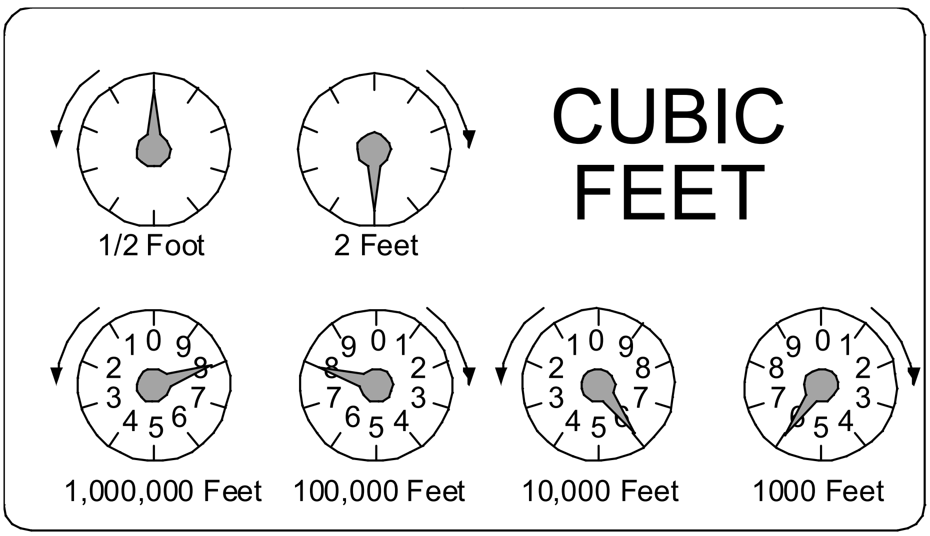
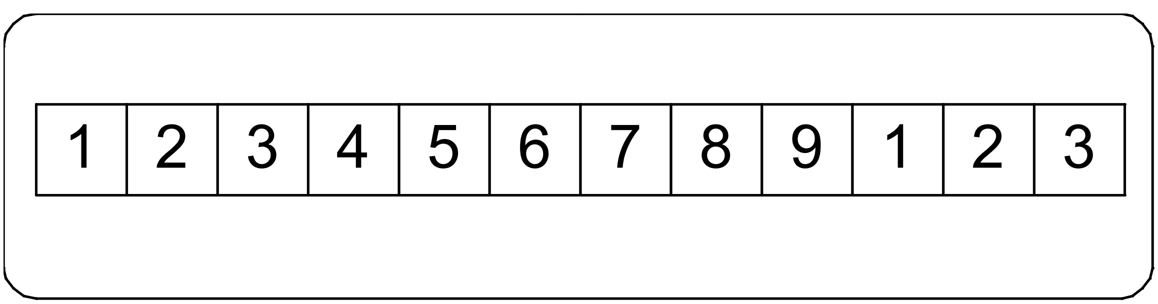
Calculating Fuel Consumption
and
Carbon Footprint of the Glass Studio

Calculating approximate fuel consumption and carbon output involves several things. With gas, it is necessary to isolate each piece of equipment, and, using a gas meter, clock the actual consumption of the unit, both in various phases of firing, and as a total for the day or week. Those using natural gas are likely to have a gas meter for the studio. The older meters are of the multiple spinning dial variety where the consumption can be measured quickly on the dial clocking half a cubic foot, or perhaps two cubic feet.



Newer models look more like an odometer, and the numbers turn only after 100 cubic feet has passed through. This is cheaper for the gas company, and easy for the meter reader, but it makes clocking the consumption of individual units tedious.



If you have the odometer meter, a call to the gas utility, with an explanation of your plan to track consumption and reduce usage, may result in your getting a dial meter installed for free. Otherwise, you can buy a full on dial type meter, or an individual flow meter to put in the gas line that will measure each piece of equipment separately. I have a source for those, and they are about $150. They can be configured for either natural gas or propane.

With propane, it is very likely that you will have to buy one type of meter or the other.

Once a dial meter is in place, it will be necessary to isolate each piece of equipment for measurement. At the end of a blowing session is the best time, because everything is all heat soaked. It only takes a few minutes to clock each unit. Turn off all the units except the one you are measuring, then go to the meter with a watch or clock with a second hand. Simply time how long it takes for the 2 cubic foot dial to go around once, or many times, for greater accuracy. If it takes two minutes for the 2 cubic foot dial to go around once, it will go around thirty times in an hour.

PROPANE

Thirty times two cubic feet is sixty cubic feet per hour.

One cubic foot of propane contains 2,488 BTU

60 cubic feet of propane contains 149,280 BTU

Your rate of consumption is 149,280 BTU/hr.

One gallon of propane contains 93,000 BTU.

149,280 divided by 93,000 equals 1.61 gallons.

Your rate of consumption is 1.61 gallons per hour.

To get cost per hour, multiply 1.61 by your price per gallon, say, $1.93

Cost per hour for that unit is $3.10/hr.

To calculate the amount of CO_2 being created per hour, divide the number of BTU consumed by 100,000.

149,280 / 100,000 = 1.4928

Multiply 1.4928 by 13.92,(the number of pounds of CO_2 generated by burning 100,000 BTU of propane)

1.4928 x 13.92 = 20.78 pounds of CO_2 per hour.

Then you can easily multiply up by days, weeks or months. Or, simply use the online calculator at my website, or the downloadable spreadsheet

NATURAL GAS

Because natural gas contains about 1000 BTU/cubic foot, your meter will spin faster than the one measuring propane, which contains 2488 BTU/cubic foot.

Clock the meter as above to find out how many cubic feet per hour are being used.

Two cubic feet in forty seconds, one cubic foot in twenty seconds

Divide 3600, which is the number of seconds in an hour, by 20 seconds.

3600/20= 180 cubic feet/hr

Multiply 180 by 1000 to get the number of BTU/ hr

180 x 1,000 = 180,000 BTU/hr

Natural gas is generally sold by the therm, which is 100,000 BTU or 100 cubic feet.

Divide 180,000 by 100,000 to get the number of therms per hour

180,000/ 100,000 = 1.8 therms

Multiply 1.8 therms by the price you pay per therm, say, $1.50

1.8 x $1.50 = $2.70 per hour.

To calculate the amount of CO_2 being created per hour, divide the number of BTU consumed by 100,000.

180,000/ 100,000 = 1.8

Multiply 1.8 by 11.71(the number of pounds of CO_2 produced by burning 100,000 BTU of natural gas.)

1.8 x 11.71 = 21.20 pounds of CO_2 per hour.

Then you can easily multiply up by days, weeks or months. Or, simply use the online calculator at my website, or the downloadable spreadsheet

The above are the calculations to get consumption rates on units like glory holes and pipe warmers, which are generally not adjusted much during the working day. Furnaces, on the other hand, have variable rates. With a controller, highest fire happens when you start the program to take the furnace up to melt temperature. Once that temperature is attained, the controller backs off on the input in order to maintain the temperature. When you add batch or cullet, the temperature drops, and the controller runs the furnace back up to high fire until the set point is again attained.

During turndown, the controller runs the furnace down to it's lowest input until it cools to the squeeze or working temperature, then turns it back up a bit to maintain that temperature. During working time, the controller is going up and down a lot due to the heat lost when you open the door to gather.

A different approach is needed for measurement. It is always good to know your consumption at highest fire. You can turn your furnace up to high fire and clock it as above. This will work with both the dial meter and the flow meter. Go through the above calculations with the dial meter in the same way. The flow meter, however, will give you the RATE of consumption directly, but it is not additive over time.

It is useful to clock a furnace with the dial meter for a whole day, since the input to the furnace is changing a lot over that time period. Write down the meter reading at the time you turn up the furnace for a melt. Check the meter again after twenty-four hours, write down the numbers, subtract the first reading from the second reading to get the number of cubic feet used.

For natural gas, divide that number by 100 in order to get the number of therms, or 100,000BTU chunks used.

Multiply your result by your cost per therm in order to determine the cost of your melt.

Multiply that same number of therms by 11.78 to get the number of pounds of CO_2 put out by the melt cycle.

For propane, multiply the number of cubic feet by 2488 to get the number of BTU consumed. Divide that number by 93,000 to get the number of gallons consumed. Multiply that number by you price per gallon to see what your melt cost is.

To get the CO_2 output, divide the number of BTU consumed by 100,000 to get the number of propane “therms.” Multiply that number by 13.92 to get the number of pounds of CO_2 produced during the melt.

On days when you are not blowing or melting, the furnace is rather stable on low fire. Measure a twenty-four hour cycle of gas consumption, and do the calculations above to find the cost and CO_2 output on the ‘off” days.

Measuring the gas consumption of the furnace during a day of blowing is a little trickier. It is necessary to have good numbers on the glory holes, pipe warmers, garages, etc. first. These numbers are relatively constant while those units are on. Calculate them for a day using the above formulae, multiplying BTU/hr by number of hours in use. Add them all up for a day. Then start a twenty-four hour measurement cycle on a blowing day. Take that total and subtract from that the calculated consumptions of the other units. You will have a pretty close approximation of how much gas the furnace has used during that twenty for hour period.

That total number measured for a blowing day can be used to calculate total consumption for a week.

Now you have three different sets of gas consumption for the furnace AND the whole shop: the melt cycle(M), the off day cycle (O), and the blowing day cycle (B).

Here is an example of a generic week cycle.

M -- One day

B -- Five days

O -- Two days.

The formula for a week would be...

1 times M plus 5 times B plus 2 times O(ff), or

1(M) + 5(B) + 2(O) = Weekly consumption

You can juggle the numbers on a spreadsheet to get weekly, monthly and yearly consumption and CO_2 output.

Electricity

Annealing ovens, fusing ovens and hot boxes use a lot of electricity and are responsible for a lot of CO_2 output at the fossil fuel fired electrical power plant. 50% of the electricity being generated is from the combustion of coal. By the time the electricity gets to you, the efficiency rating is 33%. That means for every 100,000 BTU that get to your shop, 3000,000 BTU have been consumed at the generating plant.

Electrical consumption is measured in kWh, kilowatt-hours, and that's how you pay for it. It is necessary to figure out how many kWh are consumed by your electric ovens.

A little background is in order.

A Watt is the unit of power. The formula,

Watts equals amps times volts, W = A x V

gives you the power rating. Multiply the Watts times 1000 and you get Kilowatts. Multiply kilowatts by the number of hours the unit is consuming power, and you get kilowatt/ hours, or kilowatts per hour.

Here are a couple of ways to do that.

First, you need to know the power rating of your oven. There are two ways to do this. Turn your oven on, and use an ammeter to measure the amps drawn by the oven. Or, if you know the amperage of each heating element, frequently 12 amps, and multiply that by the number of elements in the oven, say, four, you get an answer of 48 amps while the oven is drawing electricity.

You also need to know the voltage of your electric supply. Generally, ovens run on 240 volts single phase, meaning that there are two power wires hooked to the elements at a voltage of 240. Plugging these numbers into the above formula,

W = 240V x 48A

Giving the answer 11,520 Watts, or 11.52 kW. This is the power rating of the oven. If the oven is consuming power all the time, it is using 11.52 kilowatts per hour, or 11.52kW/hr

Elements go off and on. We need to figure out what percentage of the time they are on.

Here is a way.

Most ovens that we use have an on/off relay, controlled by a digital controller, that makes noise when it is on, when power is going through to the oven, When the controller opens the relay and no power is going through, it gets quiet. This allows us to clock the thing with a watch or clock with a second hand. Here is a sample of data from when I clocked one of my ovens.

	Seconds On	Seconds Off
	12	16
	17	19
	13	20
	11	20
	12	20
	8	25
	12	19
Totals	85	139

Total Time period 224 Seconds

To get the percentage of time that the oven is on, divide the number of seconds the oven was on, 85, by the total of the times the oven was on and off, 85 plus 139, getting 38%

Multiply 38% by the power rating of 11.52 kW to get 4.37. This is the average number of kilowatts used in an hour, meaning 4.37 kilowatt/hours.

Multiply this number of kWh by your cost per kWh to see how much your oven costs to run per hour. Call it 10 cents per kWh.

.10 x 4.37 = .437, about $.44 per hour.

Then you can easily multiply up by days, weeks or months. Or, simply you the online calculator at my website, or the downloadable spreadsheet

By the time it gets to you, the CO_2 output for one kWh produced by burning coal is 2.14 pounds.

Multiply your kWh total for a day, a week, a year, by 2.14 pounds to see what the CO_2 output for that oven is.

To clock an oven for a day is a bit difficult because there is the heatup, the hold, and the cool down to track. The heat up is pretty easy. Mine takes an hour to heat up, full on, so this oven uses 11.52 kWh for the heat up. The cool down is trickier. We have clocked the oven for when it is heated up, holding setpoint, and closed. During the day, it is opened a lot, causing the controller to heat it back up to setpoint, using more energy. During the annealing cycle, the oven is cooling and using less energy than what we measured. So, just average it out. It will be reasonably close if, for the whole cycle, you use the values you clocked while it was on and closed.

So, turn it on at 7 am, load from 8 to 5, anneal until 1 am when it shuts down. That's 18 hours.

18hrs x $.44 = $7.92.

CO_2 output is,

18Hrs. x .437 kW = 7.87 kWh

7.87 kWh x 2.14 pounds CO_2 = 16.83 pounds CO_2 per day.

Elecric Melters

Most electric furnaces are controlled by proportional systems that vary output over time. This makes it very difficult to clock consumption. I do have some data from an electric furnace owner who was able to determine that his 275 pound electric furnace, melting once per week and blowing five days per week, uses 6,230 kWh/month. This is very close to what the manufacturer predicted.

At 10 cents/kWh, that’s $623 per month, responsible for13,332 pounds of CO_2 output per month, and 80 tons of CO_2 per year, using electricity from a coal fired power plant.