

**Appendix G**

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**Cost Effectiveness Analysis**

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## Appendix G: COST EFFECTIVENESS ANALYSIS

### G.1 APPROACH FOR COST EFFECTIVENESS ANALYSIS

In general, the reduction of agricultural waste from the pruning or the removal of orchards and vineyards by grinding or chipping followed by conversion to either biomass fuel or land incorporation results in fewer emissions when compared to open burning; however, these operations may incur extra costs over those associated with open burning. To examine the cost feasibility of these alternatives, cost effectiveness (CE) in dollars per ton of emission reduction is defined as the cost differential between chipping or grinding and open burning in dollars per acre divided by the difference between burning and chipping in per acre total emissions (PM<sub>2.5</sub> + NO<sub>x</sub> + VOC), or:

$$CE = \left( \frac{(\$ / \text{acre})_{\text{chip}} - (\$ / \text{acre})_{\text{burn}}}{(\text{tons-emissions/acre})_{\text{burn}} - (\text{tons-emissions/acre})_{\text{chip}}} \right)$$

The cost effectiveness calculated by the above expression will primarily be a function of the type of tree or plant (which determines the difficulty of removal and the amount and fuel quality of the waste, affecting both the denominator and numerator of the above expression) and of the total acreage which affects the numerator of the above expression since operations on smaller acreages cost more per acre due to the project minimums imposed by most orchard contractors.

### G.2 PER ACRE COSTS AND EMISSIONS

#### G.2.1 Orchard Removals

Costs and emissions associated with orchard removals, both by open burning and by grinding for biomass, have been developed in Chapter 5 and are presented in Tables 5-4, 5-5 and 5-6 of this report. As stated there, per acre cost for orchard removal increases for smaller acreage due to minimum project charges for both burning and for grinding to biomass. When larger acreages are removed, the per acre cost reaches a flat minimum rate. Likewise, per acre emissions are somewhat greater for small acreages due to the emissions associated with delivery and mobilization of equipment at the project site which is independent of acreage removed.

## **G.2.2 Disposal of Orchard Prunings for Surface Harvested Nut Orchards**

Costs and emissions associated with the disposal of pruning by open burning, grinding for biomass and by chipping for land incorporation have also been developed in Chapter 5. The emissions are presented in Tables 5-7 and 5-8 of this report. As shown there, per acre emission reductions are greater when considering land incorporation chipping in lieu of open burning (versus grinding to biomass fuel in lieu of open burning). Also, analysis of the per acre costs presented in Chapter 5 indicates that the costs for land incorporation chipping are better defined and are less variable since issues associated with price, quality and demand for biomass fuel are not present.

## **G.3 COST EFFECTIVENESS ANALYSIS**

### **G.3.1 Orchard Removals**

Table G-1 presents the results of the District's evaluation of cost effectiveness of converting orchard removal waste to biomass fuel by grinding versus open burning for orchards other than citrus. Likewise, Table G-2 presents the results of the District's evaluation of cost effectiveness of converting orchard removal waste to biomass fuel by grinding versus open burning for citrus orchards. The tables present results for plot sizes between 1 and 20 acres, and include the cost and emission information presented in Tables 5-4 and 5-5 (expected emissions and cost for burning per acre, expected emissions and cost for grinding per acre, differential emissions and cost per acre) and the cost effectiveness calculations. The cost structure shown in the tables reflects a \$5,000 minimum charge required for orchard removals by grinding to biomass and a minimum charge of \$1,150 for orchard removal by open burning. The flat per acre charge only becomes effective after the minimum project cost is exceeded. As a result, per-acre costs and cost effectiveness value is generally higher for smaller acreages, trending to a lower fixed value for larger acreages as would be expected.

Table G-3 presents a similar analysis for vineyard removals using the emissions and cost data of Table 5-6 (Chapter 5). As with orchards, per-acre costs and cost effectiveness value is generally higher for smaller acreages, trending to a lower fixed value for larger acreages.

**Table G-1  
Cost Effectiveness Analysis Using District Data  
Open Burning versus Grind and Haul for Orchards other than Citrus**

**Cost Basis: Chipper Contractor Quotations Jan 2010**

Orchard Removal Size	Open Burning			Grind & Haul			Difference			Cost Effectiveness						
	Emissions Tons per Acre		Cost \$/acre	Emissions Tons per Acre		Cost \$/acre	Emissions Reduction Tons per Acre		Cost \$/acre	\$ Per Ton		NO <sub>x</sub> + PM <sub>2.5</sub> + VOC				
	NO <sub>x</sub>	PM <sub>2.5</sub>	VOC	NO <sub>x</sub>	PM <sub>2.5</sub>	VOC	NO <sub>x</sub>	PM <sub>2.5</sub>	VOC	NO <sub>x</sub>	PM <sub>2.5</sub>		VOC			
1	0.0945	0.1240	0.1075	\$1,150	0.0575	0.0145	0.0065	\$5,244	0.0370	0.1095	0.1010	\$4,094	\$110,600	\$37,400	\$40,500	\$16,500
2	0.0925	0.1243	0.1073	\$575	0.0503	0.0143	0.0065	\$2,744	0.0422	0.1100	0.1008	\$2,169	\$51,400	\$19,700	\$21,500	\$8,600
3	0.0918	0.1242	0.1072	\$383	0.0480	0.0142	0.0065	\$1,911	0.0438	0.1100	0.1007	\$1,527	\$34,900	\$13,900	\$15,200	\$6,000
4	0.0915	0.1241	0.1073	\$288	0.0468	0.0141	0.0065	\$1,494	0.0447	0.1100	0.1008	\$1,207	\$27,000	\$11,000	\$12,000	\$4,700
5	0.0913	0.1242	0.1072	\$267	0.0465	0.0141	0.0065	\$1,244	0.0448	0.1101	0.1007	\$977	\$21,800	\$8,900	\$9,700	\$3,800
6	0.0912	0.1242	0.1072	\$267	0.0460	0.0141	0.0065	\$1,077	0.0452	0.1101	0.1007	\$810	\$17,900	\$7,400	\$8,000	\$3,200
7	0.0911	0.1241	0.1072	\$267	0.0459	0.0141	0.0065	\$958	0.0452	0.1100	0.1007	\$691	\$15,300	\$6,300	\$6,900	\$2,700
8	0.0910	0.1242	0.1072	\$267	0.0456	0.0141	0.0065	\$869	0.0454	0.1101	0.1007	\$602	\$13,300	\$5,500	\$6,000	\$2,300
9	0.0909	0.1242	0.1072	\$267	0.0456	0.0141	0.0065	\$800	0.0453	0.1101	0.1007	\$533	\$11,800	\$4,800	\$5,300	\$2,100
10	0.0909	0.1242	0.1072	\$267	0.0453	0.0141	0.0065	\$744	0.0456	0.1101	0.1007	\$477	\$10,500	\$4,300	\$4,700	\$1,860
12	0.0908	0.1242	0.1072	\$267	0.0450	0.0140	0.0065	\$661	0.0458	0.1102	0.1007	\$394	\$8,600	\$3,600	\$3,900	\$1,530
14	0.0908	0.1242	0.1072	\$267	0.0450	0.0141	0.0065	\$632	0.0458	0.1101	0.1007	\$365	\$8,000	\$3,300	\$3,600	\$1,420
15	0.0908	0.1242	0.1072	\$267	0.0449	0.0141	0.0065	\$632	0.0459	0.1101	0.1007	\$365	\$8,000	\$3,300	\$3,600	\$1,420
16	0.0908	0.1242	0.1072	\$267	0.0448	0.0141	0.0065	\$632	0.0460	0.1101	0.1007	\$365	\$7,900	\$3,320	\$3,620	\$1,420
18	0.0907	0.1242	0.1072	\$267	0.0448	0.0141	0.0065	\$632	0.0459	0.1101	0.1007	\$365	\$8,000	\$3,320	\$3,620	\$1,420
20	0.0907	0.1242	0.1072	\$267	0.0447	0.0141	0.0065	\$632	0.0460	0.1101	0.1007	\$365	\$7,900	\$3,320	\$3,620	\$1,420

Basis:

- 30 BDT/acre for other orchard
- 4 BDT/acre for roots
- Roots are burned in burning case
- Roots are transported to composting operation for grinding case
- Grind & haul cost includes \$244 for root composting

**Table G-2  
Cost Effectiveness Analysis Using District Data  
Open Burning versus Grind and Haul for Citrus**

*Cost Basis: Chipper Contractor Quotations Jan 2010*

Orchard Removal Size	Open Burning			Grind & Haul			Difference			Cost Effectiveness						
	Emissions Tons per Acre		Cost \$/acre	Emissions Tons per Acre		Cost \$/acre	Emissions Reduction Tons per Acre		Cost \$/acre	\$ Per Ton						
	NO <sub>x</sub>	PM <sub>2.5</sub>	VOC	NO <sub>x</sub>	PM <sub>2.5</sub>	VOC	NO <sub>x</sub>	PM <sub>2.5</sub>	VOC	NO <sub>x</sub>	PM <sub>2.5</sub>	VOC	NO <sub>x</sub> + PM <sub>2.5</sub> + VOC			
1	0.0945	0.1240	0.1075	\$1,150	0.0575	0.0145	0.0065	\$5,244	0.0370	0.1095	0.1010	\$4,094	\$110,600	\$37,400	\$40,500	\$16,500
2	0.0925	0.1243	0.1073	\$575	0.0503	0.0143	0.0065	\$2,744	0.0422	0.1100	0.1008	\$2,169	\$51,400	\$19,700	\$21,500	\$8,600
3	0.0918	0.1242	0.1072	\$400	0.0480	0.0142	0.0065	\$1,911	0.0438	0.1100	0.1007	\$1,511	\$34,500	\$13,700	\$15,000	\$5,900
4	0.0915	0.1241	0.1073	\$400	0.0468	0.0141	0.0065	\$1,494	0.0447	0.1100	0.1008	\$1,094	\$24,500	\$9,900	\$10,900	\$4,300
5	0.0913	0.1242	0.1072	\$400	0.0465	0.0141	0.0065	\$1,244	0.0448	0.1101	0.1007	\$844	\$18,800	\$7,700	\$8,400	\$3,300
6	0.0912	0.1242	0.1072	\$400	0.0460	0.0141	0.0065	\$1,077	0.0452	0.1101	0.1007	\$677	\$15,000	\$6,200	\$6,700	\$2,600
7	0.0911	0.1241	0.1072	\$400	0.0459	0.0141	0.0065	\$958	0.0452	0.1100	0.1007	\$558	\$12,400	\$5,100	\$5,500	\$2,200
8	0.0910	0.1242	0.1072	\$400	0.0456	0.0141	0.0065	\$869	0.0454	0.1101	0.1007	\$469	\$10,300	\$4,300	\$4,700	\$1,800
9	0.0909	0.1242	0.1072	\$400	0.0456	0.0141	0.0065	\$800	0.0453	0.1101	0.1007	\$400	\$8,800	\$3,600	\$4,000	\$1,600
10	0.0909	0.1242	0.1072	\$400	0.0453	0.0141	0.0065	\$769	0.0456	0.1101	0.1007	\$369	\$8,100	\$3,400	\$3,700	\$1,440
12	0.0908	0.1242	0.1072	\$400	0.0450	0.0140	0.0065	\$769	0.0458	0.1102	0.1007	\$369	\$8,100	\$3,300	\$3,700	\$1,440
14	0.0908	0.1242	0.1072	\$400	0.0450	0.0141	0.0065	\$769	0.0458	0.1101	0.1007	\$369	\$8,100	\$3,400	\$3,700	\$1,440
15	0.0908	0.1242	0.1072	\$400	0.0449	0.0141	0.0065	\$769	0.0459	0.1101	0.1007	\$369	\$8,000	\$3,400	\$3,700	\$1,440
16	0.0908	0.1242	0.1072	\$400	0.0448	0.0141	0.0065	\$769	0.0460	0.1101	0.1007	\$369	\$8,000	\$3,350	\$3,660	\$1,440
18	0.0907	0.1242	0.1072	\$400	0.0448	0.0141	0.0065	\$769	0.0459	0.1101	0.1007	\$369	\$8,000	\$3,350	\$3,660	\$1,440
20	0.0907	0.1242	0.1072	\$400	0.0447	0.0141	0.0065	\$769	0.0460	0.1101	0.1007	\$369	\$8,000	\$3,350	\$3,660	\$1,440

Basis:

- 30 BDT/acre for citrus
- 4 BDT/acre for roots
- Roots are burned in burning case
- Roots are transported to composting operation for grinding case
- Grind & haul cost includes \$244 for root composting

**Table G-3  
Cost Effectiveness Analysis Using District Data  
Open Burning versus Grind and Haul for Vineyards/Kiwis**

*Cost Basis: Chipper Contractor Quotations Jan 2010*

Orchard Removal Size	Open Burning			Grind & Haul			Difference			Cost Effectiveness						
	Emissions Tons per Acre		Cost \$/acre	Emissions Tons per Acre		Cost* \$/acre	Emissions Reduction Tons per Acre		Cost \$/acre	\$ Per Ton						
	NO <sub>x</sub>	PM <sub>2.5</sub>	VOC	NO <sub>x</sub>	PM <sub>2.5</sub>	VOC	NO <sub>x</sub>	PM <sub>2.5</sub>	VOC	NO <sub>x</sub>	PM <sub>10</sub>	VOC	NO <sub>x</sub> + PM <sub>2.5</sub> + VOC			
1	0.0210	0.0220	0.0190	\$1,150	0.0305	0.0030	0.0020	\$5,725	0.0000	0.0190	0.0170	\$4,575	N/A	\$240,800	\$269,100	\$172,600
2	0.0193	0.0220	0.0190	\$575	0.0233	0.0028	0.0018	\$3,225	0.0000	0.0192	0.0172	\$2,650	N/A	\$138,000	\$154,100	\$81,800
3	0.0185	0.0220	0.0190	\$383	0.0210	0.0027	0.0017	\$2,392	0.0000	0.0193	0.0173	\$2,008	N/A	\$104,100	\$116,100	\$58,900
4	0.0183	0.0220	0.0190	\$288	0.0199	0.0026	0.0016	\$1,975	0.0000	0.0194	0.0174	\$1,688	N/A	\$87,000	\$97,000	\$47,900
5	0.0180	0.0220	0.0190	\$230	0.0195	0.0026	0.0016	\$1,725	0.0000	0.0194	0.0174	\$1,495	N/A	\$77,100	\$85,900	\$42,400
6	0.0179	0.0220	0.0190	\$213	0.0190	0.0026	0.0016	\$1,558	0.0000	0.0194	0.0174	\$1,345	N/A	\$69,300	\$77,300	\$37,700
7	0.0176	0.0219	0.0190	\$213	0.0186	0.0026	0.0016	\$1,439	0.0000	0.0193	0.0174	\$1,226	N/A	\$63,500	\$70,500	\$34,300
8	0.0178	0.0219	0.0189	\$213	0.0183	0.0026	0.0016	\$1,350	0.0000	0.0193	0.0173	\$1,137	N/A	\$58,900	\$65,700	\$31,500
9	0.0177	0.0219	0.0189	\$213	0.0181	0.0026	0.0016	\$1,281	0.0000	0.0193	0.0173	\$1,068	N/A	\$55,300	\$61,700	\$29,500
10	0.0177	0.0220	0.0190	\$213	0.0182	0.0026	0.0016	\$1,225	0.0000	0.0194	0.0174	\$1,012	N/A	\$52,200	\$58,200	\$27,900
12	0.0176	0.0220	0.0190	\$213	0.0178	0.0026	0.0016	\$1,142	0.0000	0.0194	0.0174	\$929	N/A	\$47,900	\$53,400	\$25,400
14	0.0175	0.0220	0.0190	\$213	0.0176	0.0026	0.0016	\$1,082	0.0000	0.0194	0.0174	\$869	N/A	\$44,800	\$50,000	\$23,700
15	0.0175	0.0220	0.0190	\$213	0.0176	0.0026	0.0016	\$1,058	0.0000	0.0194	0.0174	\$845	N/A	\$43,600	\$48,600	\$23,000
16	0.0175	0.0219	0.0190	\$213	0.0176	0.0026	0.0016	\$1,038	0.0000	0.0193	0.0174	\$825	N/A	\$42,700	\$47,400	\$22,500
18	0.0175	0.0219	0.0189	\$213	0.0175	0.0026	0.0016	\$1,003	0.0000	0.0193	0.0173	\$790	N/A	\$40,900	\$45,700	\$21,600
20	0.0175	0.0220	0.0190	\$213	0.0175	0.0026	0.0016	\$975	0.0000	0.0194	0.0174	\$762	N/A	\$39,300	\$43,800	\$20,700

\* Grind and haul cost includes \$650 per acre for removal of wire and stakes  
\$75 per acre for composting roots

Basis

- 5 BDT/acre for Vineyard
- 1 BDT/acre for roots
- Roots are burned in burning case
- Roots are transported to composting operation for grinding case

**G.3.2 Prunings**

Based on the above emissions, the District has examined cost effectiveness only for land incorporation chipping operations (which provides the greatest emission reduction). The results are presented in Table G-4. The analysis is based on an orchard of twenty acres with chipping costs varying between \$30 and \$60 per acre. This price range is inclusive of both the District's information and the estimate provided by the ag industry.

Based on the information developed by the District, the most likely scenario is a chipping price between \$30 to \$45 per acre which yields a cost effectiveness varying between approximately \$1,052 and \$3,026 per ton of emission reduction.

<b>Table G-4 Cost Effectiveness of Land Incorporation Chipping in Lieu of Open Burning for Disposal of Orchard Pruning (20 Acre Orchard)</b>								
Chip Cost (\$/acre)	Burning Cost (\$/acre)	Delta Cost (\$/acre)	NOx		PM2.5		VOC	
			Emission Reduction (lb/acre)	Cost Effectiveness (\$/ton)	Emission Reduction (lb/acre)	Cost Effectiveness (\$/ton)	Emission Reduction (lb/acre)	Cost Effectiveness (\$/ton)
30	22	8	1.5	10,667	7.7	2,078	6	2,667
45	22	23	1.5	30,667	7.7	5,974	6	7,667
60	22	38	1.5	50,667	7.7	9,870	6	12,667