Determining Treatment Cost of Pallets Under Dielectric Heating Criteria

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Dielectric Properties of White Oak

RH: 90% Temp(C): 25 Source: James 1975

		Dielectric constant	Dielectric loss tangent	Dielectric loss factor	Permittivity
		ε'	**tanδ**	**ε"**	**ε***
10 MHz	Radial	8.3	0.35	2.91	5.40
	Tang	7.3	0.21	1.53	5.77
	Long	14	0.33	4.62	9.38
50 MHz	Radial	6.6	0.24	1.58	5.02
	Tang	6.6	0.16	1.06	5.54
	Long	12	0.20	2.40	9.60

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Temp increase rate & power density

$$DT/dt = \frac{P}{c\rho}$$

Wood Species dependent

$$P = 55.63\ x\ 10^{-12}\ f\ \varepsilon''\ (V/d_1 + d_2\varepsilon_1{}^*)^2$$

DT/dt: Time rate of temperature increase (˚C/sec)
P: Power density (W/m^3)
c: specific heat of material (kJ/kg˚C)
ρ: material density (kg/m^3)

f: Frequency of dielectric oven (Hz)
ε“: Dielectric loss factor
V: Voltage across the electrode (V)
d_1, d_2: thickness of dielectric materials (m)
$\varepsilon_1{}^*$: Dielectric permittivity

Transforming Power Consumption to Cost

Power Consumption	Treatment Time	Load+Unload Time	Production Hrs/Day	Loads/Day	Total Treatment Time under Power	Pallets Eq. Treated per day	Energy consumed per day	1 kilowatt-hour (kWh) cost	Energy cost per day	Energy cost per month	Energy cost per year	Energy cost per pallet
kWh	min	min			hrs		kWh	Cents	US$	US$	US$	US$
675	30	15	8	11	5.33	964	3600	6.81	$245	$7,355	$88,258	$0.25
150	135	15	8	3	7.20	289	1080	6.81	$74	$2,206	$26,477	$0.25

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In the previous example, we demonstrated how the energy cost, which is by far the largest component of treatment variable cost, can be calculated for dielectric treatment chambers.

How then, do these projected costs compare to traditional heat treatment as currently practiced?

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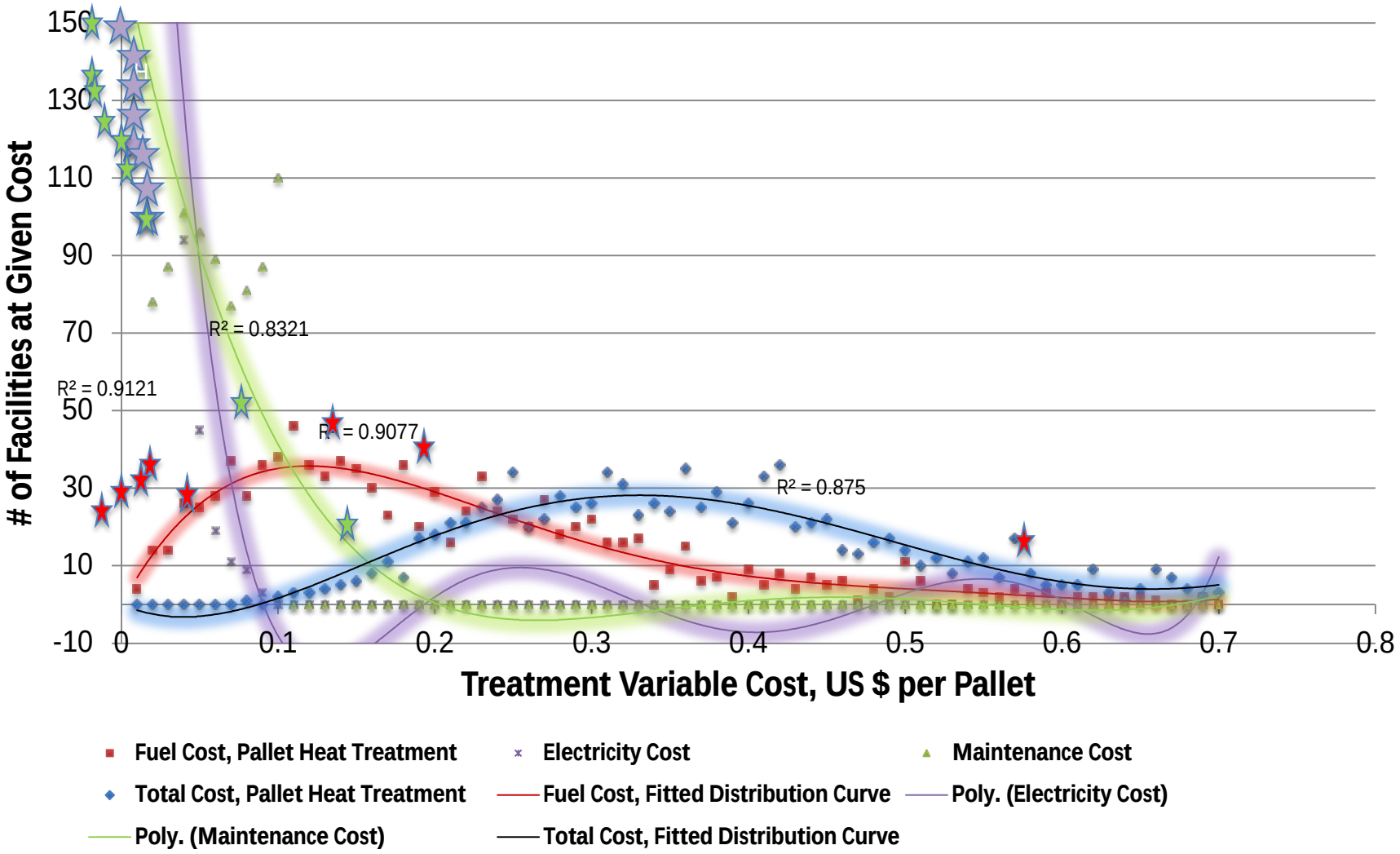
Current HT Costs in US

- Data collected in 2013-14 from US pallet treaters via email survey and direct survey at major pallet industry conference. Tepid response to survey…many responses incomplete or questionable. Many companies do not know actual cost of pallet treatment, treatment costs not typically broken out from general operations in accounting records. Hearsay and off-the-cuff cost estimates found unreliable when compared to actual cost data.
- Companies surveyed on HT chamber costs, age of chamber, capacity, annual production, fuel type and consumption, fuel price, maintenance costs, and hours in operation in past year.
- Survey data from 8 operational treatment chambers deemed appropriate, reliable and accurate. Cost numbers generally reflected findings of major pallet industry cost study performed in 2006-07 performed with proprietary data.
- Cost component distributions generated through Monte Carlo simulation that conformed to cost data approximations from both studies.
- As future work generates more interest in the technology, future data points will be collected to validate cost curves generated for and assumed in the study. Industry sensitivity towards cost data sharing, unfortunately, ensures that validation data will be minimal.

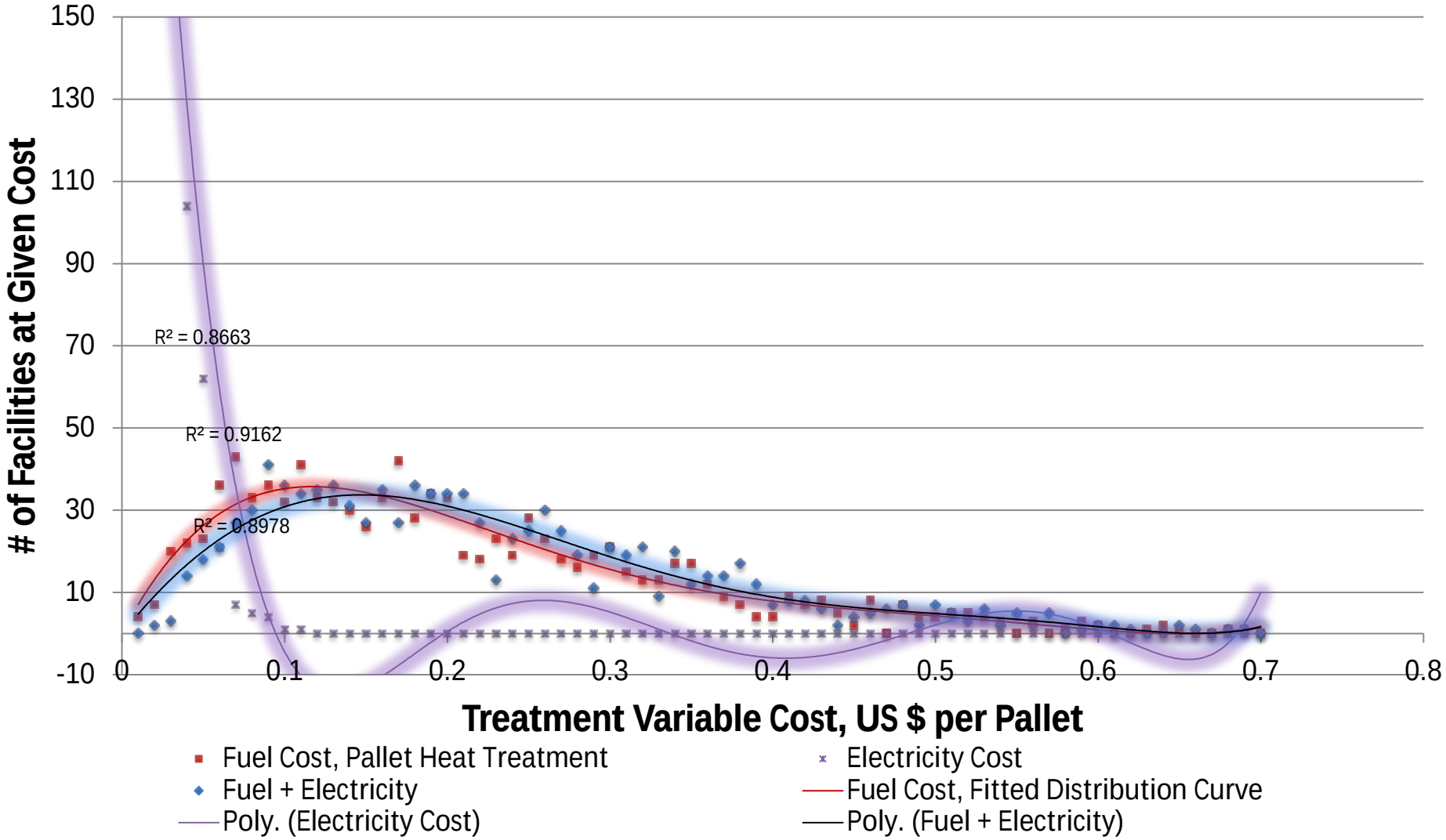
Statistical Assumptions Made to Generate Cost Curves

- Maintenance Cost = Exponential(.1)
- Fuel Cost = Inverse Gamma(2,10)
- Electricity Cost = Gamma(2,1)
- Total Variable Cost = (M + F + E)
- Total Power Cost = (F + E)

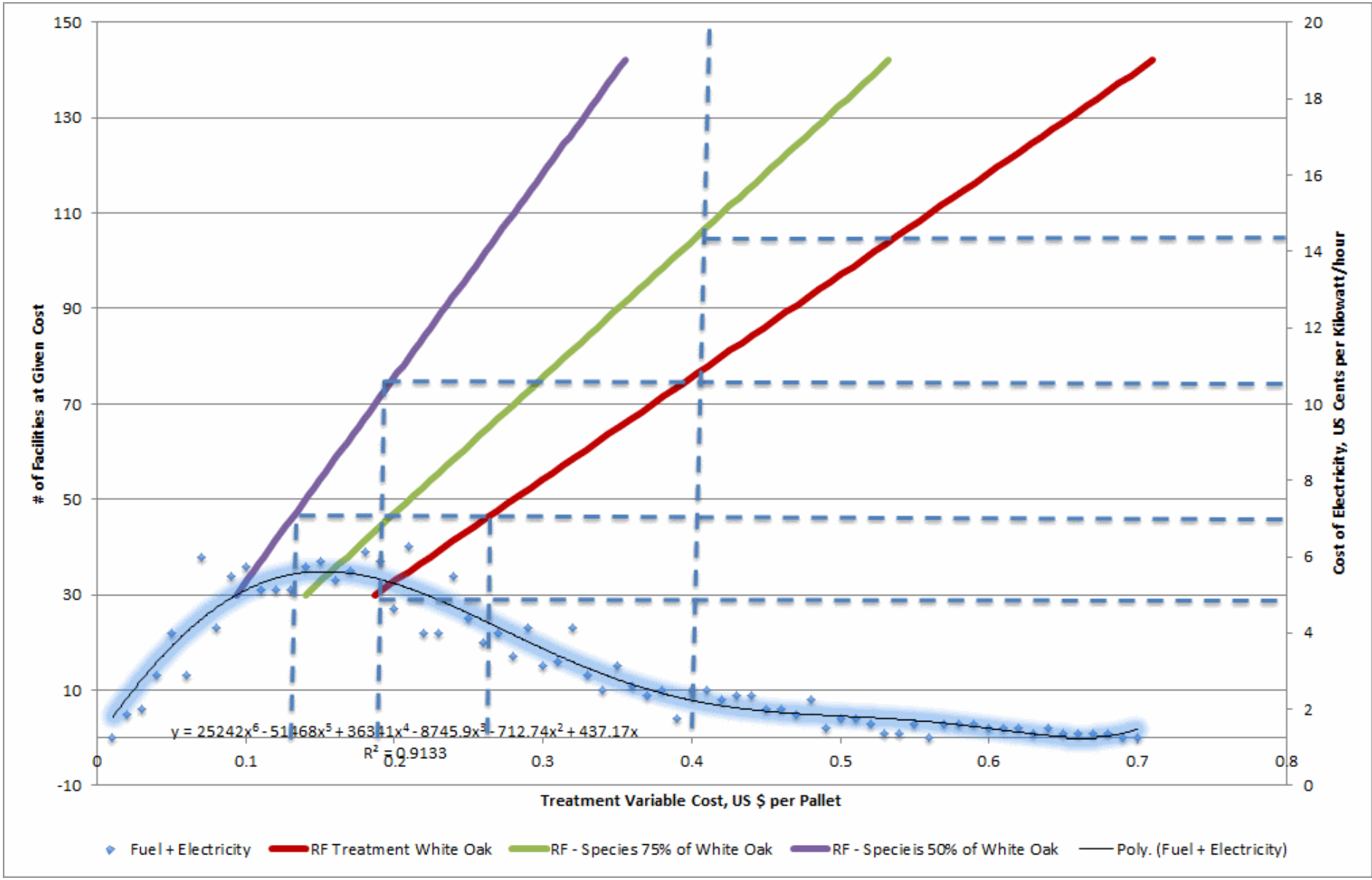
Variable Cost of Pallet Heat Treatment



Power Cost of Conventional Heat Treatment



When is dielectric heating cost effective



Conclusions

- Dielectric treatment costs vary with wood species, moisture content, dielectric heating frequency, and technology efficiency.
- Capital investment cost using DH determined by heating rate requirements.
- Dielectric treatment shows more promise for higher-cost, lower-volume treaters, but heating rate requirements need to be lifted to reduce capital investment.
- The results presented here focused on variable based on fundamental energy engineering relationships relative to all HT scenarios. Capital costs and other fixed costs are case-specific and cannot yet be estimated.

How you can help

- Are treaters in other countries willing to share cost data for conventional HT or MeBr?