

Learning from Biomass Supply Chains

Forest Biomass Feedstock for Biomass Powerplants

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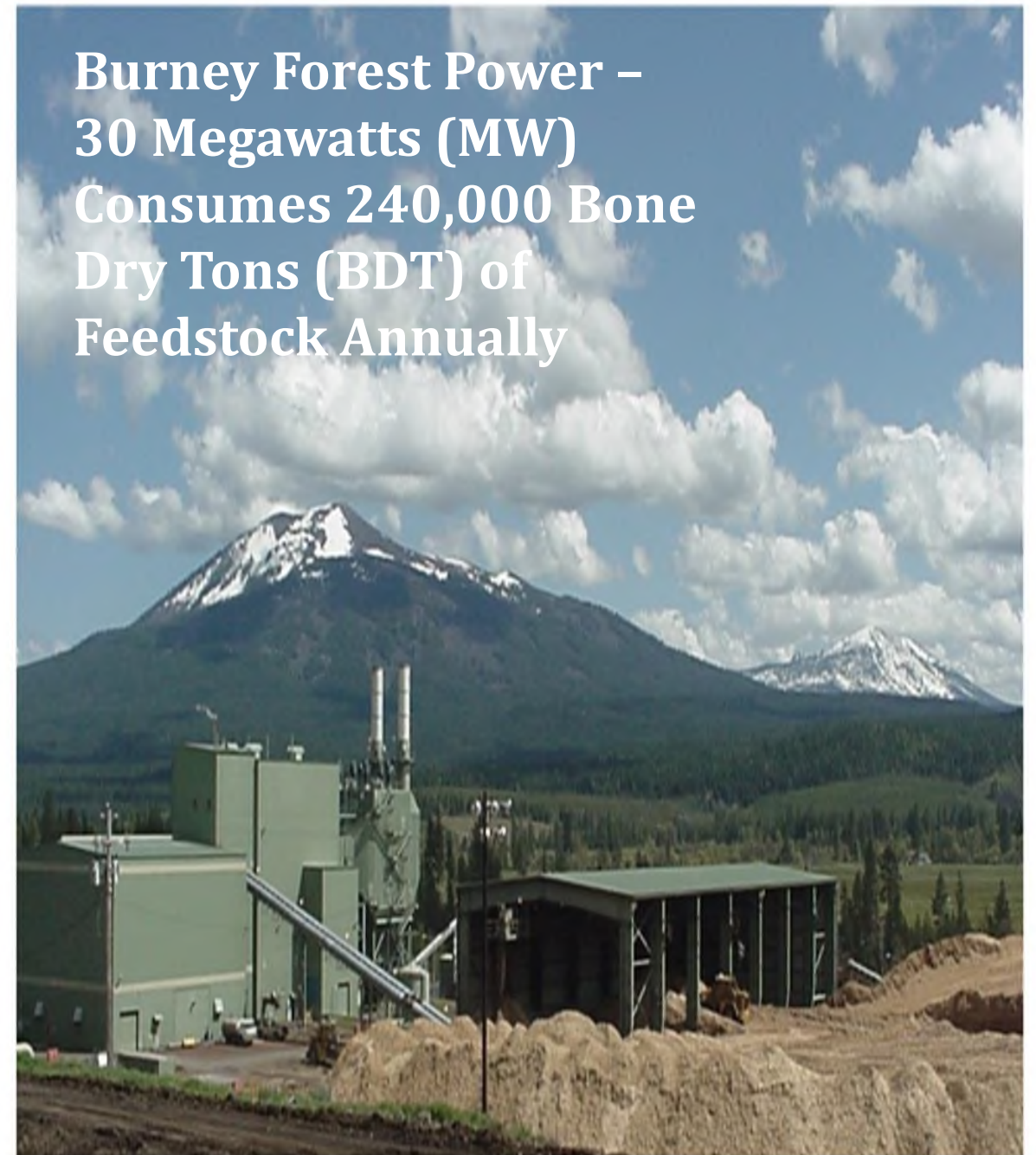
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BIOMASS POWERPLANTS

- **Existing Biomass Powerplant Industry**
- **Relative Abundance and Distribution of Forest Biomass Feedstock**
- **Methods, Costs, and Constraints of Obtaining Forest Biomass Feedstock**
- **Regulatory Constraints and Incentives to Acquisition and Use**
- **Innovative Solutions**

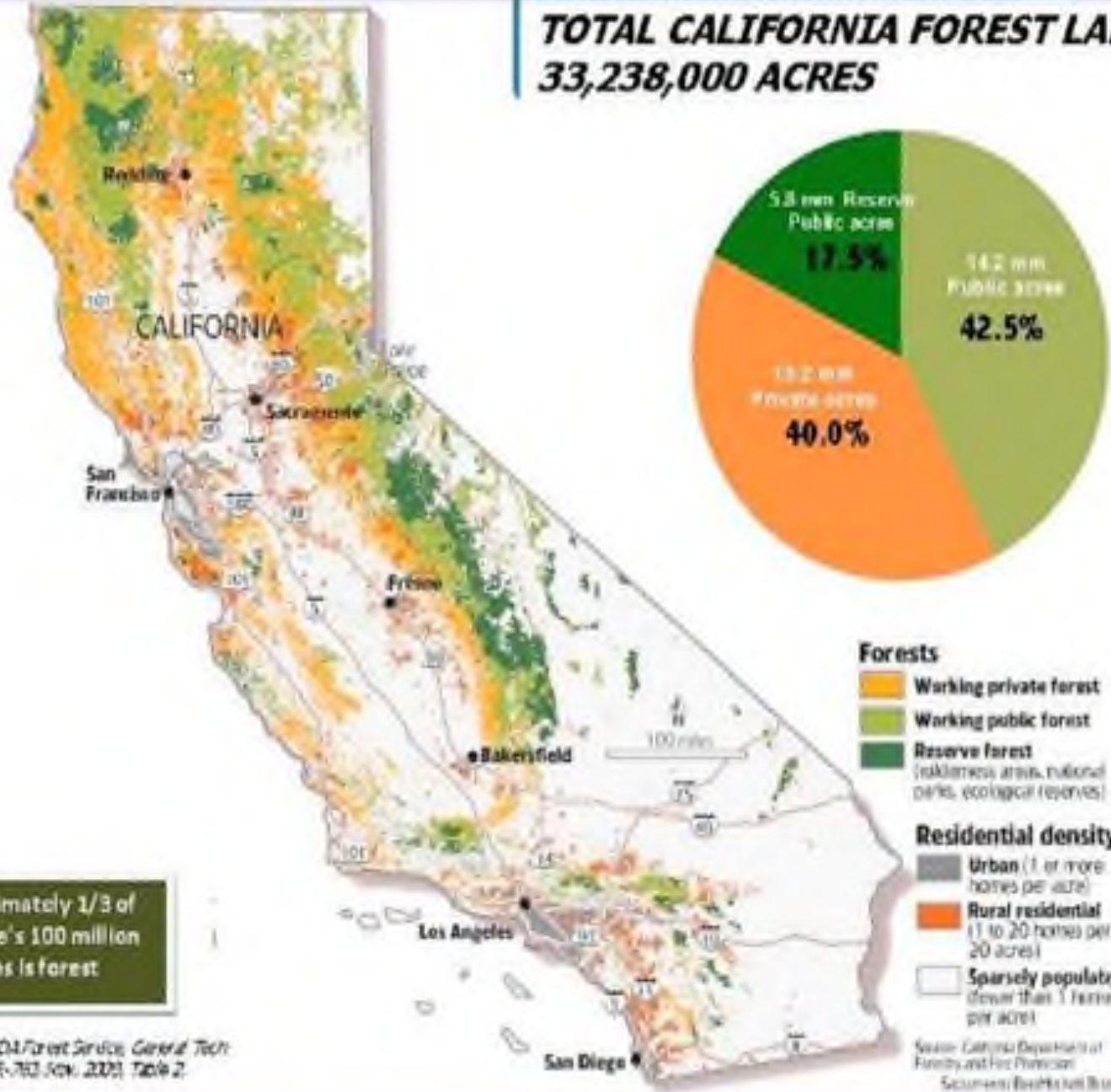


Existing Biomass Powerplant Industry

- **14 Stand-Alone + 8 Co-Gen – Total 22 Operating Powerplants with 562 MW of Operating Capacity (consumes total of 4.5 million Bone Dry Tons (BDT) of Feedstock/Year)**
- **12 Idle Powerplants with 257 MW of Operating Capacity (Potential to Consume 2 million BDT of Feedstock/Year)**



**TOTAL CALIFORNIA FOREST LAND
33,238,000 ACRES**



Distribution of Forest Biomass Feedstock (Light Green - National Forest
Light Orange - Private Forest)

Bakersfield to Oregon Border

Approximately 1/3 of the state's 100 million acres is forest

Data source: USDA Forest Service, General Tech. Report RM-194 GTR-763 (Nov. 2003), Table 2.

Source: California Department of Forestry and Fire Protection, Sacramento Forest Health Bureau.



**Typical National Forest
Pre-treatment Conditions**

Relative Abundance of “GREEN” FOREST BIOMASS Feedstock

**Forest Biomass generated from
Mechanical Thinning on National
Forests annually
= 1.1 million Bone Dry Tons
(BDT) (138 Megawatts (MW))**

**Private Land Forest Biomass
generated from Timber
Harvesting annually
= 1-2 million BDT (125-250 MW)**

**Saw/Veneer Mill Residues = 1.1
million BDT (138 MW)**



Forest – No Fuels Reduction



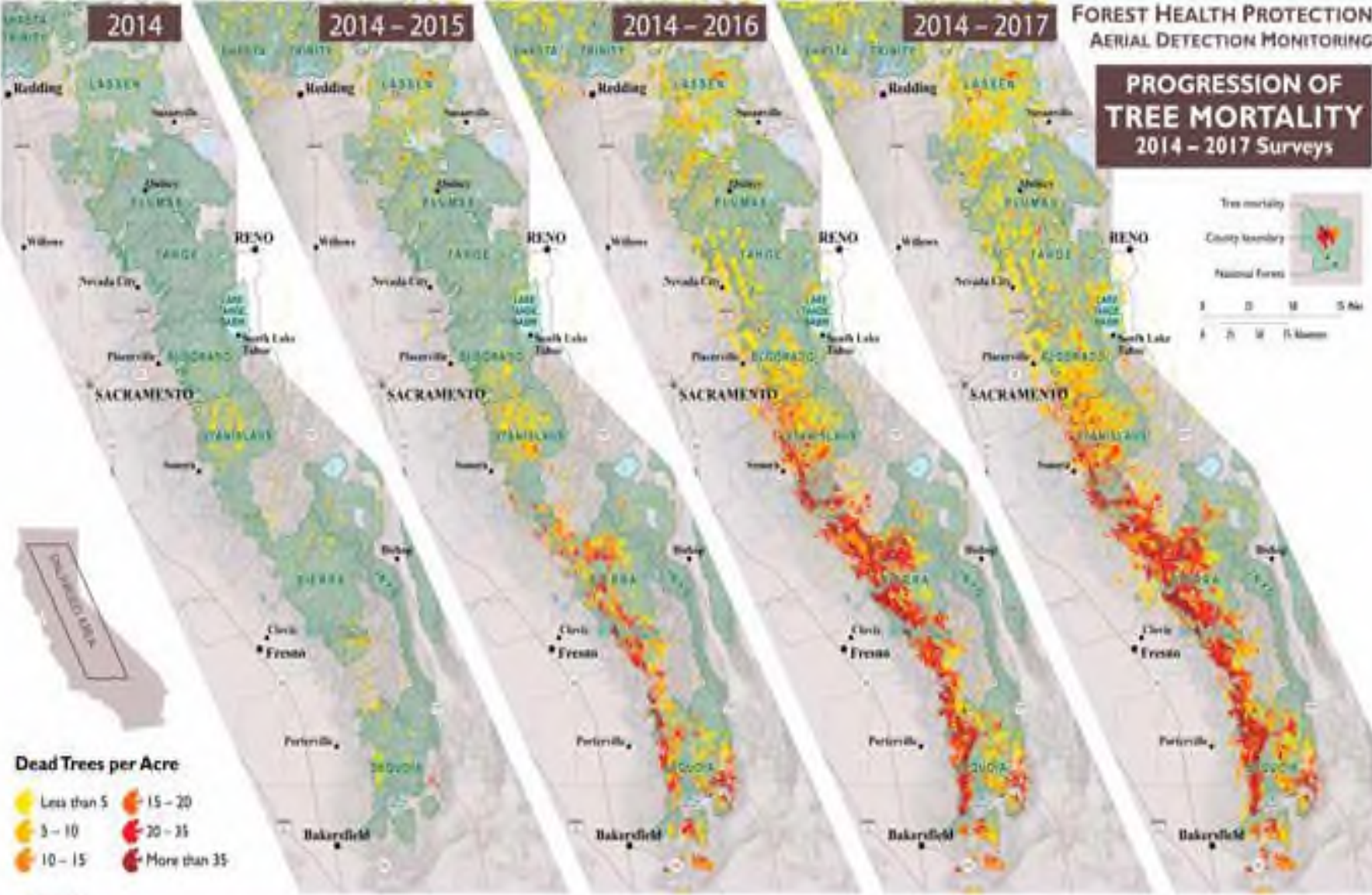
National Forest Mechanically Thinned

GREEN FOREST BIOMASS Pile

**1 Bone Dry Ton
(BDT) = about 2
green Tons**

**8,000 BDT = 1
Megawatt (MW)
of Electric Power**




 FOREST HEALTH PROTECTION
 AERIAL DETECTION MONITORING

**PROGRESSION OF
 TREE MORTALITY
 2014 - 2017 Surveys**

Tree Mortality – Central and Southern Sierras

**75% of Tree Mortality is from
 Interstate 80 south to
 Bakersfield**

**The Sierra National Forest
 east of Fresno has 760,000
 acres (75% of the entire
 Forest) impacted**

**Standing Beetle-Killed Trees
 are beginning to rot off
 sufficiently at the base to fall
 over**

**In the high severity beetle-kill
 zone (Sonora-Bakersfield),
 there is up to 50 Bone Dry
 Tons of dead trees/acre**

Dead Trees per Acre

Less than 5	15 – 20
5 – 10	20 – 35
10 – 15	More than 35



***Abundance of Insect
and Disease Killed
Trees***

**Central and
Southern
Sierras alone have
over 3.9 million
acres impacted
containing 96
million dead trees
with about 50
million bone dry
tons of beetle-killed
trees**

2 Primary Forest Biomass Disposal Options

Open Field Pile Burning



Controlled Combustion in a Biomass Powerplant Boiler



Comparison of Emissions Between Biomass Boilers and Open Field Burning

Pollutant	Field Burning (lb./Ton)	Biomass Boiler (Lb./Ton)	% Reduction for Biomass Boiler (Percent)
Sulfur Oxides	1.7	0.04	97.6%
Nitrogen Oxides	4.6	0.70	84.8%
Carbon Monoxide	70.3	0.40	99.4%
Particulates	4.4	0.26	94.1%
Hydrocarbons	<u>6.3</u>	<u>0.00</u>	<u>100.0%</u>
Total	87.3	1.40	98.4%

Methods/Costs of Forest Biomass Removal

Cut, Skid, Delimb, Pile

\$30/BDT (Generally paid for from green tree thinning lumber value)

Load and Haul Commercial Size Trees



Costs of Forest Biomass Removal (Cont'd)

- **Chip, Load**
\$26/BDT



- **Haul (\$110/hour Chip Van)**
(about \$40/BDT)



Total Cost of Forest Biomass Delivered to a Powerplant

Cut, Skid, Pile (Limbs, Tops, Small Trees & Brush)	\$30/BDT
Chip and Load	\$26/BDT
Haul	<u>\$40/BDT</u>

Total Forest Biomass Delivered Cost = \$66-96/BDT (lower amount of green tree thinning has sufficient commercial size trees to pay for getting biomass into a pile)

6.6 to 9.6 cents/kW-hr Forest Biomass Feedstock delivered +
6 cents/kW-hr to own, operate, maintain, repair, and routinely retrofit a Biomass Powerplant

Total = \$12.6-15.6 cents/kW-hr compared to Wind/Solar at 5 cents/kW-hr

Regulatory Constraints and Incentives to Acquisition and Use

Incentive?

How to get Forest Biomass (12-15 cents/kW-hr) competitive with 5 cent/kW-hr Wind/Solar?

98% reduction in Emissions by consuming wood waste in a Biomass Boiler compared to Open Field Pile Burning

The published monetized value of the emissions reduction is 11 cents/kW-hr (Environmental Benefit)

About \$5/month on a residential Electric Bill in the form of a Public Goods Charge

Most Promising Innovation

- **Wood-Based Nanotechnology**

- **The Microfibrils from cellulose have exceptional strength and flexibility**

- **Products that Microfibrils can be used for:**

- 1) Reinforced Concrete (up to +26% strength)**

- 2) Flexible Electronics; single crystal silicon nanomembranes for thin film Transistors, . . .**

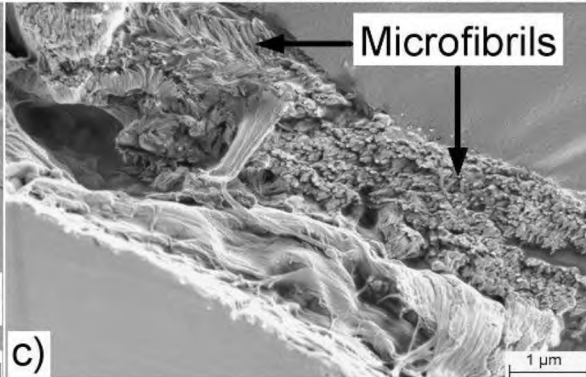
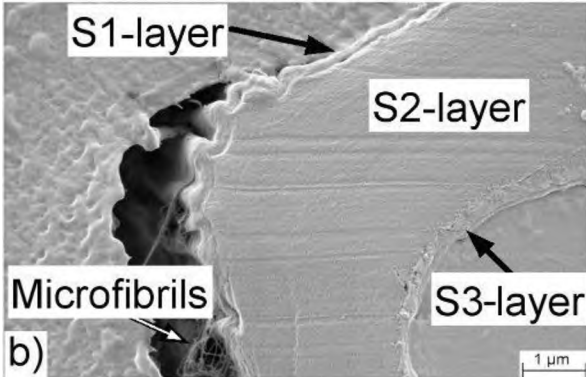
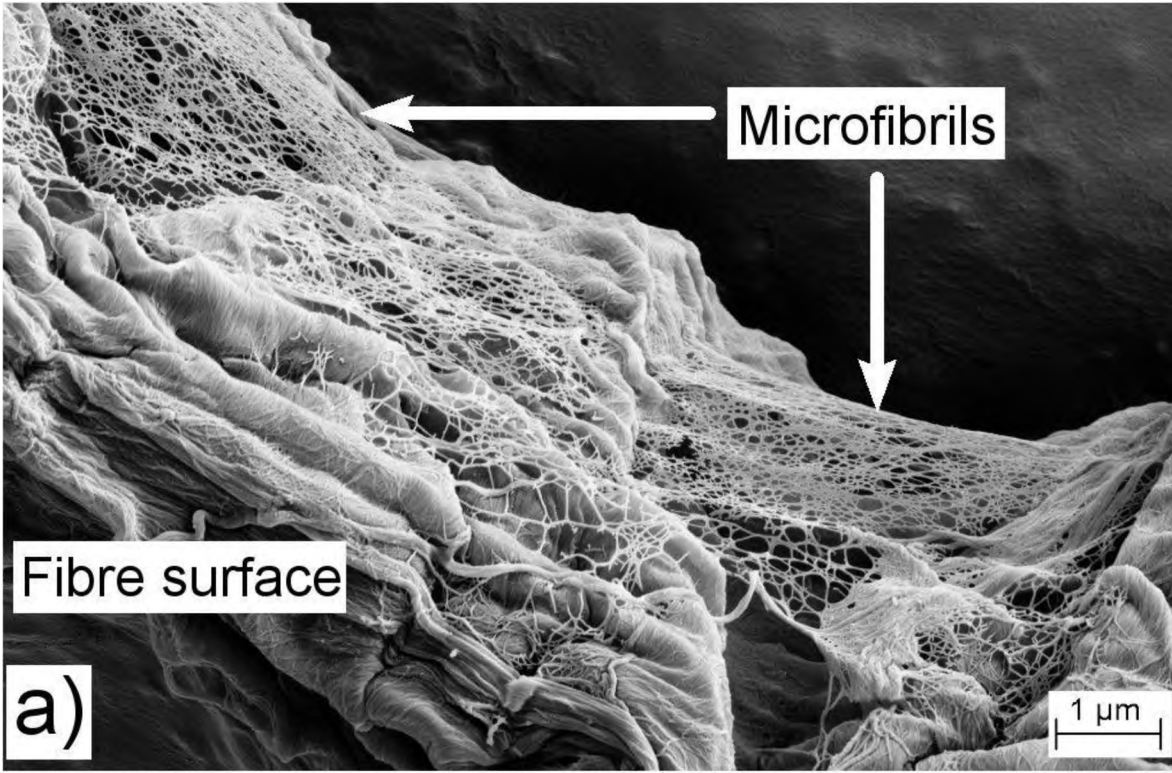
- 3) Advanced electrodes for solar cells and generating hydrogen fuel**

- 4) . . .**

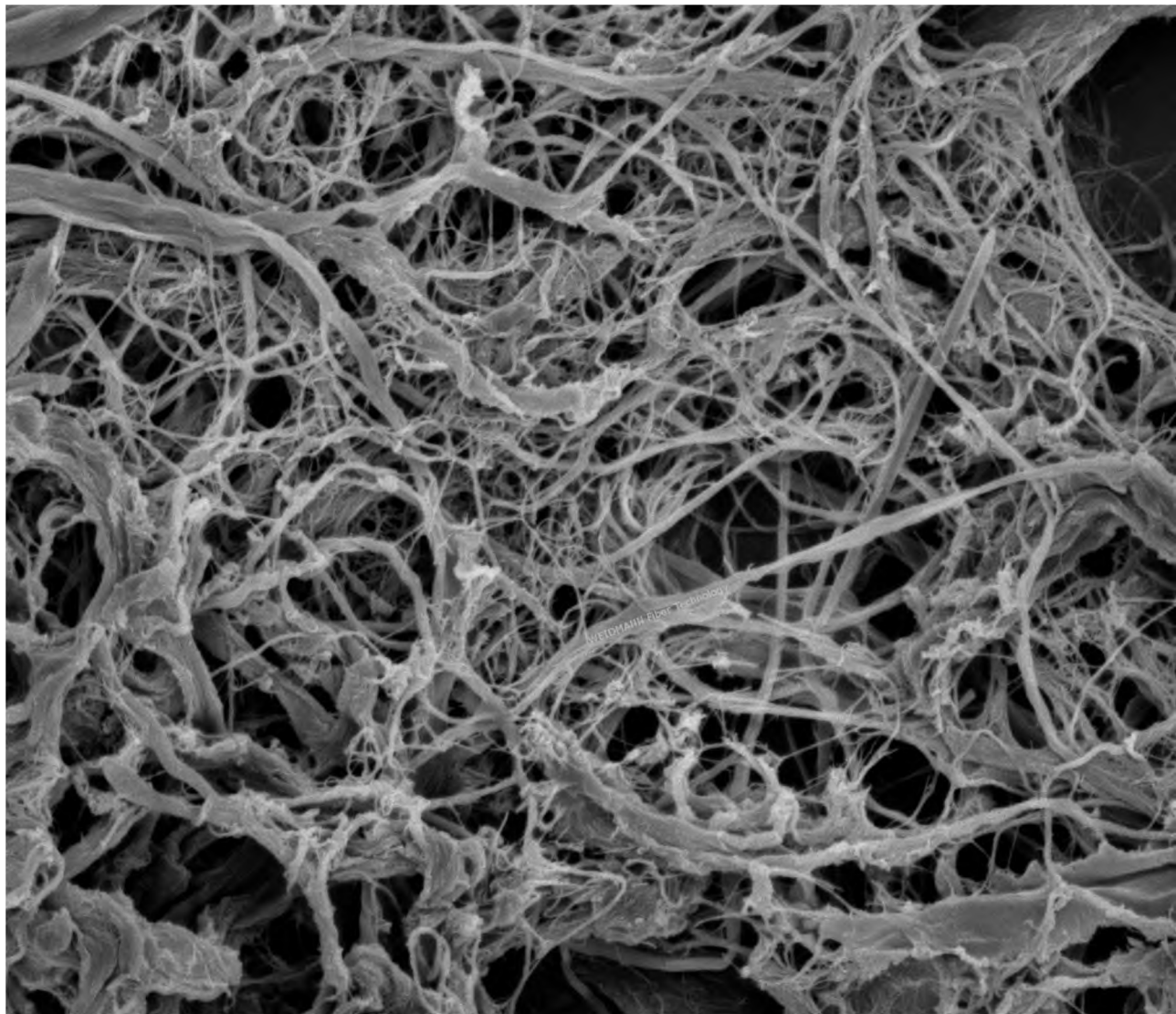
Forest Service Madison Lab



Microfibrils



- Pulped Cellulose



det	HV	mag	WD
TLD	5.00 kV	10 000 x	5.5 mm

10 μ m

BioRam Biomass Powerplants and Feedstock Requirements from Tier 1/Tier 2 High Hazard Zones

Bio Ram – SB 859 11/24/2016								
Powerplant	Utility	Term	Start Date	MW	% from Tier 1/ Tier 2 HHZ			Remarks
					2017	2018	2019+	
Ultrapower (Chinese Station)	SCE	5 Yr	3/1/2017	18	50	60	80	
RioBravo-Fresno*	SCE	5 Yr	1/2/2017	24.3	50	60	80	Reverted
RioBravo-Rocklin	SCE	5 Yr	1/2/2017	24.4	50	60	80	
BurneyForestPower	PGE	5 Yr	12/15/2017	29	50	60	80	
Wheelabrator (Anderson)	PGE	5 Yr	12/1/2017	34	80	80	80	
Loyalton								Idle
Honey Lake Power (Wendel)	SDG&E	5 Yr	1/1/2017	24	50	60	80	

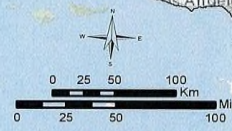
* - reverted to 8.9 cents/kW-hr to relieve eliminate their Tier 1/Tier 2 feedstock requirement

Drought Related Tree Mortality
High Hazard Zones
Tier One & Tier Two
March, 2018

- Tier 1 High Hazard Zones 2018
- Tier2 High Hazard Zones 2018
- High Priority Counties
- Communities

Tier 1 High Hazard Zones:
These are areas where tree mortality directly coincides with critical infrastructure. They represent direct threats.

Tier 2 High Hazard Zones:
These are areas defined by watersheds (HUC 12, average 24,000 acres) that have significant tree mortality as well as significant community and natural resource assets.



Projection California Teale Albers
Scale 1:4,400,000
at 8.5"x11"
March, 2018

Tier 1/Tier 2 High Hazard Zones (21 million acres)

80% of forest biomass feedstock requirement for BioRam Powerplants