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Title

Energy generation power: an example of research concerning industrial waste as fuel in furniture industries used in practical classes at a mechanical engineering course

AUTHORS

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Introduction

On north eastern region of Rio Grande do Sul state, Brazil, the most common economical use given to wood waste is the sale of shavings to aviaries.

The use of this kind of waste for power generation would be an interesting application since most of the companies are small and thus a solution for power generation in terms of equipment can be simple and at a relatively low cost.

Based on the bibliographical data found, the potential for power generation with waste from the furniture industry can be evaluated, in spite of necessary simplifications and considering performance of equipment not yet under study.

The research

Furniture industries waste could be used as fuel to co-generation of heat and power in order to minimize its disposal on the environment and environmental impact as well. Research involving 95 enterprises of different sizes and product types was made in the mountain region of Rio Grande do Sul State, Brazil.

A division was made in four segments: wood (21 enterprises), particle board (27 enterprises), MDF (Medium Density Fiber) (33 enterprises) and plywood (13 enterprises). For each segment it was analyzed the waste generation over unities of mass and energy consumed, total (kWh) and specific (kWh/m3)

The investigation shows that, according to the raw material employed, the energy production percentage could vary as follows:

MDF – 85.7%;

wood – 70.5%;

particle board - 48.7% and

plywood – 19.1%.

Gasification Studies

Applying the results to the evaluated industries, the energy generation potential from waste produced can be assessed.

Table 1 shows values for waste generation and energy needs, as well as percent energy needed waste can fulfil and average power for a 12 h operation days. Table 2 shows total and Specific Energy Spending

Table 1 – Waste Generation and Energetic Needs

Raw material	Waste [kg/day]	Energy [kWh/day]	Production [%]	POT [kW]
Wood	1817,7	2580,1	70,5	218,3
Particle board	2740,7	5625,5	48,7	476,0
MDF	1442,1	1683,0	85,7	142,4
Plywood	96,8	506,0	19,1	42,8

Table 2 –Total and Specific Energy Spending

Type of raw material	Total Energy [MWh/month]	Specific Spending [kWh/m^3]
Wood	56,8	230,6
Particle board	123,8	86,2
MDF	35,9	125,1
Plywood	11,1	158,6

Practical classes

This research was used in practical classes of the Mechanical Engineering Course of the Pontifícia Universidade Católica do Rio Grande do Sul (PUCRS) and Universidade de Caxias do Sul (UCS), Rio Grande do Sul, Brazil.

The pedagogic procedure involved resources of SPSS statistical software, powerpoint and data show. The objective was offer sbsidies to the students for critical analyses over real data. Frequencies, percents, cross tables, analysis of variance, correlations and regressions were also used to enrich the analyses

The students grades were considered

Data analysis

The research was used in classes with the aim to offer to the students an example of quantitative analysis on real data and of regional interest

Below a resume of the pedagogic procedures used: frequencies, descriptives and associatios

Line tipe

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	In serie	56	59,6	59,6	59,6
	By mesure	30	31,9	31,9	91,5
	Both	8	8,5	8,5	100,0
	Total	94	100,0	100,0	

Raw material

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Wood	21	22,3	22,3	22,3
	Particleboard	27	28,7	28,7	51,1
	MDF (Medium Density Fiber)	33	35,1	35,1	86,2
	Plywood	13	13,8	13,8	100,0
	Total	94	100,0	100,0	

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Sawdust kg	94	,00	449345,0	14686,09	51972,71
Sharings kg	94	,00	189410,0	5077,320	24625,83
Scraps kg	94	,00	526500,0	16543,48	60209,74
Total production in kg	94	,98	10200,00	617,7159	1573,017
Total waste kg	94	,00	773755,0	36306,90	110554,1
Valid N (listwise)	94				

	N	Minimum	Maximum	Mean	Std. Deviation
Total consumption kWh/month	93	100,00	750000,0	57841,61	137856,5
Specific consumption kWh/m3	94	,30	3254,40	195,0606	362,16136
Specific waste kg/m3	94	,00	1128,06	165,6632	195,01998
Valid N (listwise)	93				

Categorized specific consumption kWh/m3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	lowest throug100	44	46,8	46,8	46,8
	100 throug 200	24	25,5	25,5	72,3
	200 throug 300	11	11,7	11,7	84,0
	300 throug 500	9	9,6	9,6	93,6
	500 throug highest	6	6,4	6,4	100,0
	Total	94	100,0	100,0	

Categorized specific waste kg/m3

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	lowest throug 50	26	27,7	27,7	27,7
	50 throug 100	20	21,3	21,3	48,9
	100 throug 200	22	23,4	23,4	72,3
	200 throug 500	19	20,2	20,2	92,6
	500 through highest	7	7,4	7,4	100,0
	Total	94	100,0	100,0	

Categorized total production kg

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	lowest throug 10	28	29,8	29,8	29,8
	10 throug 100	32	34,0	34,0	63,8
	100 through 1000	18	19,1	19,1	83,0
	1000 through 5000	14	14,9	14,9	97,9
	5000 through highest	2	2,1	2,1	100,0
	Total	94	100,0	100,0	

Categorized total waste kg

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	lowest through 1000	24	25,5	25,5	25,5
	1000 through 5000	30	31,9	31,9	57,4
	5000 through 20000	19	20,2	20,2	77,7
	20000 through 100000	13	13,8	13,8	91,5
	100000 throug highest	8	8,5	8,5	100,0
	Total	94	100,0	100,0	

Categorized total production kg * Raw material Crosstabulation

			Raw material				
			Wood	Particleboard	MDF (Medium Density Fiber)	Plywood	Total
Categorized total production kg	lowest throug 10	Count	6	2	15	5	28
		% within Categorized total production kg	21,4%	7,1%	53,6%	17,9%	100,0%
	10 throug 100	Count	9	9	7	7	32
		% within Categorized total production kg	28,1%	28,1%	21,9%	21,9%	100,0%
	100 through 1000	Count	4	7	7	0	18
		% within Categorized total production kg	22,2%	38,9%	38,9%	,0%	100,0%
	1000 through 5000	Count	2	7	4	1	14
		% within Categorized total production kg	14,3%	50,0%	28,6%	7,1%	100,0%
	5000 through highest	Count	0	2	0	0	2
		% within Categorized total production kg	,0%	100,0%	,0%	,0%	100,0%
Total		Count	21	27	33	13	94
Fisher Exact Test p=0.017		% within Categorized total production kg	22,3%	28,7%	35,1%	13,8%	100,0%

Categorized specific consumption kWh/m3 * Raw material Crosstabulation

			Raw material				
			Wood	Particleboard	MDF (Medium Density Fiber)	Plywood	Total
Categorized specific consumption kWh/m3	lowest throug100	Count	2	18	17	7	44
		% within Categorized specific consumption kWh/m3	4,5%	40,9%	38,6%	15,9%	100,0%
	100 throug 200	Count	8	6	8	2	24
		% within Categorized specific consumption kWh/m3	33,3%	25,0%	33,3%	8,3%	100,0%
	200 throug 300	Count	5	0	5	1	11
		% within Categorized specific consumption kWh/m3	45,5%	,0%	45,5%	9,1%	100,0%
	300 throug 500	Count	4	2	2	1	9
		% within Categorized specific consumption kWh/m3	44,4%	22,2%	22,2%	11,1%	100,0%
	500 throug highest	Count	2	1	1	2	6
		% within Categorized specific consumption kWh/m3	33,3%	16,7%	16,7%	33,3%	100,0%
Total		Count	21	27	33	13	94
Fisher Exact Test p=0.006		% within Categorized specific consumption kWh/m3	22,3%	28,7%	35,1%	13,8%	100,0%

Categorized total waste kg * Raw material Crosstabulation

			Raw material				
			Wood	Particleboard	MDF (Medium Density Fiber)	Plywood	Total
Categorized total waste kg	lowest through 1000	Count	5	3	9	7	24
		% within Categorized total waste kg	20,8%	12,5%	37,5%	29,2%	100,0%
	1000 through 5000	Count	7	8	10	5	30
		% within Categorized total waste kg	23,3%	26,7%	33,3%	16,7%	100,0%
	5000 through 20000	Count	3	5	10	1	19
		% within Categorized total waste kg	15,8%	26,3%	52,6%	5,3%	100,0%
	20000 through 100000	Count	3	7	3	0	13
		% within Categorized total waste kg	23,1%	53,8%	23,1%	,0%	100,0%
	100000 throug highest	Count	3	4	1	0	8
		% within Categorized total waste kg	37,5%	50,0%	12,5%	,0%	100,0%
Total		Count	21	27	33	13	94
Fisher Exact Test p=0.109		% within Categorized total waste kg	22,3%	28,7%	35,1%	13,8%	100,0%

Categorized specific waste kg/m3 * Raw material Crosstabulation

			Raw material				
			Wood	Particleboard	MDF (Medium Density Fiber)	Plywood	Total
Categorized specific waste kg/m3	lowest throug 50	Count	4	11	8	3	26
		% within Categorized specific waste kg/m3	15,4%	42,3%	30,8%	11,5%	100,0%
	50 throug 100	Count	6	9	5	0	20
		% within Categorized specific waste kg/m3	30,0%	45,0%	25,0%	,0%	100,0%
	100 throug 200	Count	3	5	8	6	22
		% within Categorized specific waste kg/m3	13,6%	22,7%	36,4%	27,3%	100,0%
	200 throug 500	Count	6	2	9	2	19
		% within Categorized specific waste kg/m3	31,6%	10,5%	47,4%	10,5%	100,0%
	500 through highest	Count	2	0	3	2	7
		% within Categorized specific waste kg/m3	28,6%	,0%	42,9%	28,6%	100,0%
Total		Count	21	27	33	13	94
Fisher Exact Test p=0.054		% within Categorized specific waste kg/m3	22,3%	28,7%	35,1%	13,8%	100,0%

Correlations

		Total production in kg	Total waste kg	Total consumption kWh/month	Specific consumption kWh/m3	Specific waste kg/m3
Total production in kg	Pearson Correlation	1	,564**	,614**	-,106	-,218*
	Sig. (2-tailed)	.	,000	,000	,310	,035
	N	94	94	93	94	94
Total waste kg	Pearson Correlation	,564**	1	,637**	-,049	-,041
	Sig. (2-tailed)	,000	.	,000	,640	,693
	N	94	94	93	94	94
Total consumption kWh/month	Pearson Correlation	,614**	,637**	1	,027	-,175
	Sig. (2-tailed)	,000	,000	.	,796	,093
	N	93	93	93	93	93
Specific consumption kWh/m3	Pearson Correlation	-,106	-,049	,027	1	,085
	Sig. (2-tailed)	,310	,640	,796	.	,414
	N	94	94	93	94	94
Specific waste kg/m3	Pearson Correlation	-,218*	-,041	-,175	,085	1
	Sig. (2-tailed)	,035	,693	,093	,414	.
	N	94	94	93	94	94

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

CONCLUSIONS

Crossings involving variables raw material, total and specific production, total and specific waste suggested further analyses.

Bivariate correlations involving variables total production, total waste, total consumption, specific consumption and specific waste suggested further analyses as well.

Students take part actively in these analyses.

In short, the results suggest a richness of analyses and interpretations.

All tables encouraged discussions among students, indicating new analyses, with an excellent pedagogic benefit from this exercise, which reached its objectives fully.

The students grades were considerer excellent .

THANK'S