. The biomass is stored separately to the coal and added to the fuel by dosing the coal conveyors en route to the coal mills. At the time of testing, the biomass being co-fired was olive residue, at a percentage of around 3% thermal input. Access is available alongside all the conveyors, so testing was undertaken in the biomass store and at points in the conveyor system before the addition of biomass, where the biomass is added, in the two transfer towers and on the bunker floor of the mill house (Figure 2).

5.2.2. Site Testing

At both plants, monitoring of inhalable dust levels was undertaken using a mixture of gravimetric personal exposure monitors and continuous dust monitors using laser scattering. At Plant B and during the second visit to Plant A, one continuous monitor was set up in a static location, identified by plant personnel as being both a common working area and prone to dust, while a second continuous monitor accompanied the test team. At various points in the conveyance system at each plant, identified in Figure 1 for Plant A and Figure 2 for Plant B, a Sartorius Airport MD8 instrument collected air samples onto gelatin filters for analysis for airborne microorganisms. Duplicate samples were taken at each location to enable spore identification and quantification of colony forming units. Sample volumes were 100 L at Plant A and 250 L at Plant B.

5.2.3. Spore Quantification and Identification

Analyses for bacteria and fungi were undertaken as follows: one of each pair of sample filters was dispersed in 100 mL sterile Maximum Recovery Diluent. When fully dispersed, 0.5 mL of varying dilutions in MRD were each spread plated onto Nutrient Agar and Rose Bengal Chloramphenicol Agar with incubation at 30 °C for 2 days and 25 °C for 5 days respectively. Numbers of colony forming units were counted after these incubation periods and converted into equivalent levels in air using the known sample volumes.

Speciation of fungal spores was carried out by the National Pollen and Aerobiology Research Unit (NPARU) at the University of Worcester, UK. Filters were incubated on Malt Extract Agar to stimulate growth and generation of spores prior to microscopic (×400) identification of spores. Only those spores of health significance were considered and no quantification was undertaken.

5.3. Results and Discussion

5.3.1. Levels of Bacteria and Fungi

The quantification of the number of colony forming units identified for both bacteria and fungi are shown in Tables 13 and 14 and Figure 3 for Plant A, and Table 15 and Figure 4 for Plant B. Levels of bacteria peaked at 7.94×10^5 cfu/m^3 at Plant A and 1.51×10^4 cfu/m^3 at Plant B. As a point of comparison, Swan *et al.* (2003) reviewed a number of studies of bacteria in outdoor air and found average values of 79–3204 cfu/m^3, with levels dependent on factors such as location and season. Peak levels of fungi were 7.8×10^5 cfu/m^3 for Plant A and 9.33×10^3 cfu/m^3 for Plant B. In outdoor air, Swan *et al.* (2003) reported highly variable fungal levels, ranging from close to zero to 9.4×10^4 cfu/m^3. These results suggest that levels of bacteria and fungi measured at these power plants were at the high end of what could be expected for an outdoor environment, with some results considerably higher and within the range where health effects have previously been observed. In comparison to other studies, the results from Plant B are similar to those observed in a Polish coal plant co-firing biomass [89].

5.3.2. Types of Bacteria and Fungi

Bacterial types identified by the laboratory were not deemed to be of health significance and so were not reported. Included among these bacterial types were *Bacillus* species, but these were considered to be environmental species rather than either of the two *Bacillus* species of concern to health, *B. anthracis* and *B. cereus* (*B. anthracis* is not associated with plant biomass and a negative test for β-hemolytic activity when grown on Blood Agar excludes *B. cereus*).

Fungal types with potential health significance were also identified for each location, although exact species identification was not available. An overview of the fungal types, along with a summary of their health significance (provided by the testing laboratory) is provided in Table 16.

As seen in Table 20, some fungal types were more prevalent than others. *Penicillium* species were ubiquitous in both plants, appearing in all samples, but while *Paecilomyces* spp. were found at most locations in Plant A, only one location in Plant B yielded this species. *Mucor* spp. were found at fice of the six locations in Plant B but in only one sample from Plant A.

All of the fungal types identified are commonly found in the environment or associated with plant material. However, they include some of the fungal types most associated with health problems when handling biomass, in particular *Aspergillus* and *Penicillium* spp., which have previously been associated with allergic responses. The presence of these species highlights the need for adequate control measures to limit personnel exposure to fungal spores, and also the importance of health surveillance to identify those persons who may be more predisposed to health effects from exposure.

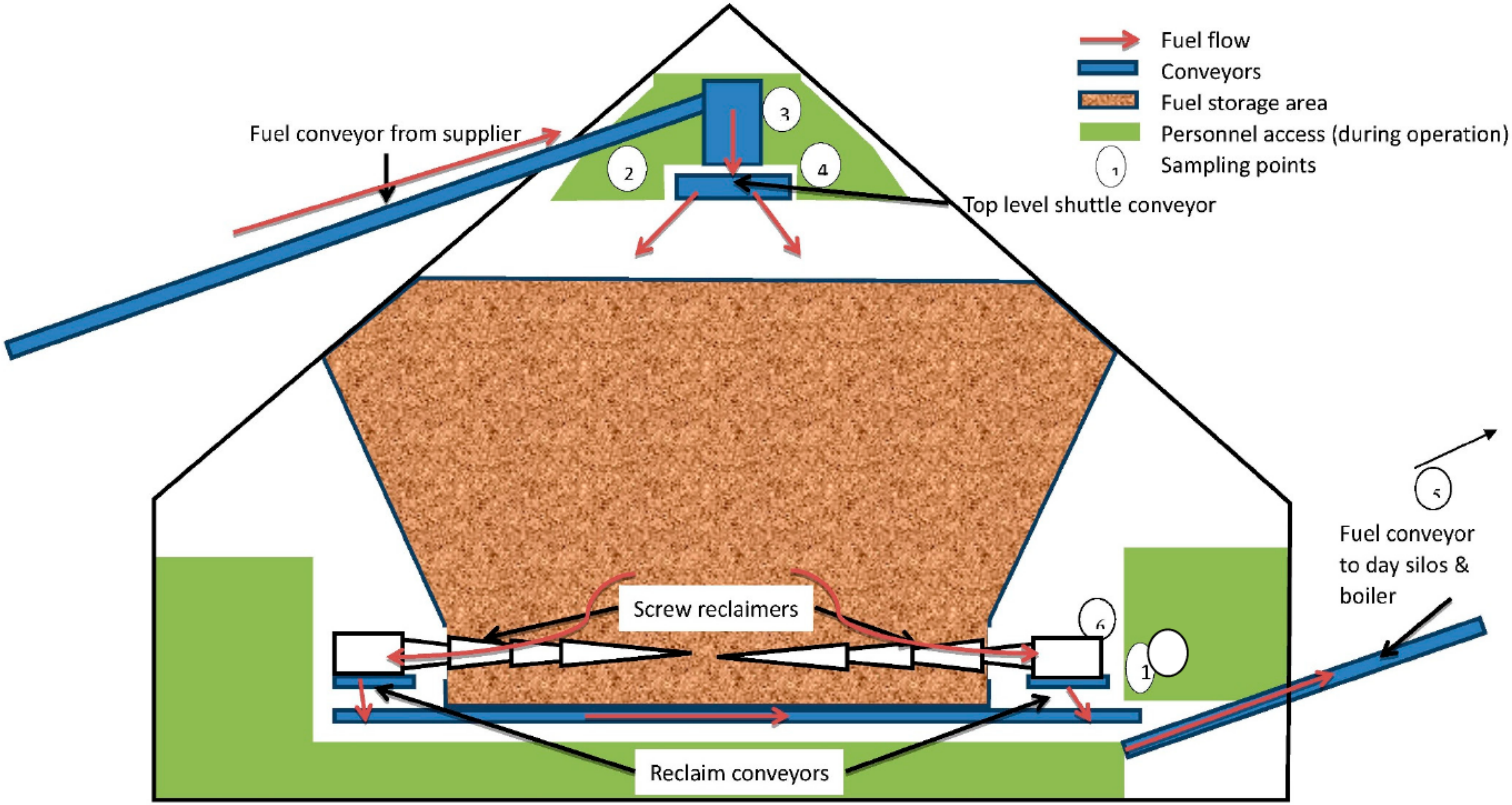

Figure 1. Schematic of fuel store layout at plant A (not to scale).

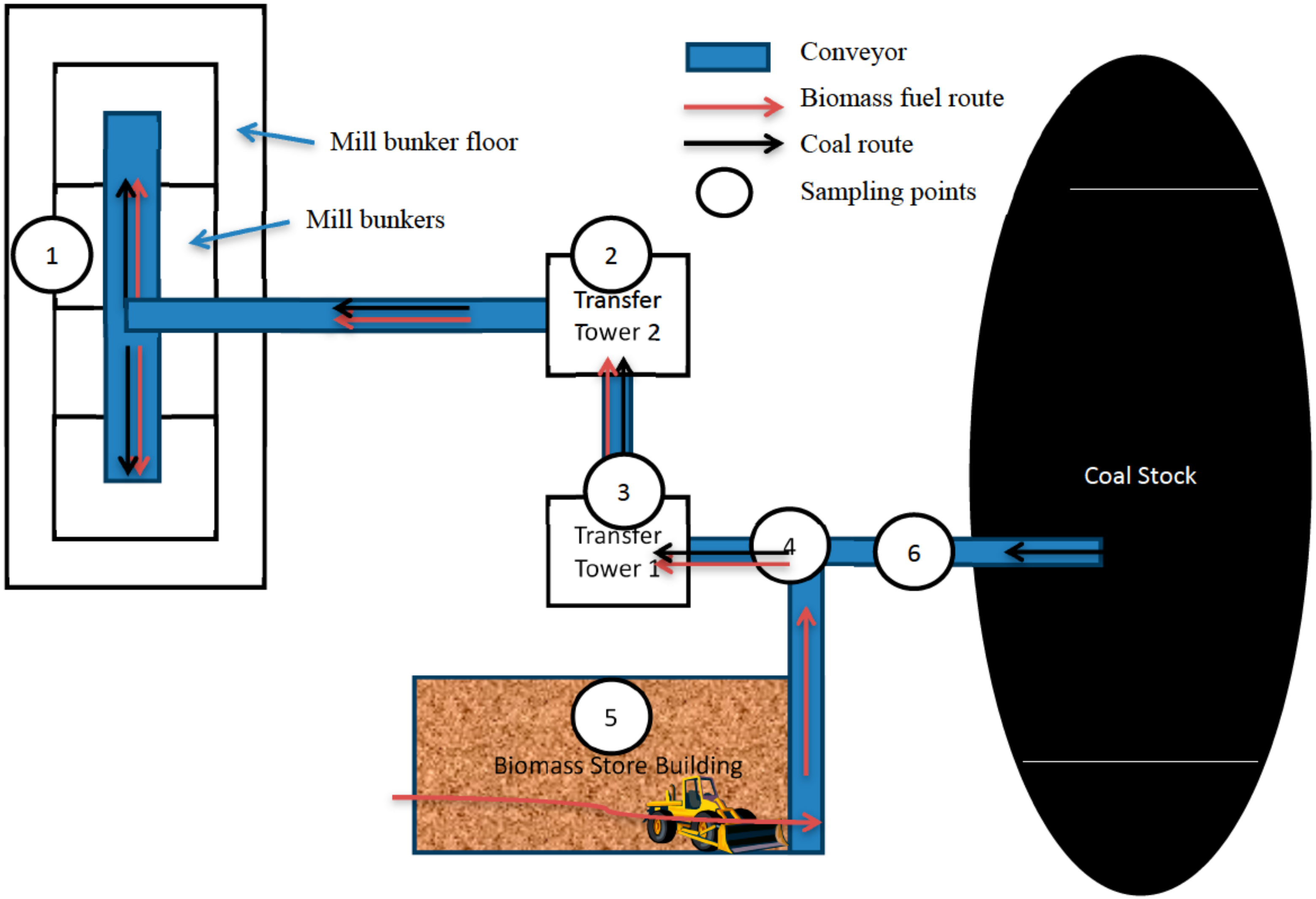

Figure 2. Schematic of handling system layout at plant B.

Table 13. Levels of Bacteria and Fungi at Plant A—Visit 1.

Sample	Colony Forming Units /m³		Genera of Health Significant Fungi Identified
	Bacteria	Fungi	
1.Screw reclaimer discharge onto conveyor to day silo	7.3×10^5	2.0×10^5	Mucor spp. Paecilomyces spp. Penicillium spp. Aspergillus spp. Yeast
2. Adjacent to shuttle conveyor, south side	3.0×10^5	7.8×10^5	Paecilomyces spp. Penicillium spp. Aspergillus spp.
3. Adjacent to fuel input conveyor	4.6×10^4	7.6×10^4	Paecilomyces spp. Penicillium spp. Aspergillus spp. Yeast
4. Adjacent to shuttle conveyor, north side	1.42×10^5	2.8×10^5	Paecilomyces spp. Penicillium spp. Yeast
Boiler house	$<2.0 \times 10^3$	4.0×10^3	Paecilomyces spp. Penicillium spp. Mycelia sterilia
Adjacent to north side screw reclaimer	2.2×10^4	2.4×10^4	Paecilomyces spp. Penicillium spp. Aspergillus spp. Yeast

Table 14. Levels of Bacteria and Fungi at Plant A—Visit 2.

Sample	Colony Forming Units/m³		Genera of Health Significant Fungi Identified
	Bacteria	Fungi	
1.Screw reclaimer discharge onto conveyor to day silo	$<1.00 \times 10^3$	3.98×10^3	*Paecilomyces* spp. *Penicillium* spp. Yeast
2. Adjacent to shuttle conveyor, south side	7.94×10^5	1.51×10^5	*Mucor* spp. *Paecilomyces* spp. *Penicillium* spp
3. Adjacent to fuel input conveyor	2.40×10^5	7.76×10^4	*Mucor* spp. *Penicillium* spp.
4. Adjacent to shuttle conveyor, north side	2.24×10^5	7.08×10^4	*Aspergillus* spp. *Mucor* spp. *Paecilomyces* spp. *Penicillium* spp.

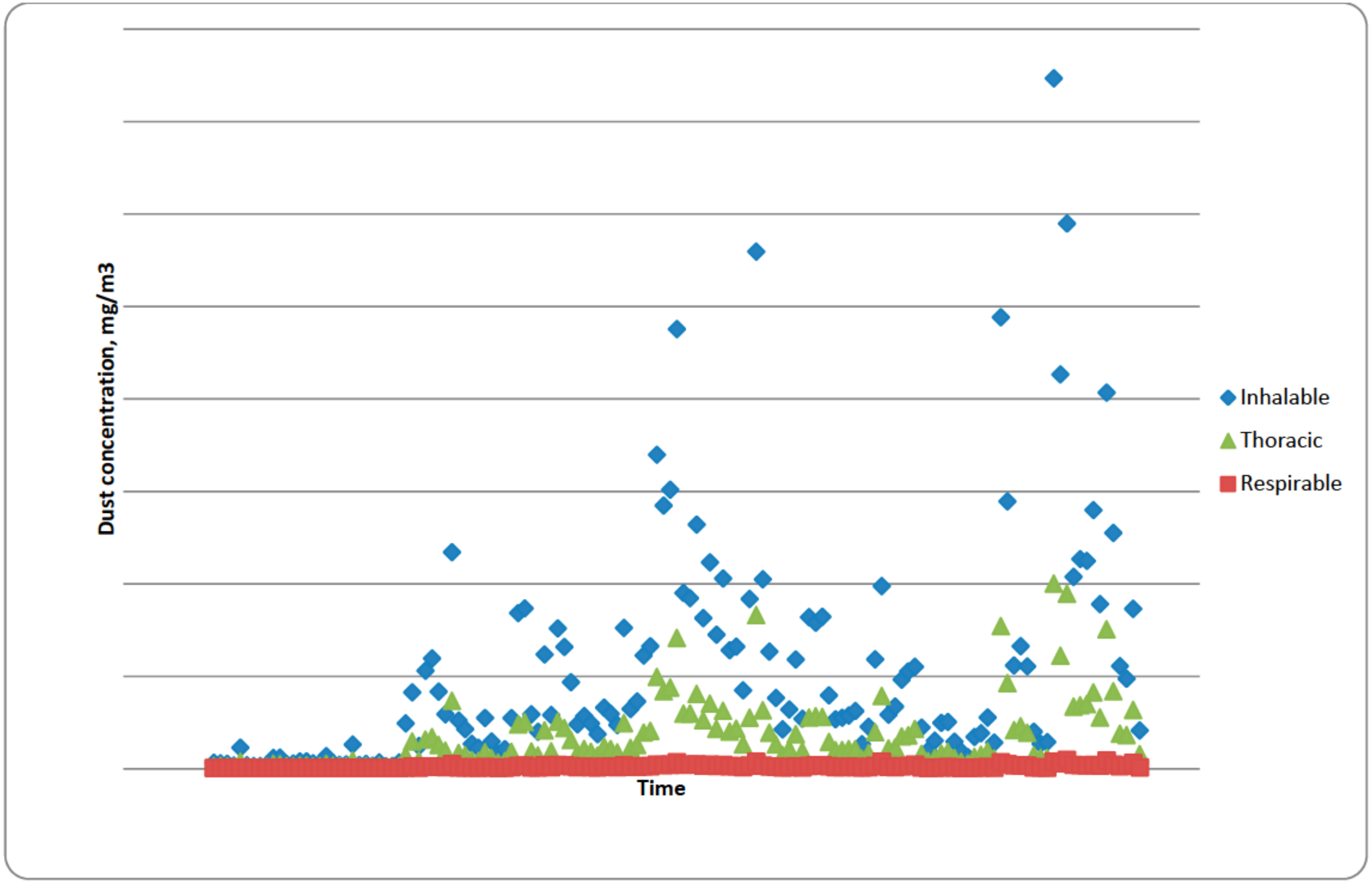

Figure 3. Measured dust levels adjacent to biomass feed hopper in plant B store shed.

Table 15. Levels of bacteria and fungi at plant B.

Sample	Colony Forming Units/m^3		Genera of Health Significant Fungi Identified
	Bacteria	Fungi	
1. Mill bunker floor	1.51×10^4	9.33×10^3	*Aspergillus* spp. *Cladosporium* spp. *Mucor* spp. *Penicillium* spp.
2. Transfer tower 2	$<3.98 \times 10^2$	$<3.98 \times 10^2$	*Aspergillus* spp. *Mucor* spp. *Mycelia sterilia* *Penicillium* spp.
3. Transfer tower 1	$<3.98 \times 10^2$	2.82×10^3	*Mucor* spp. *Paecilomyces* spp. *Penicillium* spp. Yeast
4. Biomass addition to coal conveyor point	1.20×10^3	4.79×10^3	*Mucor* spp. *Penicillium* spp.
5. Biomass store	$<3.98 \times 10^2$	$<3.98 \times 10^2$	*Mucor* spp. *Penicillium* spp.
6. Coal conveyor prior to biomass addition	$<3.98 \times 10^2$	7.41×10^3	*Aspergillus* spp. *Penicillium* spp.

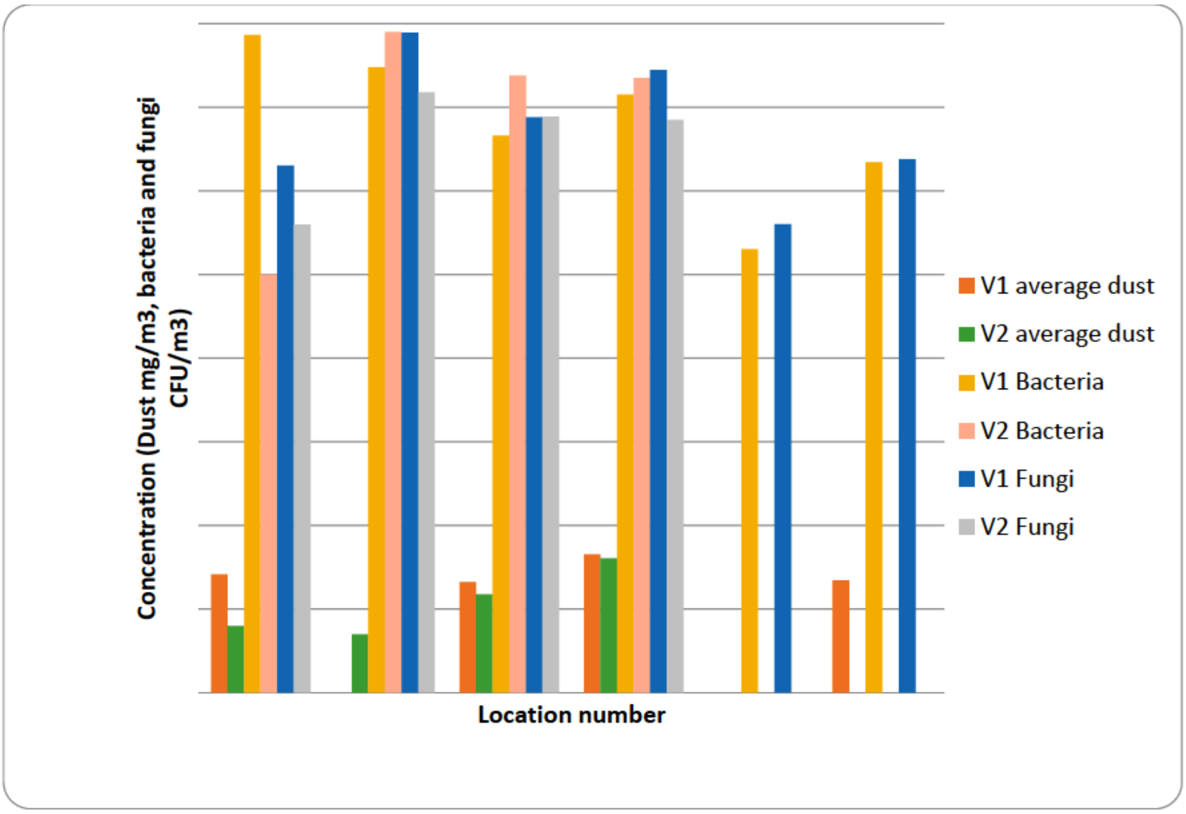

Figure 4. Dust, bacteria and fungi levels at plant A during visit 1 and visit 2 (note logarithmic scale). Limit of detection for bacteria and fungi is 3.98×10^2.

5.3.3. Dust Levels in Plants

Summaries of the results from personal and static monitors at each plant are shown in Tables 17–19 and Figures 3 and 4. Continuous monitoring results represent the exposures of the test team and so in some cases are averaged over relatively short periods (~15 min). Static monitoring results represent longer periods (generally 2–3 h). Longer-term (overnight) testing was attempted during the first visit to Plant A, but this was unsuccessful and the data are not presented.

Monitored dust levels in Plant A were surprising low, given visible evidence of dust accumulation on surfaces in the upper area of the store (sampling points 2–4). In the lower area of the store there was very little dust accumulation on surfaces. This reflects the different systems used in the store; in the upper level, the fuel free-falls from the input conveyor to the shuttle conveyor (although this is partially enclosed) and from there to the surface of the wood chip pile, creating opportunities for dust within the fuel to become airborne. In contrast, during the reclaim of the fuel, the screw augers are removing material from an essentially static pile and transfer distances between conveyors are much smaller, with the result that there is limited formation of dust. Discussions with the plant personnel indicate that the highest dust levels in the upper store are often seen during start-up of the conveyor system (due to the disturbance of settled dust) and when dry waste wood is being fed to the store, with the dust coming from degraded particle board. As the system was in continuous operation and primarily carrying wet forestry woodchip during the testing, it is probable that dust levels in the store are often significantly higher than those recorded. Under normal operation, plant personnel only spend limited time in the A-frame, primarily for cleaning and for maintenance checks; monitoring of the store is via video feed to the main control room.

During start-up, access to the upper store is restricted; for general access to the upper level at other times, dust masks with a P3 rating (according to European standard EN149) are required as standard. However, when dust levels are visibly high, if undertaking work likely to generate airborne dust (such as cleaning), or if working for extended periods, air-fed hoods are used.

Table 16. Potential health implications of identified fungal types.

Fungal Group	**Health Significance**
Aspergillus spp.	Common environmental organism being found in soil, plant debris, decaying fruit and vegetables as well as indoor environments. Can act as a potent allergen causing allergic asthma with some species producing mycotoxins. Some species can cause infection in humans invading the lungs, sinuses and other sites sometimes causing deep infections in immunocompromised persons. Non-immunocompromised persons may also occasionally show infection of sinuses and lungs.
Mucor spp.	Widespread in soil, plants, decaying vegetation *etc.* May cause zygomycosis or mucormycosis in humans—infection of nose, septic arthritis, dialysis-associated peritonitis, renal infections, gastritis and lung infections. Exacerbated by persons being immunocompromised or being diabetic
Penicillium spp.	Widespread throughout environment especially associated with soil and decaying vegetation. May cause allergic asthma and lead to irritation of respiratory tract. May occasionally cause more serious illness with species capable of producing mycotoxin.
Paecilomyces spp.	An inhabitant of soil and decaying vegetation, occasionally found in foods and in air. Often isolated from compost. May give rise to allergic reactions with the immunocompromised most at risk.
Yeasts	Common airborne fungus. May be a problem if a person has been previously exposed and has become hypersensitive. High levels may cause allergies.
Mycelia sterilia	Ubiquitous with some being important plant pathogens.
Cladosporium spp.	Widely distributed in air and rotten organic material and is frequently isolated from foods. Infection may lead to skin lesions, keratitis, nail infections, sinusitis and lung infection.

Table 17. Average and maximum inhalable dust levels at plant A—visit 1.

Location number	**Continuous Monitor**	
	Average inhalable dust level, mg/m^3	**Maximum inhalable dust level, mg/m^3**
1	0.26	0.39
3	0.21	0.32
4	0.45	1.30
6	0.22	0.67

Levels of dust at Plant B were generally higher than at Plant A. Within the storage shed at Plant B, vehicle movements restricted access of the test team, so the continuous dust monitor results presented are for an area away from the main working zone. It was, however, possible to set up a continuous monitor as a static monitor closer to the area where the biomass is fed onto the conveyance system using a front loader. The results from this monitor are shown in Figure 5. It can be seen that ambient dust levels in the storage shed were low prior to the start of operations at 10:30, but after this time there were occasional high levels (up to 37 mg/m^3) of inhalable dust—most likely representing tipping operations. Levels of respirable dust remained low (<1 mg/m^3) throughout, indicating that the dust generated was inhalable but not respirable. This is the only area at the plant where it can be assumed that the majority of the dust exposure is from the biomass itself (there may also be a contribution from the diesel vehicles), as throughout the rest of the plant there is a contribution from coal. This can be seen with the results from location 6, where only coal dust is expected, but the second highest maximum dust level was seen. The results of the gravimetric personnel monitor accompanying the test team were nearly 10× higher than those from the continuous monitor (14 mg/m^3 verses 1.84 mg/m^3) and above the UK workplace exposure limit for inhalable dust of 10 mg/m^3. It is not clear whether this difference in results is "real" and reflects the variability of monitoring in an area of changing conditions, or is indicative of limitations in sampling methods. For example, disturbance to dust accumulated on surfaces while moving around the plant may create localized areas of very high dust concentrations that may be picked up by one monitor but not the other. In addition, non-inhalable dust may settle onto gravimetric filters, artificially increasing the collected mass, or the characteristics of the dust may make it difficult for continuous systems to detect.

Table 18. Average and maximum inhalable dust levels at plant A—visit 2.

Location number	Continuous Monitor		Static Monitors
	Average inhalable dust level, mg/m^3	**Maximum inhalable dust level, mg/m^3**	**Average inhalable dust level, mg/m^3**
1	0.063	3.4	
2	0.05	1.83	1.10
3 (static monitor)	0.37	2.46	0.55
3 (test team monitor)	0.15	1.59	
4	0.405	1.65	
Outside	0.21	6.8	

Table 19. Average and maximum inhalable dust levels at plant B.

Location number	Continuous Monitor		Gravimetric Monitor
	Average inhalable dust level, mg/m^3	**Maximum inhalable dust level, mg/m^3**	**Average inhalable dust level, mg/m^3**
1	6.10	9.64	
2	1.24	5.85	
3	1.89	3.78	
4	1.98	3.71	
5 (static monitor)	5.31	37.34	4.00
5 (test team monitor)	0.45	1.32	
6	1.58	27.66	
Coal plant control room	0.25	0.57	
Outside	0.41	2.11	
Test team gravimetric monitor			14.23

Table 20. Summary of fungal species identified.

Site	**Plant A**										**Plant B**					
	1. Screw reclaimer discharge onto conveyor to day silo		2. Adjacent to shuttle conveyor, south side		3. Adjacent to fuel input conveyor		4. Adjacent to shuttle conveyor, north side		5. Boiler house	6. Adjacent to north side screw reclaimer	1. Mill bunker floor	2. Transfer tower 2	3. Transfer tower 1	4. Biomass addition to coal conveyor point	5. Biomass store	6. Coal conveyor prior to biomass addition
Visit	1	2	1	2	1	2	1	2	1	1						
Identified fungal types																
Mucor spp.	√			√		√		√			√	√	√	√	√	
Paecilomyces spp.	√	√	√	√	√		√	√	√	√			√			
Penicillium spp.	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
Aspergillus spp.	√		√		√			√		√	√	√				√
Yeast	√	√			√		√			√			√			
Mycelia sterilia									√			√				
Cladosporium spp.											√					

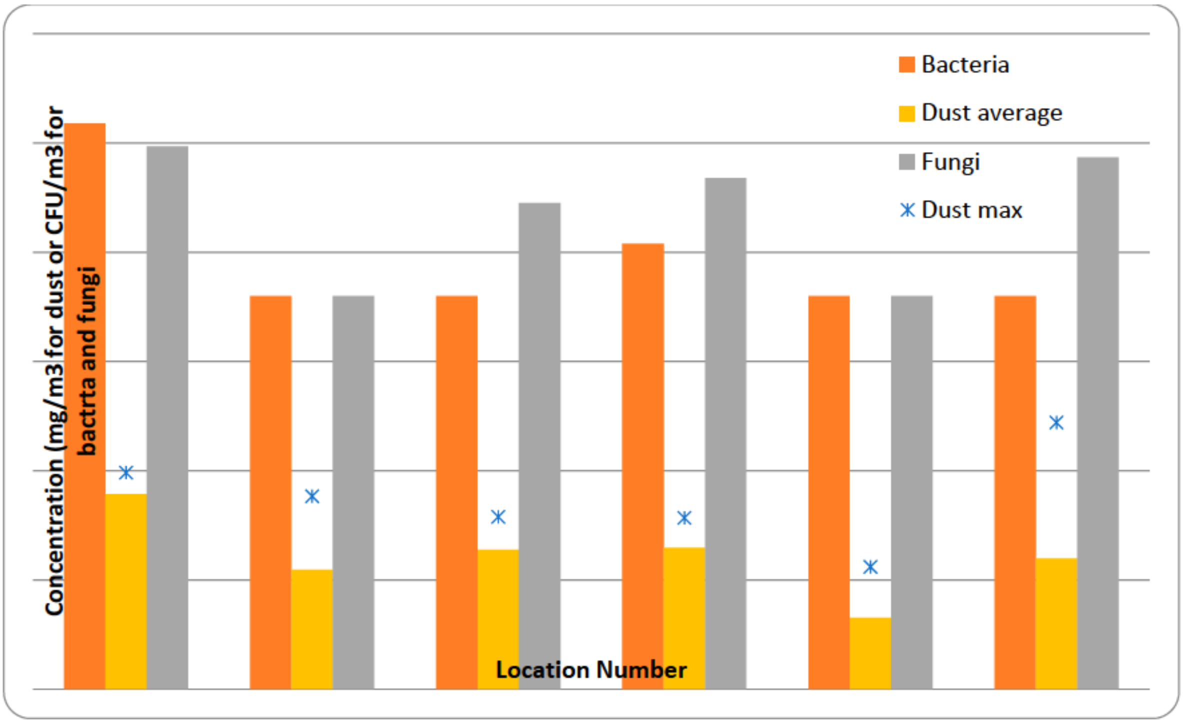

Figure 5. Dust, bacteria and fungi levels at plant B (note logarithmic scale). Limit of detection for bacteria and fungi is 3.98×10^2.

5.4. Conclusions of Field Sampling

This limited study highlights some of the additional hazards associated with the use of biomass for power generation compared with coal generation. The exposure levels to dust, fungi, and bacteria varied between the two plants monitored, being affected by factors such as the location within the plant, activities in the immediate area of the monitors, and most likely other factors, including the biomass type and seasonal conditions. The discrepancy between gravimetric and continuous dust monitors located in the same area of the plant highlights the uncertainties associated with any monitoring campaign and the influencing factors that must be considered. Levels of bacteria and fungi were within the range seen in other related industries such as agriculture and composting, but were generally higher than levels considered typical of ambient outdoor air. They were also above the levels where health effects have been identified in previous studies. The types of fungi identified were all commonly found in the environment, but included some such as *Aspergillus* and *Penicillium* species which are known to be associated with allergic and respiratory effects. It is therefore important that the risk to workers is properly evaluated when biomass is considered as a fuel, with factors such as biomass type, handling, and storage methods and the interaction between workers and biomass taken into consideration. Where possible, good practice should be used to minimize the risk of bioaerosol formation; methods could include minimization of storage times and avoidance of conditions which could promote mold growth (such as accumulation of biomass dust in warm, moist conditions). Process control of occupational exposure risks is preferable to reliance on personal protective equipment due to factors such as proper fit and maintenance which can reduce the protection factor of, e.g., dust masks.

6. Conclusions

The aim of this review was to summarize the state of knowledge regarding potential occupational hazards related to biomass-powered electricity generation. Due to the limited number of publically available occupational monitoring, assessment, or epidemiological studies, it provides an overview based primarily on extrapolation of potential exposures and adverse health outcomes derived from diverse industrial hygiene, laboratory and epidemiological work conducted in related wood or agricultural industries, or other ambient exposure scenarios, including uncontrolled biomass burning, in non-worker populations.

However, even with this severe limitation, this qualitative extrapolation does provide indications of potential hazards associated with the use of biomass that are not regularly encountered in fossil-based power generation, which should be considered in the context of protecting worker health through the development of monitoring and control plans. Pre-combustion risks include the following: particulate matter containing bioaerosols and biogenic organics such as fungi, bacteria, and other microbial components capable of inducing irritation (e.g., ocular and dermal), acute or chronic allergic responses (e.g., dermatitis, rhinitis, or conjunctivitis) and chronic allergic responses (e.g., occupational asthma). Additionally, as IARC classifies at least some wood dust as carcinogenic, it remains prudent to control dust levels, particularly as for many authorities lower OELs are specified for wood dust than for general dust. As an organic fuel, biomass lacks the stability of traditional coal or petroleum fuels and has a tendency to decompose, create changing exposure scenarios and requiring different handling, transport, and storage considerations to minimize both microbial growth (e.g., spore formation, endotoxin release, *etc.*) and off-gassing of volatile organics or other gases (e.g., carbon monoxide). Where this degradation cannot be avoided, specific monitoring and control programs may be required. It remains to be seen if biomass applications in the power sector put workers at higher risk of more severe respiratory diseases observed in agriculture or other industries, such as organic dust toxic syndrome or allergic alveolitis (e.g., Farmers Lung). Regardless, proactive training on unique handling practices and health surveillance focused on respiratory considerations for workers will not only provide a safety buffer, but also encourage and provide data to support monitoring, occupational exposure and risk assessments.

Combustion and post-combustion occupational exposures, along with related health and safety concerns, appear likely to mirror current, more traditional combustion scenarios. In addition to appropriate technology controls, worker training on appropriate ash handling during operational and maintenance procedures will parallel current best practices. However, the available data on biomass physiochemical properties as they relate to emissions and solid waste streams indicate that some of the hazards may be different to those from fossil-based generation, particularly when using waste fuels, and so this should be considered when evaluating worker risk.

Limited public domain information is available from on-going health and injury surveillance of power generation workers, particularly for health outcomes of highest concern (e.g., respiratory, irritation, sensitization). Additional studies at power plants utilizing a variety of technologies and biomass stock fuels, particularly with personal and task specific monitoring, may be required to understand the background prevalence of symptoms and disease among workers and move health and safety research forward as the global interest in, and application of, biomass as a renewable energy source increases.

Author Contributions

Sharan L. Campleman conceived of and launched the project. Annette C. Rohr managed manuscript contributions from co-authors and prepared the manuscript draft. Christopher M. Long, Michael K. Peterson, Susan Weatherstone, Will Quick, and Ari Lewis all contributed important intellectual input to the manuscript. All authors approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest. Annette C. Rohr is employed by the Electric Power Research Institute (EPRI), an independent nonprofit 501(c)3 organization that funds external research at a number of universities and institutes worldwide. S.L. Campleman was previously affiliated with EPRI. Gradient and E.ON Technologies both received funding from EPRI to contribute to the manuscript.

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From: EnergyPlan2019@RedwoodEnergy.org
Sent: Monday, October 21, 2019 2:53 PM
To: Lori Taketa
Subject: FW: Biomass Power Comments

Follow Up Flag: Follow up
Flag Status: Flagged

-----Original Message-----
From: Mel Kreb [redacted]
Sent: Saturday, October 19, 2019 11:48 AM
To: EnergyPlan2019@RedwoodEnergy.org
Cc: Valerie Elder <info@thebuckeye.org>
Subject: Biomass Power Comments

To: Redwood Coast Energy Authority

My wife and I own organically certified Flood Plain Produce and farm a total of five acres on the north end of the Avenue of the Giants in Pepperwood. Ten years ago we applied fly ash from a local cogen plant to one part of our garden. That part of the garden continues to need less summer watering and for some reason vegetables grow better there than the rest of the garden. Obviously not a scientific study but as farmers we spend a lot of time observing and analyzing what is happening on our farm and take effective action when necessary.
We believe cogen carbon can be stored in Humboldt County soil and is beneficial to the soil and the plants growing in it. We would not want to loose this source of potential fertilizer. Please use this letter at your public meeting on cogen.

Thank you for reviewing our input. Contact us if you need further information.

Mel and Holly Kreb
Flood Plain Produce
31117 State Highway 234
Scotia, CA 95565

707-722-4330

From: EnergyPlan2019@RedwoodEnergy.org
To: [redacted]; EnergyPlan2019@RedwoodEnergy.org
Cc: Lori Taketa
Subject: RE: No Biomass. NOT CLEAN
Date: Wednesday, October 23, 2019 12:21:56 PM

Thanks for your comment, Matt. We'll add it to the list of public comments on our website.
In case you missed Friday's workshop about biomass, here is the link to the full video.
https://vimeo.com/368199665

Best,
Nancy

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

From: Matt OBrien [redacted]
Sent: Wednesday, October 23, 2019 10:12 AM
To: EnergyPlan2019@RedwoodEnergy.org
Subject: No Biomass. NOT CLEAN

This idea seems in direct contradiction to the intended goal of clean energy and environmental stewardship. Thanks for your time. Back to drawing board. Good luvk.
Cheers
Registered Voter
Matt O'Brien

From:	EnergyPlan2019@RedwoodEnergy.org
To:	Daniel Noel; EnergyPlan2019@RedwoodEnergy.org
Cc:	Lori Taketa
Subject:	RE: CAPE community comment
Date:	Monday, November 4, 2019 11:17:40 AM

Thank you for your comment, Daniel. We will include this with the public comments, and we'll take each point into consideration.

You might find some of the information you seek on our website:

Power resources: https://redwoodenergy.org/community-choice-energy/about-community-choice/power-sources/power-procurement/
Biomass: https://redwoodenergy.org/community-choice-energy/about-community-choice/power-sources/local-biomass/
The RePower Humboldt/CAPE workshop and public outreach schedule:
https://redwoodenergy.org/services/planning/

An event at HSU addressing the potential of an onshore wind project:
https://www.humboldt.edu/events/sustainability?trumbaEmbed=eventid%3D385333252%26view%3Devent%26-childview%3D%26returnUrl%3Dhttps%253A%252F%252Fwww.humboldt.edu%252Fevents%252Fsustainability

Thank you for being a part of our update process,
Nancy

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

From: Daniel Noel [redacted]
Sent: Friday, November 1, 2019 10:26 PM
To: EnergyPlan2019@RedwoodEnergy.org
Subject: CAPE community comment

My name is Daniel Noel, I'm an environmental studies student at HSU, Arcata resident and Humboldt county registered voter. I am very interested in our local energy and appreciate the creation of RCEA and community choice energy.

Biomass:
Given we have a local timber industry it makes sense to use this waste stream. My greatest concern with biomass is the Amount of Green House Gasses (GHGs) being released from it. To my knowledge the use of whole trees in biomass and some forms of bio-waste can emit more GHGs than coal fired power plants. Given the climate crisis it is everyone's duty to reduce the amount of GHGs being emitted into the air. To understand this we need a study about the biomass and waste being burned in our facilities to determine how pollution it creates.
I've heard that we pay more for biomass per energy unit than other forms of energy. Biomass from timber industries is a waste stream that is created from removing and processing trees which we all need to breathe. We should not pay a higher rate per energy unit for biomass. Especially when companies we purchase from like Humboldt Redwood Co. have a history of unsustainable forestry practices that threaten Humboldt

county's ecosystems.

Better understanding Biomass fits with CAPE goals for education and commitment to local energy and jobs. A lower price for biomass in support of lower energy rates and justice given that trees are a resource we all benefit from, therefore we should all benefit from their use.

Conclusion:
1. Local biomass and biowaste health and emissions study.
2. Less support of eco-destructive industry and lower rates for power supply.

Wind power:
Any renewable energy project in Humboldt county must empower this community. What does that look like?
1. Coordination with local tribes and respecting sacred land.
Terra gen on-shore wind project does not do this.
2. Not using unsustainable and ecosystem destructive methods like clear cutting.
Clear cutting and endangerment of important ecosystems is currently part of the the Terra gen onshore wind project.
3. Owning our own energy. The PG&E caused fires and following outages are a perfect example of negligence by private corporations. The bottom line of any corporation in America is profit. We will continue to be exploited and at the mercy of these companies so long as we have to rely on their energy infrastructure. The Terra-gen project has even denied the possibility of a union for construction of this project. If we create our own energy project then we can create a just energy, enjoy the financial benefits, and build climate and disaster resiliency. We <u>need</u> energy projects that will allow Humboldt county to own it's own energy if we want to see any justice and resiliency in the energy sector.

Water and Waste: This is the most important topic in my mind
<u>Human waste:</u> Here me out: our society is subject to a major logical flaw, that we are separate from nature. This is false since we clearly evolved from nature and every part of society uses resources that are part of this earth. We are part of this earth and so is our poop. Treating our urine and feces as something inherently destructive to nature is a major flaw in logic. There is an amazing amount of nutrients, energy, and potential to use our human waste in compost and to grow food. We should make it legal to compost our own waste and not necessitate complicated and expensive sewer systems.
The necessity of western designed sewer systems denies low-income people the opportunity to own or build their own home since these technologies come at a high price. It also denies this energy from being returned to the earth.

Education:
I appreciate the efforts of RCEA to coordinate with Schaatz energy center. At the same time I think there needs to be more energy put into education and outreach efforts. I was not aware of any of the CAPE input meetings/ workshops until they had all passed. Additionally there is an extreme lack of information about where this energy is sourced. I appreciated the energy profile which allows us to see percentages of which type of energy we are using. The RCEA should go further and provide information on where each of these energies is sourced from including amount used, amount paid for this energy, location where energy is produced and which companies are being produced.

If you are interested:

New HSU Environmental Studies professor , Deepti Chatti, is teaching a course on Energy Justice in the Spring 2020 semester. This would be a great opportunity to collaborate and study/discuss energy justice in Humboldt county and engage an entire class of eager students in understanding local energy politics. deepti.chatti@humboldt.edu

Daniel Noel
HSU Environmental Studies Major
Humboldt Sunrise Movement

From: Colin Fiske
To: EnergyPlan2019@RedwoodEnergy.org
Subject: CAPE Update Draft 2 Comments
Date: Wednesday, October 30, 2019 2:22:04 PM

RCEA Staff,

I am writing to comment on the updated draft CAPE as an individual community member, not in my capacity as a Community Advisory Committee member or a member or representative of any other local group.

I appreciate all of the work that RCEA staff have put into this document, and I support the majority of it. I particularly appreciate the vision of achieving net-zero greenhouse gas (GHG) emissions countywide by 2030, a target which demonstrates the ambition necessary to tackle the climate crisis in a meaningful way on a local level.

However, I remain very concerned that this vision could be compromised by RCEA's continued commitment to buying electricity produced by the burning of wood (biomass). I believe you attempted to address this concern with the new clause in the draft specifying that there should be ongoing lifecycle analyses to confirm the short- and long-term carbon neutrality of biomass electricity. I very much support this new clause. However, the commitment to demonstrating carbon neutrality appears to be subsumed by the more highly emphasized commitments to "support biomass" and "procure local biomass energy." In other words, there is no commitment *not* to procure local biomass energy if a life-cycle analysis demonstrates a net climate impact in the short or long term. I encourage you to make such a commitment clearly in the CAPE.

Additionally, while the Board-adopted goal of procuring 100% clean and renewable energy by 2025 is included in the updated draft, it does not clearly define "clean and renewable." In the context of the rest of the document, it seems that "clean and renewable" has been simplified to just "state-defined renewable," and the attempt to define "clean" has been dropped. I encourage you to adopt a simple definition of "clean," such as: "An electricity source will be considered clean if the best available science demonstrates that it is carbon-neutral or carbon-positive on all time scales and does not have a significant negative impact on human health and the environment."

Thanks for considering my comments. Don't hesitate to reach out with any questions.

Colin Fiske

From: EnergyPlan2019@RedwoodEnergy.org
To: [redacted] EnergyPlan2019@RedwoodEnergy.org
Cc: Lori Taketa
Subject: RE: Let''s be free of the massive grid that failed us
Date: Friday, November 1, 2019 10:41:34 AM

Hi Kim,
Thank you, we will add this to our public comments and will be considered as we update our strategic plan.

Watch our website for continuing opportunities to engage with us on this.
https://redwoodenergy.org/

Warm regards,
Nancy

Nancy Stephenson
Community Strategies Manager | Redwood Coast Energy Authority
(707)269.1700 x 352 | www.RedwoodEnergy.org

From: kim douglas [redacted]
Sent: Wednesday, October 30, 2019 11:16 PM
To: EnergyPlan2019@RedwoodEnergy.org
Subject: Let's be free of the massive grid that failed us

Can we please have some discussion about how a small land owner can supply his place solar, wind energy anything to get Humboldt out if the PG&E pockets. Lets empower the people of Humboldt.

Sent from Yahoo Mail on Android

From:	Information
To:	Lori Taketa
Subject:	FW: Biomass
Date:	Friday, November 1, 2019 12:15:52 PM

Public Commnet…?

From: Petra Bingham [redacted]
Sent: Thursday, October 31, 2019 3:42 PM
To: Information <info@redwoodenergy.org>
Subject: Biomass

Hello,
I would like to reach out with some information that your organization might be well aware of already abd hopefully it's trying to move away from ASAP.
I just read this in the recent Sierra Club newsletter:

Biomass industry in CA inefficient, expensive and highly polluting

Daniel Barad, Biomass campaign representative for Sierra Club California, presented to Sonoma Group Conservation Committee and members of the public on Monday, Oct. 7 on the problematic situation with biomass power plants throughout the state.

Barad, who has been studying this issue since 2017, said since the tree mortality crisis began in 2010, the State of California has allowed and provided subsidies for biomass powerplants to remove dead trees from public lands. The powerplants transport the trees to their facilities and incinerate them to create electricity.

“129 million trees died between 2012 and 2017,” said Barad. “Gov. Brown created the tree mortality task force in 2015, which could have done a lot of good things, like drawing attention to forestry management. It could have addressed the risks of dying trees, and it could have funded tree removal projects on the most dangerous trees and figured out how to use the trees in the most efficient ways. Instead, Brown propped up six biomass facilities, which were about to lose their contracts. They were not in the best locations, and they used this crisis to get new contracts.”

Biomass plants emit three times as much carbon as natural gas (methane) and 1.5 times as much as coal. Its emissions include fine particulate matter, which is very toxic and causes significant health issues, including asthma, among people who live near the plants.

Three of these plants are located in the Redwood Chapter region in Humboldt County.

Not only are these biomass plants a form of dirty energy, they also are expensive to operate. Trucks must transport the wood, grind it into wood chips and then burn it. Because of the expense, facilities look to find the cheapest and closest fuel, which includes nearby agricultural waste and green waste trucked out of cities. They also use material from commercial logging operations and clear-cutting operations.

The high cost of this energy generation is passed on to the ratepayers when we use electricity.

Sierra Club California recommends spreading the word about the problems with biomass incineration by contacting your local state legislators, writing letters to the editor or op-eds or participate in in-district lobbying.

Thank you for looking for better options than biomass for our RE Power Plus subscription!!!!

Petra Bingham

[redacted]

From:	Matthew Marshall
To:	Lori Taketa; Nancy Stephenson
Subject:	FW: Kids will thank us for wind power
Date:	Friday, November 1, 2019 12:05:00 PM

More CAPE public input below:

From: Natalynne DeLapp [redacted]
Sent: Friday, November 1, 2019 11:18 AM
Subject: Kids will thank us for wind power

My Word

Kids will thank us for wind power
By John Schaefer
Times-Standard Nov. 1, 2019

Humboldt County will soon address whether to permit the Terra-Gen Wind Project, located south of Scotia. The Planning Commission holds a hearing for the Draft Environmental Impact Report (DEIR) on Thursday, Nov. 7 at 4 p.m. The impacts of burning fossil fuels are clear: the Kincade and other fires, floods in the Midwest, heat waves in the Arctic, and thousands of desperate people fleeing Central America and Africa.

News today foretells a bleak future for our grandchildren if we don't arrest the climate crisis promptly.

It's not just for our grandchildren's future that pollutionfree electricity is a good idea. The state has mandated that all electricity be renewable by 2045, and the Redwood Coast Energy Authority recently chose to meet that goal by 2025. We can't do that without the Terra-Gen Project.

The good news is that no place is better situated than Humboldt to take advantage of the need for pollution-free electricity.

Solar and wind are the cleanest choices, and indications are that Terra-Gen will be lower in cost than other options. We'll need as much as we can get if we are also to convert transportation to electric in the next decade or two.

Wind farms provide good jobs, both in construction and operation. Everyone I've met in wind farms (and in solar power plants) loves his or her job. I've worked as a research project manager and consultant in renewable energy since 1985, and I've been around a lot of wind farms.

From that experience, I can say that there are downsides to having wind turbines nearby. In Minnesota, I heard complaints that construction trucks damaged the roads, and didn’t fix them. In Texas, ranchers complain that wind operators didn’t shut gates, a no-no in ranch country.

In Illinois, Indiana, Minnesota, Pennsylvania and New York, neighbors living close to turbines justifiably complain about noise. They also complain about red warning lights at night and shadow flicker, moving shadows on their homes when the sun is low in the east or west. Clearly, those wind turbines were installed too close to homes, some as close as a few hundred yards.

Those valid objections to wind power elsewhere don’t matter here. Terra-Gen’s turbines will be high up on the ridges. To my knowledge there aren’t any homes up there. Scotia and Rio Dell are far enough away that residents won’t hear anything.

Of course, if residents look carefully they will see turbines on the ridge. One reads complaints about altered viewscapes, but that kind of NIMBYism years ago would have kept us in the nineteenth century.

A recent study by Lawrence Berkeley Lab showed that only 10 percent of residents living 1 to 3 miles from wind turbines had negative opinions, with 64 percent holding favorable views.

One hears objections about bird deaths, and the DEIR addresses that issue better than I can. Of one thing I am sure, however. Terra-Gen won’t cause species extinction the way the climate crisis has and will in the future.

Fire is a potential risk. Fires do ignite (rarely) in wind turbines, just the way they do in houses, cars, and fossil-fueled power plants. What complicates a wind turbine fire is that it’s usually atop a 300 foot tower. Spectacular scenes of wind turbine fires can be found on the web.

Wind turbines now are fully instrumented, so any ignition— from electrical faults, hydraulics, or overheated brakes— should trigger prompt fire suppression. Complaints I’ve read that a company is making a profit make no sense in the real world of today. For better or for worse, we live in an economy where investments either yield profits or they won’t occur. Yes, wind investors will make money, but absent that investment the owners of fossil-fueled power plants will make even more. Who are the good guys in that scenario?

Massive concrete foundations will remain after wind turbines go out of service, perhaps 30 years from now. I fear we may not have conquered the climate crisis by then, so that turbines installed in 2020 will be replaced by others in 2050. Whatever new equipment is installed then will be embodied in new nacelles, probably mounted on existing towers and on existing foundations.

Thus, those massive foundations will serve forever as monuments to Humboldt County's foresight in addressing the climate crisis. Viewing them, our grandchildren will thank us for choosing a livable future.

John Schaefer worked in the utility industry for 40 years, 30 of those in renewable energy. His first job in California was construction with PG& E, when it was a different kind of company. He holds an engineering Ph.D. from Stanford.

--
Natalynne DeLapp
Humboldt Wind Project
[redacted]

RECEIVED
NOV 7 2019
Redwood Coast Energy Authority

Power going off is
good for us -
Get back to reality -

Cell phones should
be next -

HMUD had program
on Saturday regarding
scientific evidence of hidden
and denial of radiation
danger of cell phones
to humans, especially the
young - We are killing ourselves
THANK YOU.

The Hightower LOWDOWN
www.hightowerlowdown.org
VOLUME 21 ♦ NUMBER 9 ♦ OCTOBER 2019 ♦ WRITTEN BY JIM HIGHTOWER

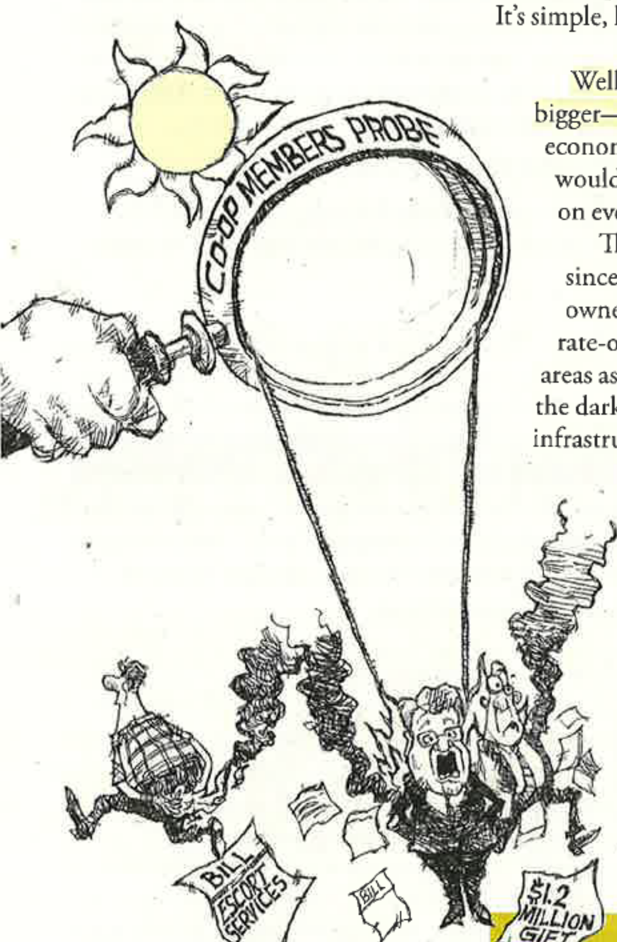
> *[RECs are] a vital resource for advancing the environmental, economic, and social justice needs of our communities.*
>
> —Derrick Johnson, former executive director of One Voice Mississippi, explaining One Voice's support of the state's REC member-owners

What if you owned your own power company?

Well ... maybe you already do.

Electric co-op member-owners are zapping co-optation.

About 40 years ago, a right-wing codger named Eddie Chiles became a momentary political celebrity in my state by buying airtime on hundreds of radio stations to broadcast his daily political rants. Having made a fortune in the Texas oil fields, he pitched himself as a rags-to-riches, self-made success story. "I'm mad Eddie," as he was known, repeatedly proclaimed that he was "mad" about big government—particularly federal programs that taxed him to help poor people, who should help themselves by becoming oil entrepreneurs like him. It's simple, he instructed in the tagline to his tirades, "If you don't own an oil well, get one."



Well, maybe you can't afford an oil well, but what if you could own something even bigger—an entire electric utility? What if you controlled an energy business that's also an economic development engine *and* a grassroots force for advancing social justice. You wouldn't own it all by yourself, but you would indeed be a full-fledged owner, with a voice on everything from hiring to setting rates, from green energy to community investment.

This empowering populist possibility has quietly existed for millions of Americans since 1937, when FDR's New Deal helped people create a vast network of member-owned and -run rural electric cooperatives (RECs). While the barons of corporate-owned utilities serviced densely populated, easy-to-wire cities, they ignored rural areas as unprofitable, leaving families, businesses, schools, and communities literally in the dark. Co-op ownership offered a bridge across this rural gap in our country's vital infrastructure—and the people rushed to cross it. Before the New Deal, some 90% of farm families had no electricity. By 1953, just 16 years later, more than 90% of them were wired, opening rural America to a world of new economic, social, and cultural opportunities.

Today, the nearly 900 RECs across the land remain powerful community engines. Owned not by Wall Street hucksters, but by local members, they:

- Provide electric power to some 42 million member/owners in 47 states (including in 93% of US counties with persistent poverty).
- Collect $45 billion a year in revenues.
- Own and maintain 42% of our electric distribution lines (covering 75% of the USA's land mass).
- Own nearly $175 billion collectively in assets.
- Maintain a $4-billion-a-year payroll—providing pay checks for some 71,000 rural employees.

ENERGY DEMOCRACY

Co-op electricity has transformed rural America, but the co-ops offer something even more electrifying: democratic power.

THE BATTLE OF CHOCTAW ELECTRIC CO-OP

For a gross example of corruption, deceit, and rigged elections by a co-op board and its manager, Oklahoma's **Choctaw Electric Cooperative** was a grand-prize stinker. Though CEC is owned by the lower-income population in this farming/working class area, the co-op was assessing members the state's highest electric bills—unless you were a board member or top manager and secretly got lower rates.

Choctaw Electric had long ago lost its populist essence, operating instead as just another monopolistic corporation run by an aloof clique of "upstanding citizens." With no real voice, members mostly quit paying attention. As one put it, "We just paid the electric bill and fussed about how high it was, and just went on about our business."

That is, until 2014, when member Doug Felker inquired about how much CEC's rates could be cut if the co-op switched from coal-generated electricity to solar. He was told: *Go away.* He didn't. Knowledgeable and persistent, this member-owner pressed further on basic finances, but the board refused to explain how bills were calculated or to share the co-op's tax returns with him and other owners. *This stinks,* he thought. *What else are they hiding?*

Felker set up a Facebook group, and thousands of members quickly echoed his concerns about board shenanigans. A core group began digging ... and the stench grew worse as they uncovered such "leadership expenses" as vacations and personal purchases charged to the membership. Then members were stunned to discover they'd been taken on a long joy ride by co-op CEO Terry Matlock, a respected church deacon, former state representative, and all-around good ol' boy. Matlock's crude indiscretions included billing members for "escort services" on out-of-town trips and for using co-op employees and heavy equipment on his personal property. The big shocker, though, was the discovery of a furtive set of books that included board authorization of a super-secret gift of $1.2 million to Matlock. As one of the group's diggers icily put it: "They increased our meter charge to give him that."

Still, the board backed its CEO, so the co-op owners had one recourse: Remove all nine board members. The bylaws required the signatures of 10% of members, but Matlock and the board refused to say how many that was. So the group did it the hard way, going door to door in the towns and remote farms in this six-county region, making calls, attending festivals, going wherever needed to gather signatures. "We just hammered, hammered, hammered," says one of the rebels. At first the board laughed. Then they panicked and lashed out at their own members. Then they tried to assuage the people's anger by firing their million-dollar CEO!

But the increasingly outraged members saw that the entire clique was corrupt and had to go. So they pressed on, finally getting twice the number of petitions needed to recall the whole bunch.

Victory? Not yet. The tyrannical slicks pulled one more trick: One by one, they resigned and appointed buddies in their places, replicating the old board but with new faces, and thereby invalidating the assiduously collected recall petitions.

Defeat? Never. The reformers shifted to the upcoming board elections, putting up five of their own team against the board incumbents and proposing new democratic bylaws. The campaign was long and hard, but the large turnout produced a landslide victory for the entire reform slate—finally restoring member authority over the Choctaw Electric Cooperative. As one of the group summed up the result: **"Everybody working together is what got it done."**

And that is exactly what co-ops are all about.

**Hat tip to We Own It (weown.it) for this story—and for all it does to support member-owners in battles against entrenched co-op boards.*

By law, every household that uses the electricity is a member and can vote for a board that has actual decision-making authority to control resources including cash flow, good jobs, a customer base, facilities, and financial acumen. Moreover, unlike the corporate ethic of "shareholder supremacy" (in which maximizing profits of investor elites reigns supreme), these decentralized, grassroots utilities were guided by an egalitarian ethic, formulated in 1937: the seven "Rochdale Principles" of cooperative organization:

- ✔ Voluntary and Open Membership
- ✔ Democratic Member Control
- ✔ Members' Economic Participation
- ✔ Autonomy and Independence
- ✔ Education, Training, and Information
- ✔ Cooperation among Cooperatives
- ✔ Concern for Community

With such a potent combination of power and principles—later expanded to include anti-discrimination, financial fairness, and other components—RECs can be a mighty force for helping rural Americans make broad-based social progress. Indeed, in the past 30 years, some RECs have formally expanded their official purpose from simply providing electricity to also investing in such community needs as solar power, high-speed internet, and financing for conservation retrofits. Many have put real money behind this vision. Since 1989, the federal agency that assists RECs has given more than $600 million in zero-interest loans and grants to co-ops that invest in development projects.

ODDITY Despite the strength and popular appeal of the co-op approach, RECs in regions where they are large and numerous (the South, Midwest, and Plains) have hardly been models of dynamic progress. Even when they face stagnant economies and widespread poverty, many co-ops charge exorbitant rates and cling to a toxic legacy of coal-fired power plants spewing pollutants.

What happened? In effect, these co-ops got co-opted, taken over by closed networks of entrenched rural power (bankers, real estate developers, ag-biz execs, old money families, trusted political retainers, *et al.*). These interests have steadily tightened their grip on these valuable utilities by using their financial power, social standing, and legal cunning—as well as crude voter suppression and outright thievery—to dominate board elections.

Once in, these clubish boards have proceeded to throw poor Rochdale out the window. Professional managers slide the decision-making and co-op books behind closed doors, they shift organizational focus from cooperative inclusiveness to condescending exclusion, and they assert that business intricacies are way too complex for mere members to mess with.

In co-ops like these, the term "member" has effectively been shriveled to mean powerless consumer … with no more clout than a member of Sam's Club. Thus, shut out of the governing circle, members lose pride of ownership and the will to participate, leaving the co-op a hollowed-out shell of its big democratic idea. A 2016 survey by the **Institute for Local Self-Reliance** found that 72% of America's REC board directors were elected by less than 10% of members.

The message from this top-down co-op management is the same one we get from corporate utilities: Be grateful you can flick on your lights—just pay your bill and leave the rest to us. Of course, in such corporatized co-ops, "us" doesn't include you and me.

WHO SITS ON THE GOVERNING BOARDS of the 313 southern RECs was revealed in a 2016 analysis produced by Wade Rathke of **ACORN International** and Ken Johnson of the grassroots training center **Labor Neighbor**. In many cases, **the results were astonishingly racist, sexist, and anti-democratic:**

In the 12 Old South states:

- 95% of the 3,051 REC board members were white, even though 22% of the co-op members were black. With only a few exceptions, the imbalance was so extreme that you'd think almost no African-Americans live there. In Louisiana, for example, where one-third of the population is black, only one of the 10 electric co-op boards included an African-American.
- Only 0.3% of board members were Latinx, despite being 10% of REC members; 10 of the 12 states had zero Latinx board members—and Florida, nearly one-fourth Hispanic, had just one Latinx on its 15 co-op boards.
- Women, a majority of co-op members, held only 10% of board seats.

Frozen in the power dynamics of the 1950s, these boards (along with many outside the South) have largely abandoned their historic democratic promise. Rather than serving as engines of upward mobility, grassroots prosperity, and civic enrichment for the rural majority who most need cooperative power, they've devolved into just another force for business as usual.

RE-MEMBER-ING THE MOVEMENT Being sad about this usurpation of co-op democracy is not a useful emotion. Better to be mad—and do something about restoring members to the center of cooperative power.

The time is now. After all, both the need and the cooperative remedy that spawned RECs some 80 years ago are present again. Widespread inequality is raging once more across our rural landscape, as is the spirit of democratic, populist rebellion. Luckily, the basic architecture of democratic co-op governance is also present and widely available—though not without determined grassroots effort. These enterprises still offer phenomenal potential for common Americans to become activist members and take charge of their economic and social destinies.

STEP 1: TAKE CHARGE OF YOUR CO-OP

This is an imperative undertaking for the *whole progressive movement,* because:

1. The long-ignored need for justice and equal opportunities in rural America (a place wrongly labeled "Trump Country") is enormous and growing more urgent.
2. RECs possess prodigious resources and collective abilities to enable the workaday majority to make real, lasting, structural change, thus providing a successful organizing model.

MONITORING CO-OP DEMOCRACY

Question: How have autocratic REC boards gotten away with openly stiffing their owner-members and flaunting the fundamental democratic principles of co-op organization?

Answer: Unlike unions, charities, and even corporations, co-op governance is virtually *unregulated and unsupervised.* The founding rationale was that member watchfulness would allow for self-regulation. But over time, the member-disempowerment tactics of entrenched boards rendered "member control" a farce. (Ostensibly, the Ag Dept.'s Rural Utility Service agency, IRS, Federal Energy Regulatory Agency, and a few state utility commissions have some oversight, but they are meek, understaffed, and ineffectual—with no bark, much less bite.)

So, it's back to the people. In 2010, reformers in Colorado pushed through a model state law requiring that co-op officials comply with standards of transparency and democratic procedures, including:

- Keep board meeting minutes and post them on co-op websites.
- Create and publicly post clear procedures for board elections.
- Make co-op membership lists available to all board candidates, not just incumbents.
- Post board members' contact info on co-op websites.
- Post meeting time, place, and agenda ten days before every board meeting.

Plus, reform activists want to make federal support—including economic development grants and loans for individual cooperatives—contingent on compliance with the rules of democratic governance.

Such basic guarantees should be a given, but sadly, when money and power are in play, enforceable rules are essential for protecting and advancing the co-ops' democratic ideals.

The Hightower LOWDOWN

VOLUME 21 ♦ NUMBER 9 ♦ OCTOBER 2019

Too many co-ops have gotten co-opted.

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PERIODICALS

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[redacted]

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❸ Despite the blatantly regressive, desperate tactics used by many current board members to cling to power, "outsiders" can win these low-turnout, relatively low-cost co-op elections by actively organizing in their communities.

In fact, in many service areas **they're already winning.** Out in the hinterlands of rural America—from the Rockies to Appalachia, Minnesota to Mississippi—gutsy groups of REC members have been mounting democratic rebellions against cliques of haughty (and powerful) directors and managers. These uprisings have been sparked by members discovering that their co-op administrators are butt deep in such outrages as self-dealing corruption, price gouging, embezzlement, rank racism, election rigging, dirty deals, and so awful much more. Infuriated, thousands of members from coast to coast have exclaimed: *Wait a minute, we own these things!* They've joined grassroots efforts to re-democratize in Choctaw (OK), Crow Wing (MN), Delta Montrose (CO), Roanoke (NC), Kit Carson (NM), Ouachita (AR), Pedernales (TX), and Valley (NV).

In addition to battling board autocracy and malfeasance, many local struggles seek to revitalize the innovative spirit that had made rural electrification such a success. Too much of today's REC hierarchy is stuck on old and filthy coal-fired technology and ignoring crucial new infrastructure needs that rural co-ops could be providing. Once again, ordinary members are rising up to demand (and increasingly to win) fights with recalcitrant managers to switch to cleaner, cheaper solar arrays and other renewable, less polluting sources; provide financing for bill-lowering, energy efficient retrofits for members' homes and businesses; establish high-speed, broadband internet service; and convert school buses and other public vehicles to electric power.

All of these democracy struggles against entrenched, elitist power are difficult, long, exacting, and uncertain—which is what makes them worthwhile and exciting to be in! The good news is that a nationwide movement is building to connect these extraordinary efforts to each other, to member training centers, to organizing resources … and to you and me.

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The good folks at the New Economy Coalition recently released their *Rural Electric Cooperative Toolkit* (***electriccooporganizing.org***) with resources for member-owners seeking to re-assert the democratic principles their co-ops were founded on. The NEC works for an "economy that meets human needs, enhances quality of life, and allows us to live in balance with nature." Doesn't that sound good? Check them out: ***neweconomy.net.***

Want to get in deeper? We Own It (***weown.it***) offers frequent webinars (such as "Rural Electric Co-ops 101"), reports (*e.g., Community Broadband Networks* and *The Economics of Clean Energy*), and inspiring videos—including one about the member victory at Choctaw Electric.

We Own It ponders the possibilites of co-ops: "With $3 trillion in assets, $650 billion a year in revenue, 2 million employees, and 130 million American member-owners, co-ops are everywhere. A just transition to a new economy, energy democracy, and climate justice runs through them."

Check out your own REC's financials, including board and executive pay, on its IRS Form 990, available on ***Guidestar.org.***

Sample forest products industry support letter. Signatures attached.

Redwood Coast Energy Authority
633 3rd Street
Eureka, CA 95501

October 11, 2019

RE: Comprehensive Action Plan for Energy ("CAPE")

Dear Sir/Madam:

I am writing this letter in support of the forest products industry in Humboldt County. As an employee or contractor currently earning a living in the forest products industry in Humboldt County it is important for me to pledge my support for the industry. I am familiar with the Redwood Coast Energy Authority county program and the benefits it offers county residents in terms of an option other than Pacific Gas & Electric, support of renewable energy, and support for the local economy. I would encourage the program to support local biomass energy and the local forest products industry for the long-term given the positive impact it provides to the county in terms of (i) jobs supporting both the residents and the county, and (ii) tax base to support county initiatives.

Please support local biomass energy.

Sincerely,

Employee/Contractor

Forestry products support letter signatures/names:

Letters received from Humboldt Redwood Company on November 7, 2019

1.	Jerrod S. McCluskey
2.	Suzanne [illegible]
3.	Stacie Nickerson
4.	Sincerely, [illegible] Employee/Contractor
5.	Pacifico Collamat Employee/Contractor
6.	Sincerely, [illegible]
7.	Sincerely, [illegible]
8.	Sincerely, [illegible]
9.	Ramon [illegible]
10.	Rocky [illegible]
11.	[illegible]
12.	Jim Masterson
13.	[illegible]
14.	Adam Figas

15.	Sincerely, Employee/Contractor
16.	Employee/Contractor
17.	pport local biomass energy.
18.	e support local biomass energy. erely,
19.	ctor
20.	
21.	ly,
22.	
23.	Employee/Contractor
24.	Sincerely, Employee/Contractor
25.	Sincerely,
26.	Sincerely,
27.	Sincerely,
28.	Employee/Contractor

29.	:ractor
30.	
31.	erely,
32.	
33.	
34.	
35.	

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To: Board of Redwood Coast Energy Authority (RCEA)
Date: October 14th, 2019
From:
Daniel L. Sanchez, PhD., Cooperative Extension Specialist; Department of Environmental Science, Policy, and Management, University of California Berkeley
Yana Valachovic, University of California Cooperative Extension County Director and Forest Advisor; Humboldt and Del Norte Counties

Dear RCEA Board,

As Specialists and Advisors with University of California Cooperative Extension, we wish to highlight the importance of continued use of local biomass as an energy source for Redwood Coast Energy Authority's (RCEA) renewable portfolio. Biomass power produces benefits for our local community, economy, *and* the environment.

Our support for bioenergy production in Humboldt County arises from its numerous benefits: clean energy, improved forest health, ambitious climate change mitigation, and rural job creation. We recognize that no energy source is perfect, but on the balance, locally produced and utilized biomass provides numerous public trust, environmental, and economic benefits. More information about the benefits of woody biomass and bioenergy is included in an appendix to this letter.

In the future, we expect innovation to create new wood utilization opportunities with the potential for enhanced economic and environmental benefits. However, focusing on new technologies ignores the role that current biomass power plants play in creating benefits at scale. Existing biomass power plants provide a backbone to accommodate the diversity of feedstocks that are available as California develops and deploys emerging technologies.

We urge RCEA to sustain their commitments to bioenergy produced electricity and to Humboldt County for both the near-term and long-term benefits.

Sincerely,

Daniel L Sanchez, Ph.D.

Yana Valachovic, RPF #2740

FAQs about Forest Biomass Energy in Humboldt

What are the benefits of energy made from forest biomass?

Forest-based biomass for this set of FAQs is defined as organic matter (materials from fuels reduction projects or the chips and bark from sawmill operations) that can be utilized to produce heat and power in emissions-controlled power plants that can provide clean energy, improved forest health, ambitious climate change mitigation, and rural job creation. **No energy source is perfect, but on the balance, locally produced and utilized biomass energy provides numerous public trust, environmental, and economic benefits** such as:

- ✓ Delivers distributed, flexible baseload generation. Biomass energy production provides a continuous 24-hour and reliable power source, unlike solar or wind that have a variation in daily and seasonal power production. Additionally, biomass power plants can be ramped up and down to meet the needs of the grid.
- ✓ An essential tool in the promotion of healthy forests and defensible communities through fuel reduction strategies for diseased and over-crowded forests that contribute to large and high intensity wildfires.
- ✓ Reduces emissions from wildfires or burn piles. Biomass power plants include effective air quality emissions technologies. Biomass emissions are substantially lower than wood stoves, wildfires, or burn piles[1].
- ✓ Reduces greenhouse gas emissions. Bioenergy production using materials from sustainably managed forests reduces long-term climate impacts by replacing fossil fuel energy sources.
- ✓ Utilizes a local product. The ability for forest landowners to sell logs to local sawmills provides an economic incentive to steward and sustainably manage local forests. Furthermore, farmers use the ash produced as an organic soil amendment.
- ✓ It's renewable. Unlike coal, oil and natural gas, which are fossil fuels that bring "new" carbon into the earth's atmosphere, biomass is an abundant and renewable source of fuel. The burning of biomass and the growth of trees creates a closed-loop system and does not contribute additional long-term atmospheric carbon. In Humboldt County biomass operations turn wood waste into electricity without compromising the essential cultural and habitat values that forests provide.

Is biomass clean energy?

There is no universally accepted definition of clean energy. Definitions can incorporate life cycle analysis, social justice, and other externalities. Nevertheless, the vast majority of scientists and governments classify biomass as both a clean energy and renewable (i.e. non-fossil fuel) source. The State of California defines biomass as a renewable energy resource along with solar, wind, geothermal, small hydro, renewable methane, ocean wave, ocean thermal, or fuel cells[2].

When bioenergy is made from locally grown small diameter trees and shrubs or the byproducts of sawmill operations it is a clean energy source. Not only do trees convert solar energy into fixed carbon, they store energy organically with far lower environmental impact than fossil fuels or batteries. This naturally fixed carbon and energy may then be managed as habitat in the forest, harvested for use as a building material, or

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[1] Springsteen B, Christofk T, York R, Mason T, Baker S, Lincoln E, Hartsough B, Yoshioka T. 2015. Forest biomass diversion in the Sierra Nevada: Energy, economics and emissions. Calif Agr 69(3):142-149. https://doi.org/10.3733/ca.v069n03p142.

[2] https://focus.senate.ca.gov/sb100/faqs

utilized as energy in a biomass power plant. Burning biomass for bioenergy production is importantly distinguished from burning fossil fuels in that *biomass is part of the actively cycled carbon in the atmosphere and was sequestered within the past 40-100 years, while fossil fuels reintroduce carbon into the atmosphere that were sequestered 60-200 million years ago and now are being reintroduced into the atmospheric carbon cycle*.

All clean energy sources have an important role to play in fighting climate change and producing renewable energy. In this regard, biomass energy provides many advantages beyond its renewable electrons, especially when fuel is sourced from the local area. From producing long-lived building materials that sequester carbon, to generating renewable heating, cooling, and power in local communities, strategic biomass utilization can support the interrelated goals of forest health, forest carbon sequestration, water and air quality, creating and maintaining local jobs, as well as keeping forests healthy for everyone's enjoyment and recreation.

How does biomass support forest health?

The fire seasons of 2017 and 2018 in California[3] have been a reality check for many, forcing a collective understanding that forest management plays a key role in wildfire risk reduction. In California alone, at least 129 million trees have died since 2010, due to a combination of fire suppression leading to overstocked and dense forests[4], drought, and pests. Managing the large number of dead trees is a difficult challenge, particularly within the context of protecting rural California residents. In January 2019 the Governor charged CAL FIRE and the Natural Resources Agency with the task of reducing fuels to protect our most vulnerable communities. CAL FIRE estimates that 15 million acres need forest restoration[5] and recognizes that "while it is not possible to eliminate wildfire risks in California; focused and deliberate action can protect communities and improve forest and fuels conditions to enable a more moderate and healthier wildfire cycle that can coexist with Californians". These challenges are not limited to the Sierra Nevada and are common throughout California including the North Coast.

The North Coast is blessed and burdened with highly productive forest and plant growth. However, all living vegetation is part of the natural carbon cycle and its fate is eventual carbon release either through decomposition or wildfire. The question is when and how? Management of this growth in the form of forest fuels reduction and the reduction of stand densities are important steps to creating more fire resilient forests and reducing uncontrolled emissions of greenhouse gasses and Short-Lived Climate Pollutants, including black carbon, during wildfires. Over the coming decade California will see an enhanced level of fuel reduction through mechanical and prescribed fire techniques and a broader level of incentives to manage fuel backlogs and improve forest health. Bioenergy utilization with emission-control technologies is an important part of the solution and provides an alternative to open-pile burning[6] of forest fuels and prescribed fire.

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[3] Governor's Executive Order N-05-19 https://www.gov.ca.gov/wp-content/uploads/2019/01/1.8.19-EO-N-05-19.pdf and the state emergency declaration http://www.fire.ca.gov/general/downloads/45-DayReportPlans/3.22.19-Wildfire-State-of-Emergency.pdf

[4] Parsons and DeBenittie (1979) Impact of fire suppression on a mixed-conifer forest. Forest Ecology and Management 21: 21–33.

[5] CAL FIRE 45 Day Report. http://www.fire.ca.gov/downloads/45-Day%20Report-FINAL.pdf

[6] Springsteen B, Christofk T, York R, Mason T, Baker S, Lincoln E, Hartsough B, Yoshioka T. 2015. Forest biomass diversion in the Sierra Nevada: Energy, economics and emissions. Calif Agr 69(3):142-149. https://doi.org/10.3733/ca.v069n03p142. http://calag.ucanr.edu/Archive/?article=ca.v069n03p142

How does forest biomass utilization support climate change mitigation?

Biomass utilization produces important climate change mitigation benefits, both by sequestering carbon and displacing carbon-intensive products. Executive Order B-55-18 'To Achieve Carbon Neutrality', issued by Governor Brown on September 10, 2018, places California on a path to net-neutral economywide emissions by 2045[7]. Carbon sequestration from forest biomass will be essential to achieving this goal, as carbon stored in living trees or wood-based lumber products can help with long-term sequestration and to offset emissions from hard-to-decarbonize sectors such as aviation, long-distance trucking, and agriculture. Further, biomass power plants support removal of hazardous forest fuels that are otherwise placing these carbon stores at risk.

Furthermore, forest biomass has an important role to play in carbon sequestration. In the near-term, maintenance of bioenergy markets will help to make reducing forest fuels economically feasible thereby helping California's forests become more resilient to wildfire or other disturbances. In the future, RCEA and other energy consumers may be able to procure net carbon-negative electricity from biomass, which permanently removes CO_2 from the atmosphere. For instance, numerous scientists and policymakers recognize that biomass utilization combined with carbon sequestration (commonly referred to as BECCS—Bio-Energy with Carbon Capture and Storage) will be necessary if we are to keep global warming significantly below 2 degrees Celsius. Supporting biomass energy through power purchase agreements and other procurement mechanisms can help drive the deployment of BECCS technologies in California as they become commercially viable.

Finally, many recognize that a "portfolio" approach to fighting climate change produces large economic benefits in comparison to those that rely solely on a limited number of energy sources[8,9]. Biomass, alongside other complimentary renewable energy sources, can play an important role in achieving cost-effective climate change mitigation.

How does the State of California view biomass and forest carbon?

California's Forest Carbon Plan, released in 2018, embraces biomass utilization as a key driver of sustainable forest management[10]. Key findings include:

- Reducing carbon losses from forests, particularly the extensive carbon losses that occur during and after extreme wildfires in forests and through uncharacteristic tree mortality, is essential to meeting the state's long-term climate goals. Fuel reduction in forests can increase the stability of the remaining and future stored carbon.
- The limited infrastructure capacity for forest management, wood processing, and biomass utilization, and the limited appropriately trained or licensed supporting workforce, are major impediments to forest restoration and ongoing forest management.

Near-term actions proposed by the State include:

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[7] https://www.gov.ca.gov/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf

[8] D.L. Sanchez, J.H. Nelson, J. Johnston, A. Mileva, D. Kammen. "Biomass enables the transition to a carbon-negative power system across western North America." *Nature Climate Change*, 5, 230–234 (2015).

[9] S.J. Davis *et al.* (with over 30 authors) "Net-zero emissions energy systems" *Science* (2018). http://science.sciencemag.org/node/711939.full

[10] Forest Climate Action Team. 2018. California Forest Carbon Plan: Managing Our Forest Landscapes in a Changing Climate. Sacramento, CA.

— Expand wood products manufacturing in California and take actions to support market growth scaled to the longer-term projections of forest productivity and resource management needs.
— Continue public investment to build out the 50 megawatt (MW) of small scale (5MW or less sized facilities), wood-fired bioenergy facilities mandated through SB 1122 (Rubio, 2012).
— Maintain existing bioenergy capacity at a level necessary to utilize materials removed as part of forest restoration and to support long-lived storage of carbon in building materials.

What role does biomass have in rural job creation?

Biomass utilization creates economic opportunities locally[11]. Forest management and restoration activities cannot be outsourced and produce many living wage jobs in our local communities. These jobs include forest management, forest operations, trucking, processing, and other value-added operations. The many steps involved in bioenergy production require that workers be employed to operate each link of the supply chain. By having an integrated infrastructure rural development persists providing both near- and long-term economic benefits.

Does biomass utilization emit greenhouse gasses?

Yes, combustion of woody materials emits CO_2, however, these gases are already in the atmospheric carbon pool as opposed to releasing stored carbon from the fossil fuel pool (e.g. utilizing coal or natural gas for energy production). In short, utilization of organic sources of carbon for building materials or sources of energy is a part of a closed loop carbon cycle. When trees emit carbon from decomposition or through combustion in a wildfire, carbon is made available as CO_2 and can be sequestered from the atmosphere through photosynthesis into new organic forms.

Is biomass power the best means of handling the waste stream generated by our local forest products industry?

Yes, at present, power produced from the utilization of feedstocks from sawmill operations is the best means to utilize this material because:

— The utilization of chips, bark, sawdust, and other smaller pieces of wood to produce heat and power in emission-controlled power plants allows for utilization of a **diversely-sized feedstock** with a range of moisture contents. Other utilization options are not as flexible in their size or moisture variation.
— This material is abundant in our **local** region and does not require the importation of other feedstocks.
— Biomass energy complements other **higher value markets**, including using chips to produce pulp and paper, using bark and chips for landscape mulch, using sawdust for compost manufacturing, and using shavings for animal bedding. Bioenergy is part of a broad solution for the sustainable and renewable use of locally available woody materials. When no other higher value markets exist, the remaining residuals are used for energy production.

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[11] Henderson, James E.; Standiford, Richard B.; Evans, Samuel G. 2017. Economic contribution of timber harvesting and manufacturing to north coast redwood region counties. In: Standiford, Richard B.; Valachovic, Yana, tech cords. Coast redwood science symposium—2016: Past successes and future direction. Proceedings of a workshop. Gen. Tech. Rep. PSW-GTR-258. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 371-381.

- Looking for new and creative technologies and markets is encouraged and over time, these markets may include composting, gasification, or other uses (see discussion below). However, at present these markets do not exist at scale in Humboldt or within reasonable transportation distances.

In the medium- to long-term, new, innovative wood products could provide enhanced climate benefits and enhanced revenues from forest products. To this end, California has founded the Joint Institute on Wood Products Innovation[12] to serve as a center for analysis, testing, and outreach to support industry retention and development in California for new wood products. The work of the Institute will support long-term ecological and economic sustainability, increase forest resilience, long-term carbon storage, and local economies.

Should we be looking to emerging technologies such as gasification to keep using biomass as a power source?

Gasification is a process that converts organic materials into carbon monoxide, hydrogen and carbon dioxide. This is achieved by reacting the material at high temperatures (typically >700 °C), without combustion, with a controlled amount of oxygen and/or steam. Wood gas is a syngas fuel which can be used as a fuel for furnaces, stoves and vehicles in place of gasoline, diesel or other fuels. Biochar is a coproduct.

It is always valuable to look for higher value options and to test emerging technologies. However, gasification technology has not been deployed at scale yet to process the amount of available sawmill residues and requires a uniform feedstock free of soil and rocks. Moisture management of the feedstock is also critical. Some of the sawmill residue could be diverted to a gasification plant, but it would require a significant capital investment and tight controls on the feedstock quality.

An additional question is what is the lifespan of a biomass power plant and what modifications and improvements can be reasonably expected or are feasible? Furthermore, do these plants really age out or can they be upgraded when new emission control technologies become available? At present both DG Fairhaven and Scotia have invested significant capital into emission control technology upgrades and are operating within their existing air quality permits requirements.

Should we be continuing with the existing centralized power plant approach or looking to more decentralized emerging technologies?

Yes, we should explore emerging technologies and yes, we should recognize the value that the existing power plants provide as a backbone to accommodate the diversity of feedstocks that are available. There are challenges to financing and permitting new facilities that also need to be evaluated and it is important to recognize that innovation takes time. A recent example was the proposed development of a BioRAM eligible 5 MW biomass plant in Arcata that was derailed when PG&E required the developer to fund an additional $6 million upgrade of the PG&E substation. It could be viewed from a “bird in the hand is worth two in the bush” perspective where we are certain in what we have and there is no guarantee that future technologies will perform adequately or at scale. Permitting and capital investments for building new

[12] https://bof.fire.ca.gov/board-committees/joint-institute-for-wood-products-innovation/

infrastructure will likely continue to be a large barrier to deployment of emerging bioenergy technologies across the State and in the North Coast.

What can be expected if the existing power plants close?

- An immediate logistical challenge to divert the ~100-120 truckloads a day to Wheelabrator Shasta (in Anderson, CA), the closest biomass facility, and assuming they would take the material. This is a 300+ mile round trip haul. There are not enough trucks available to move this material.
- In the longer term, forest landowners, managers, and product manufacturers would be affected as these sectors shrink. Specific Humboldt groups include:
    - Manufacturing: Humboldt Redwood Company, Green Diamond, Mad River Lumber, North Fork Lumber, Schmidbauer Eureka, Pacific Clears, CW Wood, Arcata Lumber Products
    - Landowners of all sizes, including all small forested landowners, Bureau of Land Management, State and National Parks, USDA Forest Service, conservation organizations, etc.
    - Municipal compost facilities such as Arcata, Humboldt Waste Management Authority, Recology, etc.
    - Many licensed timber operators and trucking companies
    - And any further development of the forest products manufacturing sector. It is reasonable to assume there would be a contraction of this sector if the biomass power plants closed.

Could the sawmill residues be utilized for compost?

While compost is a promising option for wood waste, the industry faces a number of barriers to reaching scale. As a result, only smaller amounts of biomass can be utilized for compost. With the county's daily production of ~100-120 truckloads of biomass a day, there is no existing option available at scale. HRC alone produces 70-100 chip vans per day (5 days/week) of this material. It would take 2.65 days to fill a football field (120 x 53 x 5 yards) to a height of 15 feet with the volume of material that HRC generates. Storing large amount of chips present fire hazards because the decomposition process releases heat and fires are common. An additional challenge is that the local compost industry is currently experiencing a contraction. Finally, some portion of the compost will decompose and emit CO_2 and methane over time and the carbon will not be permanently sequestered.

Is biomass energy more expensive than other renewables?

Community-scale biomass facilities in California are currently receiving 12.7 to 19.7 cents per kilowatt (kWh) hour of power; RCEA is currently paying 6.5 cents per kWh for power from DG Fairhaven and Scotia. In contrast, distributed solar is typically 6 to 7 cents and large scale solar is 3-4 cents per kWh[13]. Biomass provides 24-hour base-load generation unlike wind and solar. If power needs were calculated on a 24-hour framework, wind and solar need other complementary sources to meet daily power demands. This is why biomass is an important Resource Adequacy tool for load serving entities. Right now, half of California's electricity comes from natural gas - so storage is not a problem because the gas provides both storage (gas can be stored) and generation- but as we phase out fossil fuels, solar and wind will increasingly require energy storage to meet demand.

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[13] Julia Levin Per. Comm., Bioenergy Association of California

The energy storage needed to fill in around solar costs 25 to 50 cents per kWh. When the cost of battery storage is added to the costs of solar, then biomass has a competitive advantage. Furthermore, battery technology is still in development and their longevity and life cycle needs to be included in our analyses. As California fully decarbonizes its economy and phases out fossil fuels, bioenergy will become increasingly cost competitive. This is due to both its flexibility, and its ability to sequester carbon from the atmosphere.

Is RCEA providing a "subsidy" to the timber industry by purchasing power from biomass from the two power plants?

It could be viewed from that perspective; however, biomass produces numerous local benefits to offset its perceived higher cost. Biomass is the primary locally available and renewable power source, a key consideration for RCEA and meets Resource Adequacy standards. Minimal trucking and processing is required to utilize this source and new infrastructure does not need to be built. Biomass utilization is providing many community benefits including: an ability to steward and improve the resiliency of our forestlands, job creation; tightly controlled emissions of low-value forest residues; disposal of urban organic wastes; and a reliable source of 24-hour power that meets local energy demands.