Carbon Tax Calculator Methodology

by Yoram Bauman and Justin Bare

Last updated September 12, 2016

This document explains the methodology behind the carbon tax shift calculator tool relating to the Carbon Washington proposal to levy a carbon tax in Washington State and use the revenue to reduce sales taxes, fund the Working Families Tax Exemption, and reduce business taxes for manufacturers. The calculator currently focuses on households, with a business calculator (outlined at the bottom of this document) coming in the future.

Full disclosure: Yoram is a leader of the Carbon Washington group and helped specify the calculator and gather the data that it uses, with research assistance from Summer Hanson and Akua Konadu. Ultimately, however, the calculator website and the code behind it is the project of UW computer science graduate student Justin Bare. It is intended to be an impartial informational tool to allow Washington State households to evaluate the impact of a carbon tax on their household. One of the goals of this post is to explain the methodology of the calculator so that others can analyze it.

Three additional comments before diving into the methodology. First, the calculator does not attempt to factor in changes in behavior that are likely to result from the carbon tax. It simply takes current household spending and evaluates the impact of the proposal.

Second, the calculator focuses on the impact of the carbon tax on spending relating to the most fossil-fuel-intensive goods: motor vehicle fuel, air travel, home heating, and electricity. It does not attempt to estimate other price impacts (for example, changes in the price of French fries at McDonalds resulting from higher costs for processing and transport and/or lower costs from reductions in taxes paid by McDonalds or French fry manufacturers) because these are likely to be small in both absolute and relative terms.

Finally, the more accurately you can estimate your carbon consumption, the more useful the calculator will be. That applies to household gasoline consumption—as noted below, there are three different options for estimating this—and it applies even more strongly to household energy use. Although there is an option for estimating household energy use using information that is at your fingertips, you will get a much better estimate if you spend a few minutes to dig through your utility bills and generate an estimate based on that data.

1 Implementation

The tool is hosted on a server in the Department of Computer Science and Engineering at the University of Washington, and is implemented as a Javascript program written by Justin. When a user goes to the site and runs the calculator, the Javascript program is downloaded to the users web browser and run locally on the users machine. This has several advantages: first, its faster to run, since the software doesnt need to communicate back and forth with the server each time information is entered; and second, no information input to the calculator is stored on the server, eliminating a potential source of privacy concerns.

The calculations shown later in this document are a clear representation of what is computed in the Javascript program. (It thus represents the ground truth of how the calculator runs)

2 Sales Tax Reduction

The Carbon Washington proposal is to lower the state sales tax by 1 percentage point, from 6.5 percent to 5.5 percent. Table 9-1 of the 2002 Tax Structure Study Report lists retail sales tax as a percentage of household income for various income brackets in Washington State, from 6.7 percent of income for households making less than $20,000 to 2.2 percent of income for households making over $130,000. (The state Department of Revenue has updated data for 2012, but it did not change the results much and so we are continuing to use the 2002 data because it is easier to use.)

These percentages are for all sales taxes (state plus local) and the Department of Revenue reports that the average total sales tax rate in Washington State is 8.95 percent. Our proposal would reduce this by 1 percentage point, i.e., to 7.95 percent, so we can combine all this information to estimate the sales tax savings for any given household. (Example: If your household income is $55,000 then you pay an estimated 3.7 percent of your income in sales taxes, i.e., $2,035. So a one percentage point reduction would save you $2,035(1/8.95)=$227.)

Finally, we smooth out the 2002 Tax Study estimates (see red line below) by using a power series estimate (black line below) from Microsoft Excel. This smooths out the discontinuous jumps evident in (for example) going from an income of $19,999 to an income of $20,001. See Figure 1 for more details.

The calculator also allows households that have a better estimate of their annual sales tax payments to directly enter that estimate in order to calculate their sales tax savings from that amount.

2.1 Calculations

The tool will ask for household income and then estimate sales tax savings using the following calculations:

$$CurrentSalesTaxRate = 8.95\%$$

$$SalesTaxRateReduction = 1\%$$

$$ApproximateAnnualSalesTaxPayment = 121.59 \times (0.001 \times Income)^{0.6919}$$

$$AnnualSalesTaxSavings = ApproximateAnnualSalesTaxPayment \times \frac{SalesTaxRateReduction}{CurrentSalesTaxRate}$$

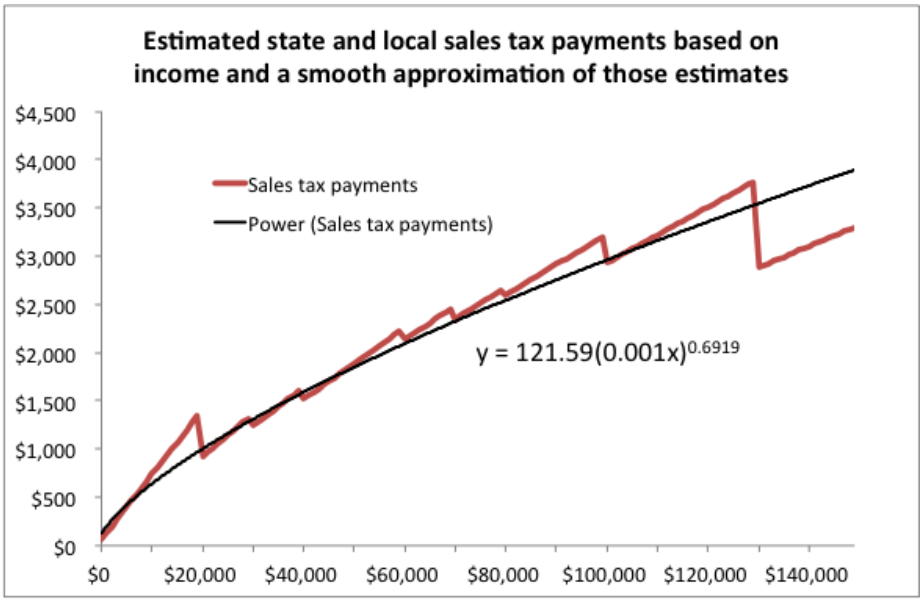


Figure 1: Source: Based on the 2002 Tax Structure Study Report.

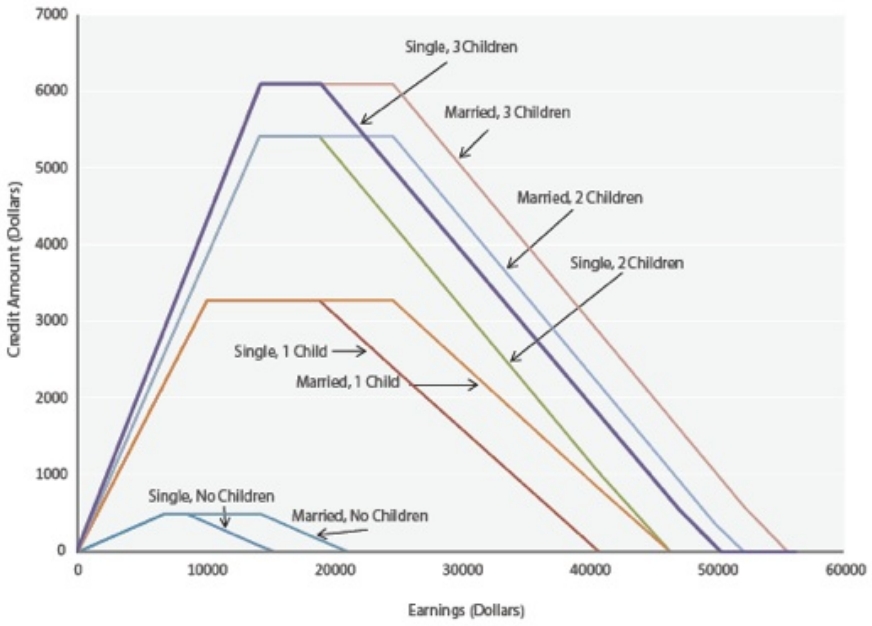
3 Working Families Tax Exemption

The Working Families Tax Exemption (WFTE) is a state-level bump-up of the federal Earned Income Tax Credit (EITC), a refundable tax credit that benefits low-income working households. (Refundable means that households receive a check if their tax due is less than the amount of the credit.)

The federal EITC provides a percentage match of earned income up to a certain level (see Figure 2). In 2014 it provides a maximum credit of $496 for households without children, $3,305 for households with 1 child, $5,460 for households with 2 children, and $6,143 for households with 3 or more children.

Twenty-five states (and New York City and Washington, DC) provide local bump-ups of the federal EITC; for example, low-income households in Kansas receive from the state government a refundable state income tax credit equal to 17% of their federal EITC. The bump-up rates range from 3.5% of the federal EITC to 50% of the federal EITC. Washington State has no income tax, but in

Figure 1: Earned Income Tax Credit by Number of Children and Filing Status, 2014



Source: 2014 EITC parameters taken from http://www.taxpolicycenter.org/taxfacts/displayafact.cfm?Docid=36

Figure 2: Source: Tax Policy Center.

2008 the state government created a sales tax exemption for working families that equals 10% of the federal EITC. This Working Families Tax Exemption currently exists in state law (RCW 82.08.0206), but it has never been funded.

The Carbon Washington proposal provides a Working Families Tax Exemption equal to 25% of the federal EITC. If it were in place in 2014, the WFTE would therefore provide a maximum credit of $124 for households without children, $826 for households with 1 child, $1,365 for households with 2 children, and $1,536 for households with 3 or more children.

3.1 Calculations

The calculator will ask for household income, tax filing status (single or married), and number of children and then determine the Working Families Tax Exemption (if any). See the similar calculator from the Washington Budget and Policy Center.

The calculations are as follows:

First determine several variables based on the number of dependents:

if the number of dependents is 0:

$$CreditRate = 0.0765$$

$$MaximumCredit = \$496$$

$$PhaseOutRate = 0.0765$$

$$BasePhaseOutIncome = \$8110$$

otherwise if the number of dependents is 1:

$$CreditRate = 0.34$$

$$MaximumCredit = \$3305$$

$$PhaseOutRate = 0.1598$$

$$BasePhaseOutIncome = \$17830$$

otherwise if the number of dependents is 2:

$$CreditRate = 0.40$$

$$MaximumCredit = \$5460$$

$$PhaseOutRate = 0.2106$$

$$BasePhaseOutIncome = \$17830$$

otherwise if the number of dependents is 3 or more:

$$CreditRate = 0.45$$

$$MaximumCredit = \$6143$$

$$PhaseOutRate = 0.2106$$

$$BasePhaseOutIncome = \$17830$$

Then calculate the income at which the credit rate begins to decrease:

if tax status is married filing jointly:

$$PhaseOutIncome = BasePhaseOutIncome + \$5430$$

otherwise:

$$PhaseOutIncome = BasePhaseOutIncome$$

Then determine if the tax filer gets the maximum credit:

if $MaximumCredit > CreditRate \times Income$**:**

$$BaseEITC = CreditRate \times Income$$

otherwise if $MaximumCredit \leq CreditRate \times Income$**:**

$$BaseEITC = MaximumCredit$$

Then determine if the tax filer's income falls into the phase out region:

if $Income > PhaseOutIncome$**:**

$$PhaseOutEITC = BaseEITC - PhaseOutRate \times (Income - PhaseOutIncome)$$

otherwise:

$$PhaseOutEITC = BaseEITC$$

Makes sure the calculated tax credit is not less than zero:

if $PhaseOutEITC < \$0$**:**

$$EITC = \$0$$

otherwise:

$$EITC = PhaseOutEITC$$

Calculate the tax exemption from the computed EITC:

$$WorkingFamilesTaxExemption = 0.25 \times EITC$$

4 Carbon Tax: Motor Gasoline

The EIA says that motor gasoline produces 8.91kg CO2 per gallon. A tax of $25 per metric ton of CO2 therefore corresponds to 22.275 cents per gallon. The calculator allows households to estimate gasoline consumption in one of three ways: (1) directly, from gasoline purchases each week, month, or year; (2) indirectly, from expenditures on gasoline each week, month, or year; or (3) indirectly, from vehicle miles traveled per year and average fuel economy. Households that use diesel fuel or that consume boat or small-plane fuel can add those quantities in this section; the numbers for kg CO2 per gallon are slightly different but good enough for an estimate.

4.1 Calculations

The calculator will ask for an estimate of household gasoline consumption (with various options, including gallons per week/month, spending per week/month, and miles per year plus miles per gallon) and determine the carbon tax accordingly. For example, a household that consumes 600 gallons per year would pay 600*0.22275 = $133.65 a year.

The calculations are as follows:

Calculate the number of times that the unit of time used occurs in a year:

if timeframe is per week:

$$TimeFrame = 52$$

otherwise if timeframe is per month:

$$TimeFrame = 12$$

otherwise if timeframe is per year:

$$TimeFrame = 1$$

Calculate the additional taxes on gasoline:

if option 1 (gallons) is used:

$$GasolineTaxes = \frac{Gallons \times TimeFrame \times (8.91\ kg\,CO_2\,per\,gallon) \times (\$25\ per\,metric\,ton\,CO_2)}{(1000\ kg\,CO_2\,per\,metric\,ton\,CO_2)}$$

otherwise if option 2 (cost) is used:

$$GasolineTaxes = \frac{Dollars \times TimeFrame \times (8.91\ kg\,CO_2\,per\,gallon) \times (\$25\ per\,metric\,ton\,CO_2)}{DollarsPerGallon \times (1000\ kg\,CO_2\,per\,metric\,ton\,CO_2)}$$

otherwise if option 3 (mileage) is used:

$$GasolineTaxes = \frac{Miles \times TimeFrame \times (8.91\ kg\,CO_2\,per\,gallon) \times (\$25\ per\,metric\,ton\,CO_2)}{MilesPerGallon \times (1000\ kg\,CO_2\,per\,metric\,ton\,CO_2)}$$

5 Carbon Tax: Air Travel

The Carbon Washington proposal includes a tax on all jet fuel loaded into planes taking off from airports in Washington State. (This is unlike BC and CA, both of which tax jet fuel only if the flight both takes off and lands in BC or CA, respectively.)

To estimate the impact of a carbon tax here, we begin by getting an estimate of how many person-miles a household travels on personal flights that leave from airports in Washington State. (We restrict this to person travel because business travel is covered by employers, and to flights that leave from airports in Washington State because those are the flights that will be subject to the carbon tax.)

We then take this distance estimate and convert to per-person jet fuel consumption by assuming that planes achieve per-passenger fuel efficiency of about 60mpg. (These figures were confirmed with a commercial airline pilot and roughly match the numbers from Appendix E of these published figures. Mileage is slightly better for medium-haul flights and slightly worse for short flights that use fuel to ascend and descend and for long flights that have to carry lots of fuel.) Finally, the EIA says that jet fuel produces 9.57kg CO2 per gallon. A tax of $25 per metric ton of CO2 therefore corresponds to 23.925 cents per gallon.

The impact of a carbon tax on air travel is surprisingly modest. For example, a flight from SEA to JFK covers about 2,400 miles, so at 60 miles per gallon per passenger that works out to about 40 gallons per passenger, corresponding to a carbon tax of about $10.

5.1 Calculations

The calculator will ask for an estimate of distance traveled by air and then convert to jet fuel by assuming 60mpg per passenger, and the carbon tax will be calculated accordingly. For example, a flight from SEA to JFK covers 2,418 miles and takes about 5 hours, so 2,418 miles at 60mpg means per-passenger jet fuel consumption of 2,418/60 = 40.3 gallons. This corresponds to a carbon tax bill of about 40.3 * $0.23925 = $9.64.

The calculations are as follows:

$$JetFuelTaxes = \frac{SeatMiles \times (9.57\ kg\,CO_2\,per\,gallon) \times (\$25\ per\,metric\,ton\,CO_2)}{(1000\ kg\,CO_2\,per\,metric\,ton\,CO_2) \times (60\ miles\,per\,gallon\,per\,passenger)}$$

6 Carbon Tax: Home Energy Use

The Residential Building Stock Assessment (RBSA) estimates that homes in Washington State average 2000 sq.ft. (Table 11, PDF p47). Our approach is therefore to determine the carbon consumption for an average home and then ask users to scale their homes accordingly based on factors including home size, quality of insulation, use of solar panels, A/C or not, apartments or townhouses or single-family homes, etc. This is not perfect but perhaps its the best we can do given the variability of housing situations. As noted in the introduction, users will get a much better estimate if they spend a few minutes to dig through their utility bills and generate an estimate based on that data.

The RBSA notes (Table 51, PDF p73) that fuel use for primary heating systems in Washington State is divided between:

- natural gas: 46.2% (of households in Washington State)
- electricity: 38.8%
- fuel oil: 3.9%
- wood: 7.6%
- propane: 2.1%
- biomass pellets: 1.5%

The RBSA also estimates that single-family homes in Washington State:

- *with electric heat* use about 11.18 kWh of electricity per sq.ft. (Table 152, PDF p130), i.e., an average house would use 22,360 kWh per year.
- *without electric heat* use about 5.50 kWh of electricity per sq.ft. (Table 152, PDF p130), i.e., an average house would use 11,000 kWh per year.
- with natural gas heat use about 732 therms per year (Table 155, PDF p132)
- with fuel oil heat mostly use 250-500 gallons per year (Table 144, PDF p124), although some use more and some use less. We are going to use an average of 527 gallons, which is the amount of fuel oil that produces the same number of BTUs as 732 therms of natural gas. (From EIA data: 732 therms of natural gas equals 73.2 mmBTU, and there are 73.15/10.15 = 7.21 gallons of fuel oil in one mmBTU, so that makes 73.2*7.21 = 527 gallons of fuel oil to produce the same number of BTUs as 732 therms of natural gas.) An alternative approach (used in a draft version of the calculator) was to use an average of 342 gallons, which was derived by noting that (1) the EIA estimates residential distillate fuel oil use in Washington State at 36m gallons; (2) the RBSA (Table 51, PDF p73) estimates that 3.9% of households in Washington State use oil as their primary fuel;

and (3) the BLS says that there are an average of 2.5 people per household in the USA, so the 6.83m people in Washington State in 2011 form about 2.7m households. If 3.9% of those households use fuel oil thats 0.1m households, and with total residential use of 36m gallons that means 342 gallons per household.

The calculations for fuel oil and natural gas are easy. The EIA says that natural gas produces about 5.306 kg CO2 per therm; a tax of $25 per metric ton of CO2 therefore corresponds to 13.265 cents per therm. And fuel oil produces about 10.15 kg CO2 per gallon; a tax of $25 per metric ton of CO2 therefore corresponds to 25.375 cents per gallon.

The calculation for electricity consumption is hard: There are over 60 utilities in the state, each with its own carbon profile, and it is not always easy to tell which utility serves which households.

Our approach begins by matching zip codes with one or more possible utilities based on our own research using this Energy Services Map (recently updated to this improved map by the BPA). Some zip codes are entirely served by a single utility but some are divided among as many as five utilities, so if necessary we ask users to specify which utility they use. This is important because utilities have very different carbon profiles, with roughly half the state using relatively high-carbon electricity from the three Investor Owned Utilities in the state (PSE, Pacific Power, and Avista) and the other half of the state using relatively low-carbon electricity from public utilities (Seattle City Light, Tacoma Power, county PUDs, etc.).

Once we know the electric utility provider, we then use Fuel Mix Disclosure Reports to calculate the carbon profile for that utility. For example, PSE is 29.76% coal, 42.16% hydro, 15.55% natural gas, 1.28% nuclear, 8.36% wind, and 2.89% other. Finally, we estimate CO2 emissions from the Fuel Mix report (PDF pages 7 and 9), e.g., the state generated 12.149 million MWh from coal and produced 13.315 million metric tons of CO2 from coal, so thats 1.1 tons per MWh or 1.1 kg CO2 per kWh. (Natural gas is 0.47 kg CO2 per kWh.) We can then calculate a weighted average for each utility to get their overall kg CO2 per kWh and use this figure (plus the $25 per metric ton carbon tax rate, plus the data on usage by an average house, plus the scale factor that the user creates to compare their usage to an average house) to get a carbon tax impacts for electricity. Similar calculations yield carbon tax impacts for households using natural gas, fuel oil, etc.

6.1 Calculations

The calculator will ask for zip code (and if necessary utility provider), and for the source of home heating (electricity, natural gas, fuel oil, wood, propane, pellets), and for an estimate of how much energy the users home uses compared to an average 2000 sq.ft. house. The calculator will then determine the carbon tax accordingly.

Example 1: An average house in PSE territory that uses electric heat would pay an extra 1.00 cents per kWh, and at 22,360 kWh per year that totals $223.60.

Example 2: An average house in Seattle City Light territory that uses electric heat would pay an extra 0.02 cents per kWh, and at 22,360 kWh per year that totals $4.47.

Example 3: An average house in PSE territory that uses natural gas heat would pay an extra 1.00 cents per kWh, and at 11,000 kWh per year that totals $110.00 plus 732 therms of natural gas at 13.265 cents per therm that totals $97.10 for a grand total of $207.10.

Example 4: An average house in Seattle City Light territory that uses natural gas heat would pay an extra 0.02 cents per kWh, and at 11,000 kWh per year that totals $1.10 plus 732 therms of natural gas at 13.265 cents per therm that totals $97.10 for a grand total of $98.20.

The calculations are as follows:

Compute the overall carbon impact per kiloWatt-hour and translate this value into cents per kiloWatt-hour based on the carbon tax rate:

for each utility:

$$CoalImpact = FractionOfEnergyFromCoal \times (1.10\ kg\,CO_2\,per\,kWh)$$

$$NaturalGasImpact = FractionOfEnergyFromNaturalGas \times (0.47\ kg\,CO\_2\,per\,kWh)$$

$$PetroleumImpact = FractionOfEnergyFromPetroleum \times (1.12\ kg\,CO_2\,per\,kWh)$$

$$TotalCarbonImpact = CoalImpact + NaturalGasImpact + PetroleumImpact$$

$$CentsPerKiloWattHour = \frac{TotalCarbonImpact \times (\$25\ per\,metric\,ton\,CO_2) \times (100\ cents\,per\,dollar)}{1000\ kg\,CO_2\,per\,metric\,ton\,CO_2}$$

Determine how much of the utility bill is paid by the user:

if utility bills are split:

$$FractionOfBillPaid = \frac{PercentOfBillPaid}{100}$$

otherwise if utility bills are not split:

$$FractionOfBillPaid = 1$$

Compute the contribution to the user's carbon tax estimate from each source, as well as the total home energy use tax:

$$NaturalGasTaxes = \frac{(5.306kg\,CO_2\,per\,therm)}{1000\ kg\,CO_2\,per\,metric\,ton\,CO_2} \times ThermsOfNaturalGas \times (\$25\ per\,metric\,ton\,CO_2) \times FractionOfBillPaid$$

$$FuelOilTaxes = \frac{(10.15kg\,CO_2\,per\,gallon)}{1000\ kg\,CO_2\,per\,metric\,ton\,CO_2} \times GallonsOfFuelOil \times (\$25\ per\,metric\,ton\,CO_2) \times FractionOfBillPaid$$

$$ElectricityTaxes = \frac{kWhOfElectricity \times CentsPerKiloWattHour \times FractionOfBillPaid}{100\ cents\,per\,dollar}$$

$$HomeEnergyTaxes = NaturalGasTaxes + FuelOilTaxes + ElectricityTaxes$$

7 Household Summary

From all of the information computed above, it is easy to obtain a net estimate of how a household will be financially affected by this policy.

7.1 Calculations

The calculations are as follows:

$$TotalSavings = AnnualSalesTaxSavings + WorkingFamiliesTaxExemption$$

$$TotalLosses = GasolineTaxes + JetFuelTaxes + HomeEnergyTaxes$$

$$TotalNet = TotalSavings - TotalLosses$$

8 Business Calculator Overview

Adapting the calculator to business use is a relatively easy process provided that the business has the necessary information about its tax payments.

Businesses pay about 32 percent of the retail sales tax in Washington State, so a one-point reduction in the state sales tax would save businesses about $380

million a year in aggregate. Calculating sales tax savings should be straightforward for businesses that collect this information. (Note that these sales tax savings are for sales tax paid by businesses on their own purchases, not sales taxes collected on sales to customers. It is also worth emphasizing that we are doing a simple calculation here and are not attempting to analyze issues such as pass-through of taxes from businesses onto their customers.)

The Working Families Tax Exemption is not relevant to businesses, so we can skip over that.

Businesses with the relevant information can use the calculator to estimate carbon tax payments relating to motor vehicle use, air travel, and commercial and industrial use. For manufacturers, EPA data might also be valuable, but note that the Carbon Washington proposal applies only to fossil fuels and not to other sources of greenhouse gases.

The main challenge for businesses will be to calculate their savings from the B&O (business) tax reductions for manufacturers. Businesses that are not manufacturers can ignore this component, but businesses that are manufacturers will need to look at the details of their B&O tax liabilities and consider issues such as the Multiple Activities Tax Credit. This will have to be done on a business-by-business basis because of the intricacies involved in the calculation.