Greenhouse Energy Consumption

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Introduction

Depending on location and luck, natural gas rates have gone from less that CAN$ 3.00 to more than CAN$ 20.00/gigajoule (Gj). Natural gas rates are currently around CAN$ 13.00/Gj, although industry "analysts" predict an increase. A gigajoule is equivalent to the energy released by the combustion of approximately 30 L (8 gal) of gasoline. It is also equivalent to approximately 950,000 BTU, 0.165 barrels of oil, or 278 kilowatt-hours of electricity.

Energy as a proportion of greenhouse crop production cost is rising. This has sparked renewed interest in energy conservation, alternate fuels, different growing facilities, new cropping systems, and so on. This article briefly touches on energy conservation and provides a simple approach for evaluating alternate fuel sources.

Energy Conservation

Awareness of the purpose of energy—what forms are needed, when, and where—is required. Proximity of source to sink is key, because efficiency can be lost during transfer. In greenhouses, the two basic heating system objectives are: (1) to heat the growing plant so it can take advantage of available light during the day and process assimilates at night; and (2) to heat the greenhouse environment to maintain a favorable vapor pressure deficit, facilitating plant transpiration and associated evaporative cooling as well as internal nutrient transport.

Humidity control is a major cost in terms of energy consumption. If replenishing CO_2 is accomplished through venting, this also becomes a major energy cost due to the associated heat loss. Options for management of both may be worth investigating.

During seed germination, humidity (reduction) and CO_2 (injection) are not issues, but proximity of the heat source to seeds is. Germination speed can be approximated using a Q_{10} factor of 2 for plant respiration (van Steenis 2009). Between 5 and 25 °C (41 and 77 °F), germination speed (respiration rate) doubles for every 10 °C (18 °F). This should be weighed against the cost of heating a growing facility. Starting with ambient outside temperatures, one can log heater-running time for each rise in set-point temperature. This information can be used when deciding on heating set points given various outside weather conditions (including both temperature and precipitation). Basically, if a 10 °C (18 °F) rise (between 5 and 25 °C [41 and 77 °F]) can be attained for less than a doubling in fuel consumption, then it is economic to increase temperature (in terms of increased germination speed and subsequent reduced crop cycle time). The added bonus is a more uniform crop. In fact, the higher the price of fuel, the more economic it is!

Common sense heat conservation techniques abound. Sealing cracks, IR trapping and/or anti-condensate polyethylene films, double polyethylene roofs, raising heating pipes higher off the ground, skirting benches, delayed heating until a facility is full, pre-germinating, and so on, are just a few. Literature suggests the biggest gain is from installation of energy curtains. (These have to seal well!) They add an insulating layer of air, reduce total air volume to heat, and limit long-wave radiation loss from the crop. They are more cost effective when installed in gutter-connected greenhouses.

Alternative Fuels

Alternative fuels are intriguing, but it quickly becomes obvious that in order to "easily" take advantage of various options, one needs to be working with a hot water heating system. Unit heaters only lend themselves to natural gas or propane, whereas any fuel can be used to heat a boiler. Some fuels require investment in extra storage, transport, and delivery systems, as well as waste removal. One interesting option is pellet fuel combustion technology, utilizing wood residues and agricultural fibers. Wood pellets in British Columbia and switchgrass pellets in Quebec are two examples.

When evaluating alternatives, consider the capital investment associated with the system technology as well as the fuel price, how the biology of the growing system may change, and don't forget government regulations with respect to waste disposal and air quality. Because the difference in fuel prices determines the payback/economic feasibility, it is imperative that fuels be compared on a dollar per gigajoule or equivalent energy content basis.

Table 1 can be used to calculate the advantages and disadvantages of various fuel types and heat sources in a greenhouse. To use the table, select your current fuel source and price. Move to the left side of the table to obtain the equivalent price per gigajoule. Now choose a new fuel source and its current price to you. How does it compare on a dollar per basis? Realize it currently takes about 2.5 Gj of energy/m^2 (0.23 Gj/ft^2) of growing space to produce a forest seedling crop. Knowing your total greenhouse area quickly gives an indication of how much money the "switch" can "make or break" you. If you are comparing to electricity, it is important to realize that its output (heat) cost equals its input (fuel) cost because it is 100% efficient. In other words, switching from a gas/wood/coal boiler to an electric boiler saves 15% in energy consumed regardless of its price.

An interesting example (from 2001 in British Columbia and expressed in Canadian dollars) is a grower with 2,500 m^2 (26,900 ft^2) of growing area on propane at $ 0.36/L ($ 1.38/gal) using unit heaters (75% efficiency). This rate equals $ 14.50/Gj input cost, which equals $ 14.50/.75, or $ 19.33/Gj (heat) output cost. Electricity is $ 0.058/kWh or $ 16/Gj input **and** output cost. The 2,500 m^2 x 2.5Gj/ m^2 x $ 3.33 gives the grower $ 20,812.50 in year 1 if a switch was made to electric element unit heaters or boilers. If wood chips were available at $ 5.00/Gj delivered, the difference in output cost would be $ 19.33 – 5.88 = $ 13.45/Gj or $ 84,062.50 in year 1! This grower installed wood-fired boilers and hot water piping under the benches.

References

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The content of this paper reflects the views of the authors, who are responsible for the facts and accuracy of the information presented herein.

Table 1. Fuel price comparison based on equivalent energy content (CAN$).

Input Price Natural Gas per Gj[1]	Equivalent Input Price Propane per L[2]	Equivalent Input Price #1 fuel oil per L[2]	Equivalent Input Price Bituminous coal per tonne[3] (3.3% mc)	Equivalent Input Price Woodchips per tonne[3] (35% mc)	Equivalent Input Price Wood Pellets per tonne[3] (2% mc)	Equivalent Input Price Electricity per KWhr	Output Price Unit Heater Heat per Gj (75% efficiency)	Output Price Boiler Heat per Gj (85% efficiency)	Output Price Electric Heat per Gj (100% efficiency)
1.00	0.03	0.04	33.00	12.66	18.00	0.00	1.33	1.18	1.00
2.00	0.05	0.08	66.00	25.32	36.00	0.01	2.67	2.35	2.00
3.00	0.08	0.11	99.00	37.98	54.00	0.01	4.00	3.53	3.00
4.00	0.10	0.15	132.00	50.64	72.00	0.01	5.33	4.71	4.00
5.00	0.13	0.19	165.00	63.30	90.00	0.02	6.67	5.88	5.00
6.00	0.15	0.23	198.00	75.96	108.00	0.02	8.00	7.06	6.00
7.00	0.18	0.26	231.00	88.62	126.00	0.03	9.33	8.24	7.00
8.00	0.20	0.30	264.00	101.28	144.00	0.03	10.67	9.41	8.00
9.00	0.23	0.34	297.00	113.94	162.00	0.03	12.00	10.59	9.00
10.00	0.25	0.38	330.00	126.60	180.00	0.04	13.33	11.76	10.00
11.00	0.28	0.41	363.00	139.26	198.00	0.04	14.67	12.94	11.00
12.00	0.30	0.45	396.00	151.92	216.00	0.04	16.00	14.12	12.00
13.00	0.33	0.49	429.00	164.58	234.00	0.05	17.33	15.29	13.00
14.00	0.35	0.53	462.00	177.24	252.00	0.05	18.67	16.47	14.00
15.00	0.38	0.56	495.00	189.90	270.00	0.05	20.00	17.65	15.00
16.00	0.40	0.60	528.00	202.56	288.00	0.06	21.33	18.82	16.00
17.00	0.43	0.64	561.00	215.22	306.00	0.06	22.67	20.00	17.00
18.00	0.45	0.68	594.00	227.88	324.00	0.06	24.00	21.18	18.00
19.00	0.48	0.71	627.00	240.54	342.00	0.07	25.33	22.35	19.00
20.00	0.50	0.75	660.00	253.20	360.00	0.07	26.67	23.53	20.00
21.00	0.53	0.79	693.00	265.86	378.00	0.08	28.00	24.71	21.00
22.00	0.55	0.83	726.00	278.52	396.00	0.08	29.33	25.88	22.00
23.00	0.58	0.86	759.00	291.18	414.00	0.08	30.67	27.06	23.00
24.00	0.60	0.90	792.00	303.84	432.00	0.09	32.00	28.24	24.00
25.00	0.63	0.94	825.00	316.50	450.00	0.09	33.33	29.41	25.00
26.00	0.65	0.98	858.00	329.16	468.00	0.09	34.67	30.59	26.00
27.00	0.68	1.02	891.00	341.82	486.00	0.10	36.00	31.76	27.00
28.00	0.70	1.05	924.00	354.48	504.00	0.10	37.33	32.94	28.00
29.00	0.73	1.09	957.00	367.14	522.00	0.10	38.67	34.12	29.00
30.00	0.75	1.13	990.00	379.80	540.00	0.11	40.00	35.29	30.00
31.00	0.78	1.17	1023.00	392.46	558.00	0.11	41.33	36.47	31.00
32.00	0.80	1.20	1056.00	405.12	576.00	0.12	42.67	37.65	32.00
33.00	0.83	1.24	1089.00	417.78	594.00	0.12	44.00	38.82	33.00
34.00	0.85	1.28	1122.00	430.44	612.00	0.12	45.33	40.00	34.00
35.00	0.88	1.32	1155.00	443.10	630.00	0.13	46.67	41.18	35.00
36.00	0.90	1.35	1188.00	455.76	648.00	0.13	48.00	42.35	36.00
37.00	0.93	1.39	1221.00	468.42	666.00	0.13	49.33	43.53	37.00
38.00	0.95	1.43	1254.00	481.08	684.00	0.14	50.67	44.71	38.00
39.00	0.98	1.47	1287.00	493.74	702.00	0.14	52.00	45.88	39.00
40.00	1.00	1.50	1320.00	506.40	720.00	0.14	53.33	47.06	40.00

[1] 1 Gj = 950,000 BTU
[2] 1 L = 0.26 gal
[3] 1 tonne = 1.1 ton