Carbon Tax Modeling for Washington State

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Background

Background: Development of CTAM

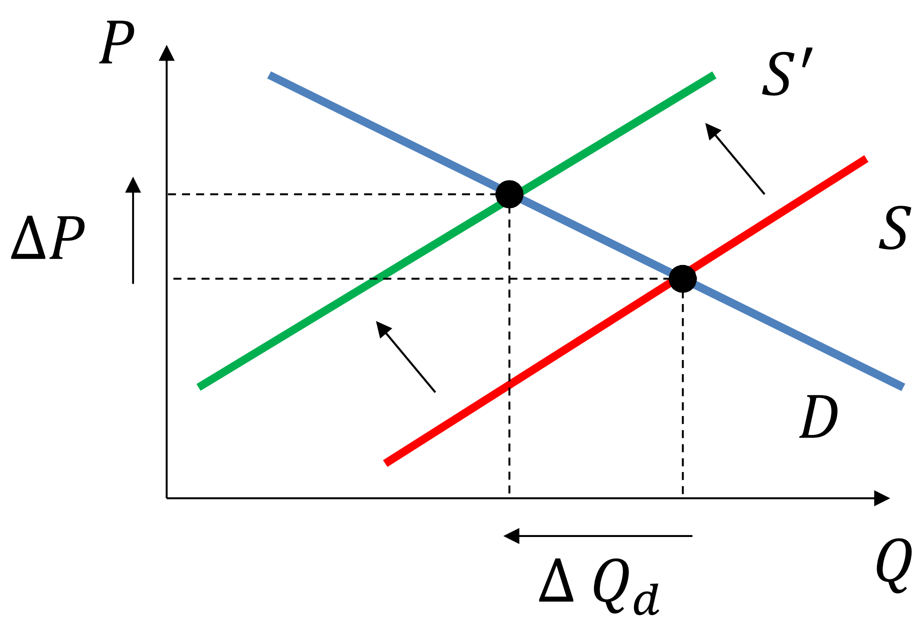
The Carbon Tax Analysis Model (CTAM) was developed by Keibun Mori in 2011 as part of his graduate work, with input from Dept. of Commerce staff and University of Washington faculty. It applies long run price elasticity values, with specific values used for each sector and fuel, to estimating the impacts of hypothetical carbon taxes on energy prices, greenhouse gas emissions and state revenues/budgets in Washington state.

In 2013 CTAM was updated with a more detailed and realistic electric sector representation, and updated energy consumption and price forecasts. Several additional updates and features were added in 2015.

Background: Carbon Tax

- A carbon tax is levied on fossil fuel based on its carbon content. The resulting higher fuel price(s) lowers the end use demand for fossil fuel(s).
- A carbon tax has several advantages over other policy options such as direct regulation.
  - collects revenues from fuel wholesalers just like a gas tax (administrative simplicity)
  - the future price impact on fuels is known (for cap & trade carbon emissions are known)
  - addresses carbon emissions from all sectors (efficient and an economy-wide solution)
  - enhances economic welfare through revenue recycling (economic optimization)

Carbon Tax Concept



D *: demand curve*

S*: supply curve*

S'*: supply curve after tax*

P*: price*

Q_d *: quantity demanded*

Background: Price Elasticity & Demand Reduction

Price Impact Specification

$$\Delta P_f = rC_f$$

r : nominal tax rate

C_f : carbon intensity

P_f : price

Demand Impact Specification

$$D'_{f,s} = D_{f,s}\left(1 + \frac{\Delta P_f}{P_{f,s}}\varepsilon_{f,s}\right)$$

$D_{f,s}$: baseline demand

$D'_{f,s}$: demand with carbon tax

P_f : price

$\varepsilon_{f,s}$: price elasticity of demand =(ΔQ/Q)/(ΔP/P)

ΔP_f : price impact

Background : CO_2 Emissions and Tax Revenue

Gross CO_2 emissions

$$\mathrm{E}' = \sum_f \sum_s D'_{f,s}\,\mathrm{E}_f$$

Tax Revenue Collected

$$\mathrm{R}' = \mathrm{r} \sum_f \sum_s D'_{f,s}\,\mathrm{C}_f$$

$D'_{f,s}$: demand with carbon tax

E_f : Fuel emission factor

r : nominal tax rate

$D'_{f,s}$: demand with carbon tax

C_f: carbon intensity

CTAM Methodology
(Carbon Tax Assessment Model)

Methodology: Price Elasticity Estimates

- CTAM's key driver is the elasticity estimates for each sector and fuel use.
- CTAM uses the weighted averages of various individual studies and meta-analysis.

Price Elasticities of Demand

Fuel or energy source by sector	Elasticity [a]		Stickiness[b] (yr)		operating values	
	default	your value	default	your value	elasticity	stickiness
Motor Fuel (Gasoline)	-0.62		10		-0.62	10
Distillate Fuel						
Electric sector	-1.26		20		-1.26	20
All Other sectors	-0.44		10		-0.44	10
Residual Fuel Oil	-0.37		10		-0.37	10
Jet Fuel	-0.23		10		-0.23	10
Natural Gas						
Residential sector	-0.40		20		-0.40	20
Commercial sector	-0.35		20		-0.35	20
Industrial sector	-0.74		10		-0.74	10
Electric sector	-0.29		20		-0.29	20
Coal (electric sector only)	-0.11		20		-0.11	20
Electricity						
Residential sector	-0.50		15		-0.50	15
Commercial sector	-0.48		15		-0.48	15
Industrial sector	-0.57		20		-0.57	20

Notes

a. These are *long-run* elasticities of demand. All default values are computed in spreadsheet 230-08c cells 'Elasticities'!BG7:BG22. Citations from original literature are in the same spreadsheet.

b. Stickiness is the length, in years, of the linear ramp over which a particular elasticity is fully rolled into the model.

Methodology: Fuel Use and Price Forecasts

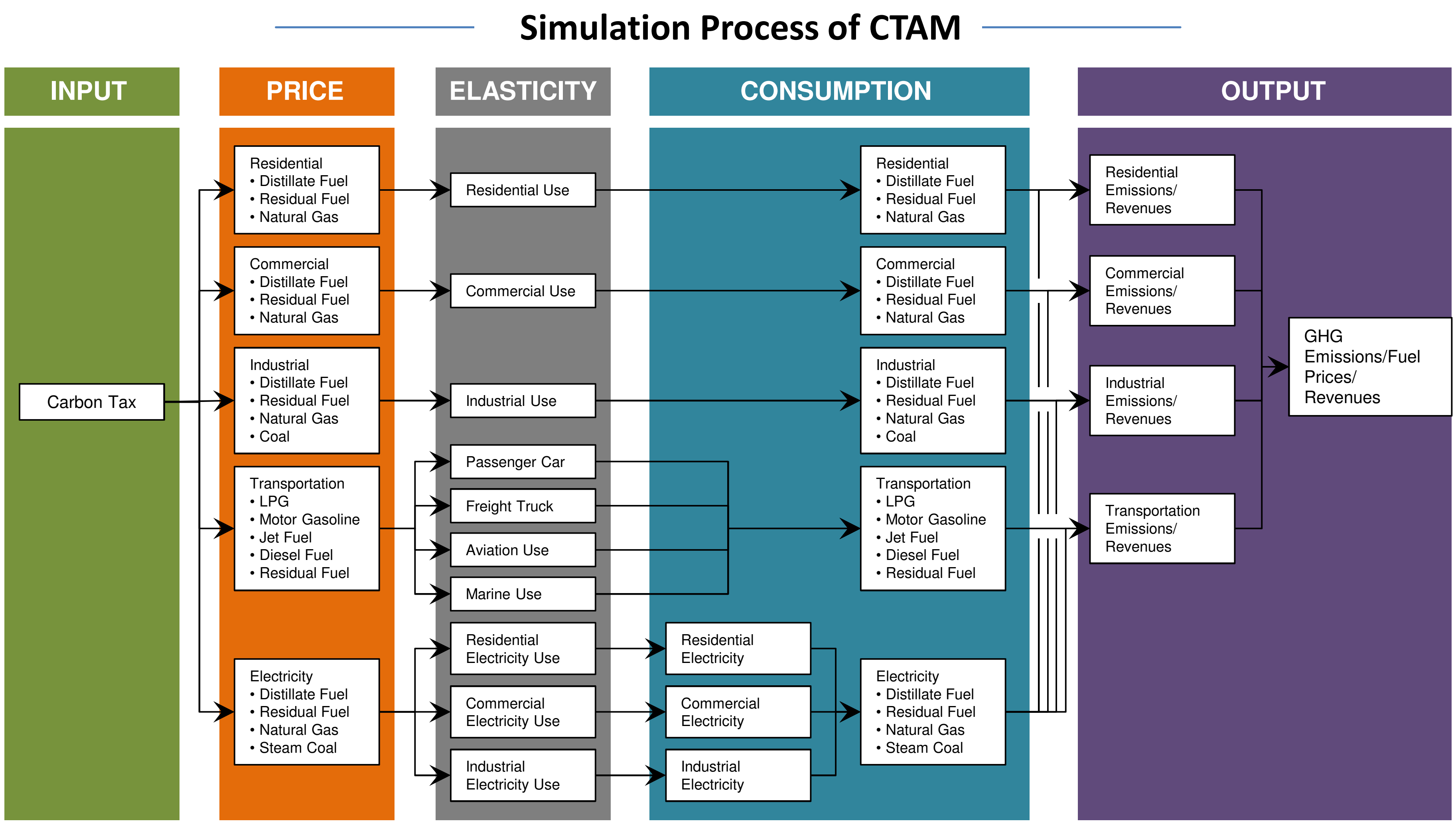
- CTAM's other key drivers are the forecasts (2015-40) of Washington state fuel consumption and prices. These are derived from Energy Information Administration (EIA) Annual Energy Outlook (AEO) forecasts.

Sector and Source	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Residential											
Liquefied Petroleum Gases	30.98	25.28	24.12	23.78	23.33	22.84	22.89	23.44	23.87	24.14	24.34
Distillate Fuel Oil	22.27	27.55	27.94	27.65	26.10	23.22	22.57	22.43	22.61	23.09	23.56
Natural Gas	10.34	10.32	9.55	10.69	11.47	11.24	10.83	11.17	11.69	11.94	11.93
Commercial											
Liquefied Petroleum Gases	24.98	22.20	20.75	20.23	19.67	19.08	19.13	19.80	20.32	20.64	20.87
Distillate Fuel Oil	21.88	27.06	27.44	27.17	25.64	20.18	19.69	19.63	19.87	20.39	20.85
Residual Fuel	12.18	20.83	17.19	16.66	16.12	13.82	13.36	13.12	13.23	13.52	13.89
Natural Gas	8.92	8.91	7.84	9.38	10.26	10.24	10.00	10.35	10.88	11.14	11.16

Sector and Source	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Residential											
Liquefied Petroleum Gases	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.007	0.007
Distillate Fuel Oil	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.002	0.002
Natural Gas	0.057	0.060	0.053	0.057	0.057	0.058	0.058	0.058	0.058	0.058	0.057
Commercial											
Liquefied Petroleum Gases	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Distillate Fuel Oil	0.009	0.012	0.012	0.011	0.010	0.010	0.011	0.011	0.011	0.011	0.011
Residual Fuel Oil	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Natural Gas	0.031	0.032	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.029

Methodology: Process

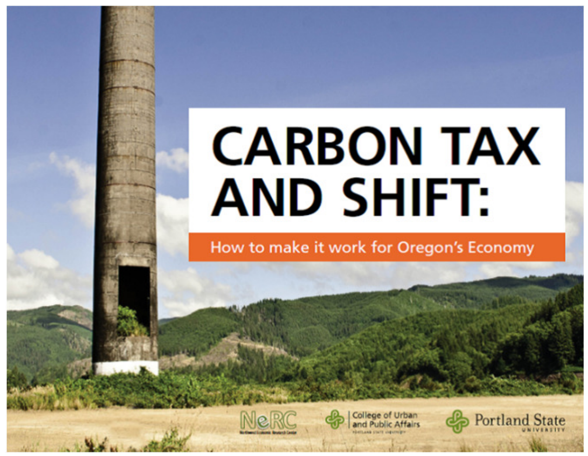
- CTAM first calculates the price impact on each fuel in each sector, and estimate the impact on the consumption level by using elasticity estimates for each fuel used.

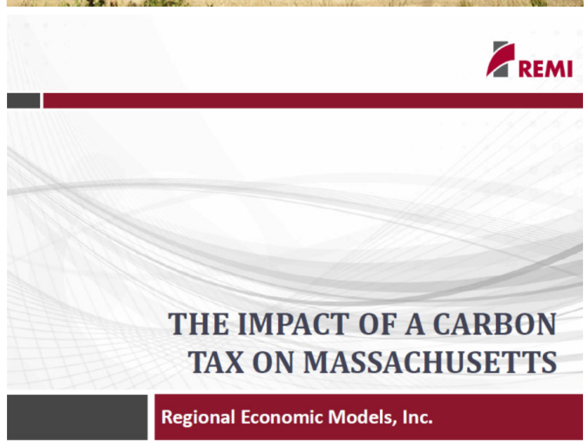


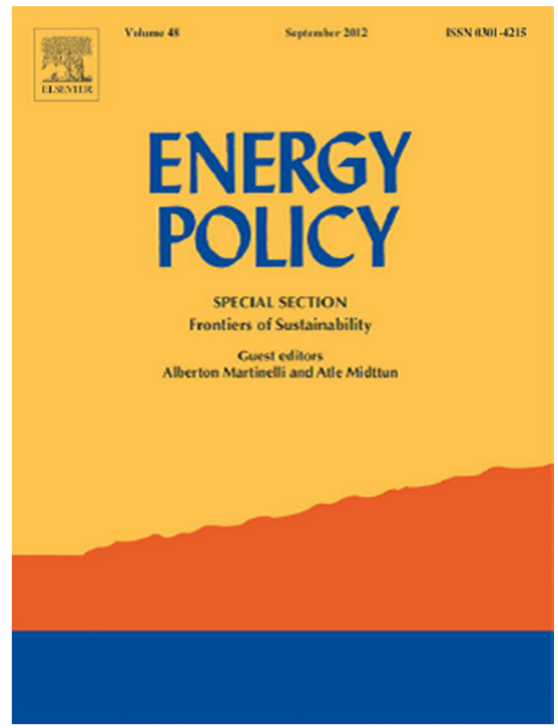
Source: [Mori (2012)]

CTAM Methodology: Applications

- Used for the 2012 Washington State Energy Strategy
- Adopted by the Northwest Economic Research Center for its study for Oregon and by Regional Economic Models, Inc. (REMI) for its study for Massachusetts.
- Published in Energy Policy
- Used by Washington OFM during 2014 CERT process by OFM and DOR during 2015 for Carbon Pollution Accountability Act revenue forecast







CTAM Update

CTAM Updates : Carbon tax + Other GHG Policies

- Carbon tax or cap and trade will not be the sole policy tool
- Other GHG policies are already in place. Examples are I-937, Centralia phase-out, appliance, and building code standards
- CTAM users may have an interest in incorporating existing and possible exogenous or complementary GHG reduction policies
- The original CTAM development staff recently completed an extensive update that incorporates exogenous GHG reduction polices
- These updates make CTAM a more versatile modeling tool.

CTAM Updates : New Elec. Calcs. & Optional Policies

- Review and update of elasticity values and energy/price forecast
- Electric sector is now consumption based , includes Centralia 2025 phase-out
- Optional phase-out of out-of state coal fired electricity generation
- Industrial process emissions (non-energy!) can be added to the model. Optional exogenous emission reductions can be applied
- Optional exogenous emission reductions to the four end-use sectors
- Optional supplemental fuel tax: Example, an increase in the federal or state fuel tax rates
- Optional Low Carbon Fuel Standard (LCFS) program
- Optional increase in the rate of electric vehicle adoption

CTAM Update: Dashboard

Carbon Tax Analysis Model (CTAM) version 3.0a (Washington State)

1. define the carbon tax

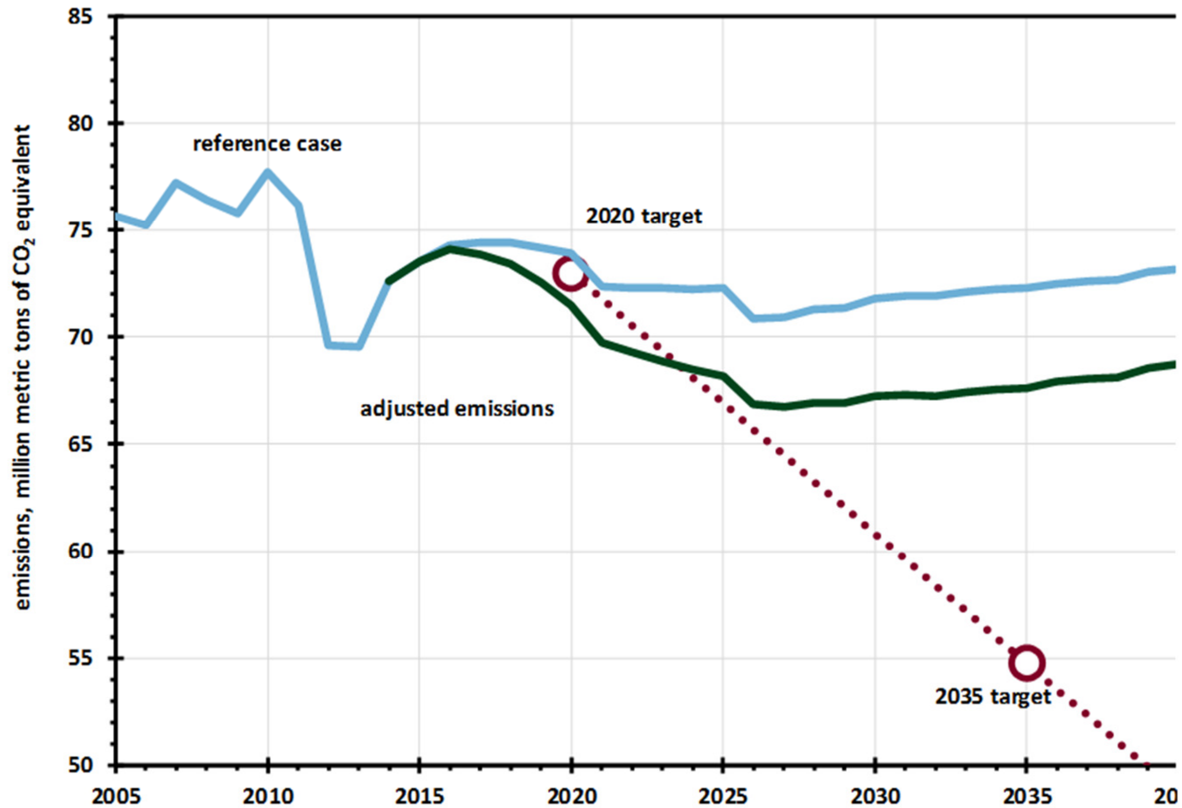
parameter description	default	your value
first year	2016	
initial rate	$10.00	
annual increment	$5.00	
maximum rate	$30.00	

2. assign fates for the revenue [note *b*]

parameter description	default	your value
Property Tax offset	0%	
Sales Tax offset	45%	
B&O Tax offset	45%	
cash rebate	10%	
state General Fund	0%	
Clean Energy Trust Fund	0%	
total revenues assigned	100%	0%

3. specify model behavior

parameter description	default	your value
baseline forecast (A, B or C)[f]	A	A
name of baseline forecast --->		reference case
include industrial process em.[d]	No	
exempt jet fuels	Yes	
exempt marine fuels	Yes	
exempt "transition coal"[g]	Yes	



4. (optional) add exogenous reductions to sector energy demands [note *c*]

sector / fuel	ramp length, years	target year	demand reduction, %	parameters valid?
residential sector				
natural gas				no
electricity				no
commercial sector				
natural gas				no
electricity				no
Industrial sector				
natural gas				no
petroleum				no

OUTPUT: energy related emissions, million metric tons CO_2

sector	2020 baseline	2020 adjusted	2020 change	2035 baseline	2035 adjusted	2035 change
residential	10.03	9.57	-4.5%	8.95	8.04	-10.2%
commercial	10.04	9.54	-5.0%	9.20	8.17	-11.2%
industrial	13.61	12.82	-5.8%	14.13	12.40	-12.3%
transportation	40.23	39.57	-1.6%	40.02	39.00	-2.5%
TOTALS	73.91	71.50	-3.3%	72.30	67.61	-6.5%
targets	73.00			54.75		
electricity *	17.84	16.71	-6.3%	15.53	13.24	-14.7%

* These are INCLUDED in each sector's emissions forecast above.

CTAM Update: Dashboard (cont.)

coal				no
electricity				no
transportation				
gasoline				no
diesel				no
jet fuel				no

5. (optional) add exogenous reductions to industrial process emissions

industrial process	ramp length, years	target year	emissions reduction, %	parameters valid?
cement manufacture				no
aluminum production				no
limestone and dolomite use				no
soda ash				no
ODS substitutes[e]				no
semiconductor manufacturing				no
electric power T&D				no

6. (optional) add a supplemental fuel tax [note *a*]

fuel	ramp length, years	target year	tax, $/gal	parameters valid?
gasoline				no
diesel				no

7. (optional) invoke a low carbon fuel standard

fuel type	ramp length, years	target year	AFCI reduction, %	parameters valid?
gasoline-like				no
diesel-like				no

8. (optional) shut down Colstrip

units	shut down Jan. 1 of....	% replaced by NG CCCT	% replaced by renewables	parameters valid?
Units 1 & 2			100%	no
Units 3 & 4			100%	no

9. (optional) increase penetration of EVs [note *h*]

	ramp length, years	target year	% gasoline displaced	parameters valid?
displacement of light vehicle fleet				no

OUTPUT: carbon tax revenue (mm$)

sector or group	2020	2035
residential	$218	$234
commercial	$203	$237
industrial	$339	$367
transportation	$885	$856
TOTALS	$1,646	$1,694
(individual)	$807	$734
(business)	$839	$960

OUTPUT: effects of revenue

revenue fate	2020	2035
Property Tax decrease	0%	0%
Sales Tax decrease	4%	3%
B&O Tax decrease	24%	16%
rebate ($/household)	$58	$52
General Fund (mm$)	$0	$0
Clean Energy (mm$)	$0	$0

OUTPUT: gross energy expenditures, billions of 2012 dollars

sector	2020 baseline	2020 adjusted	2020 change	2035 baseline	2035 adjusted	2035 change
residential	3.46	3.99	15.3%	3.75	3.95	5.3%
commercial	3.31	3.85	16.1%	3.66	3.87	5.7%
industrial	3.64	3.97	9.1%	4.59	4.71	2.5%
transportation	14.39	15.06	4.6%	18.07	18.66	3.3%
TOTALS	24.81	26.87	8.3%	30.08	31.20	3.7%

OUTPUT: energy prices, 2012 dollars

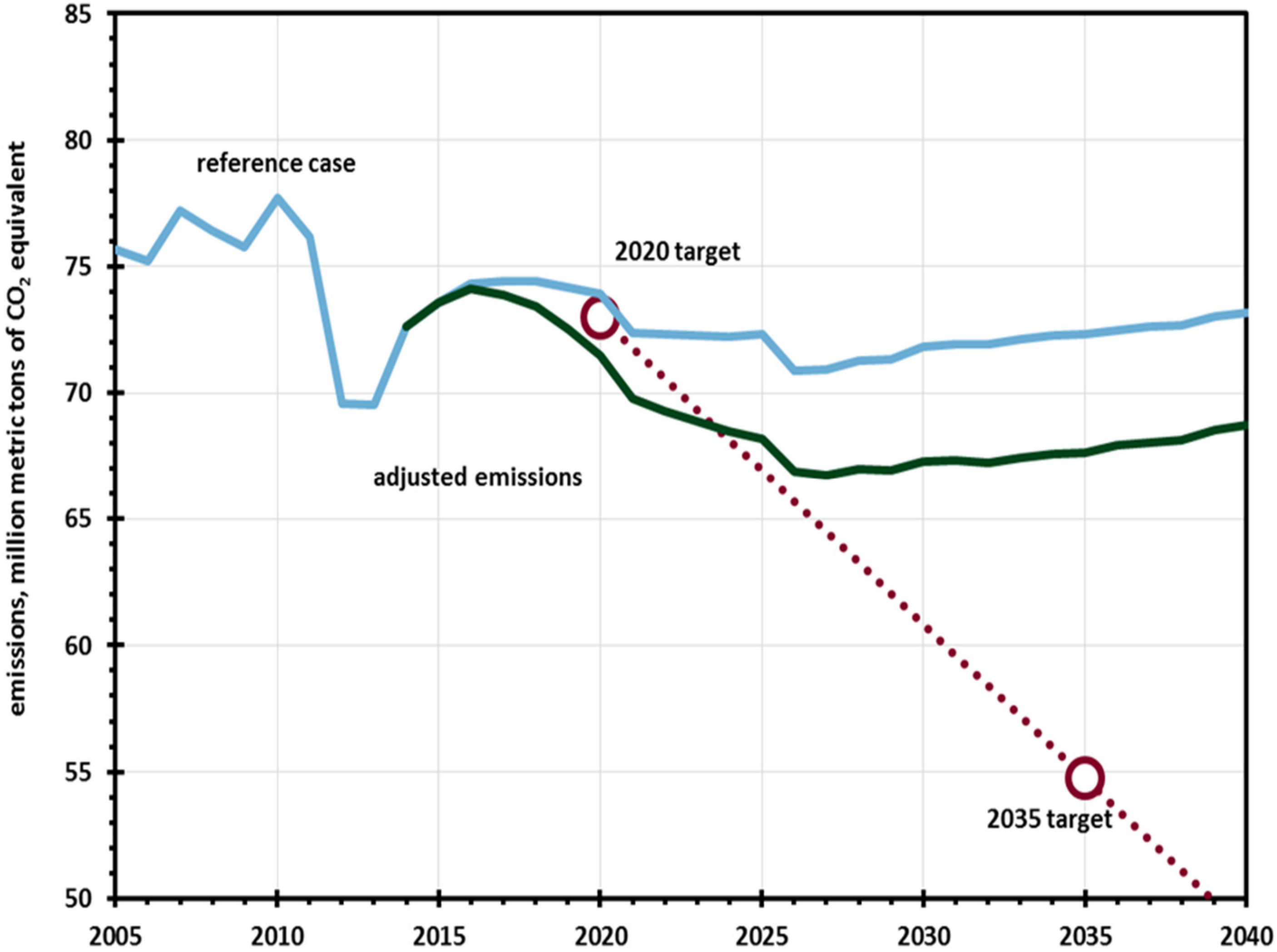
fuel	2020 baseline	2020 adjusted	2020 change	2035 baseline	2035 adjusted	2035 change
residenital NG, $/therm	1.19	1.35	13.3%	1.54	1.70	10.3%
residential elec., ¢/kWh	7.89	9.58	21.4%	8.12	9.05	11.4%
industrial NG, $/mmBtu	6.80	8.39	23.4%	8.36	9.95	19.0%
industrial elec., ¢/kWh	4.03	4.89	21.4%	4.35	4.85	11.4%
residual oil, $/bbl	77.09	77.09	0.0%	113.37	113.37	0.0%
gasoline, $/gal	3.40	3.66	7.8%	4.23	4.49	6.3%
diesel, $/gal	4.01	4.31	7.5%	4.99	5.29	6.0%

Examples

Examples: CTAM Answers Some Basic Questions

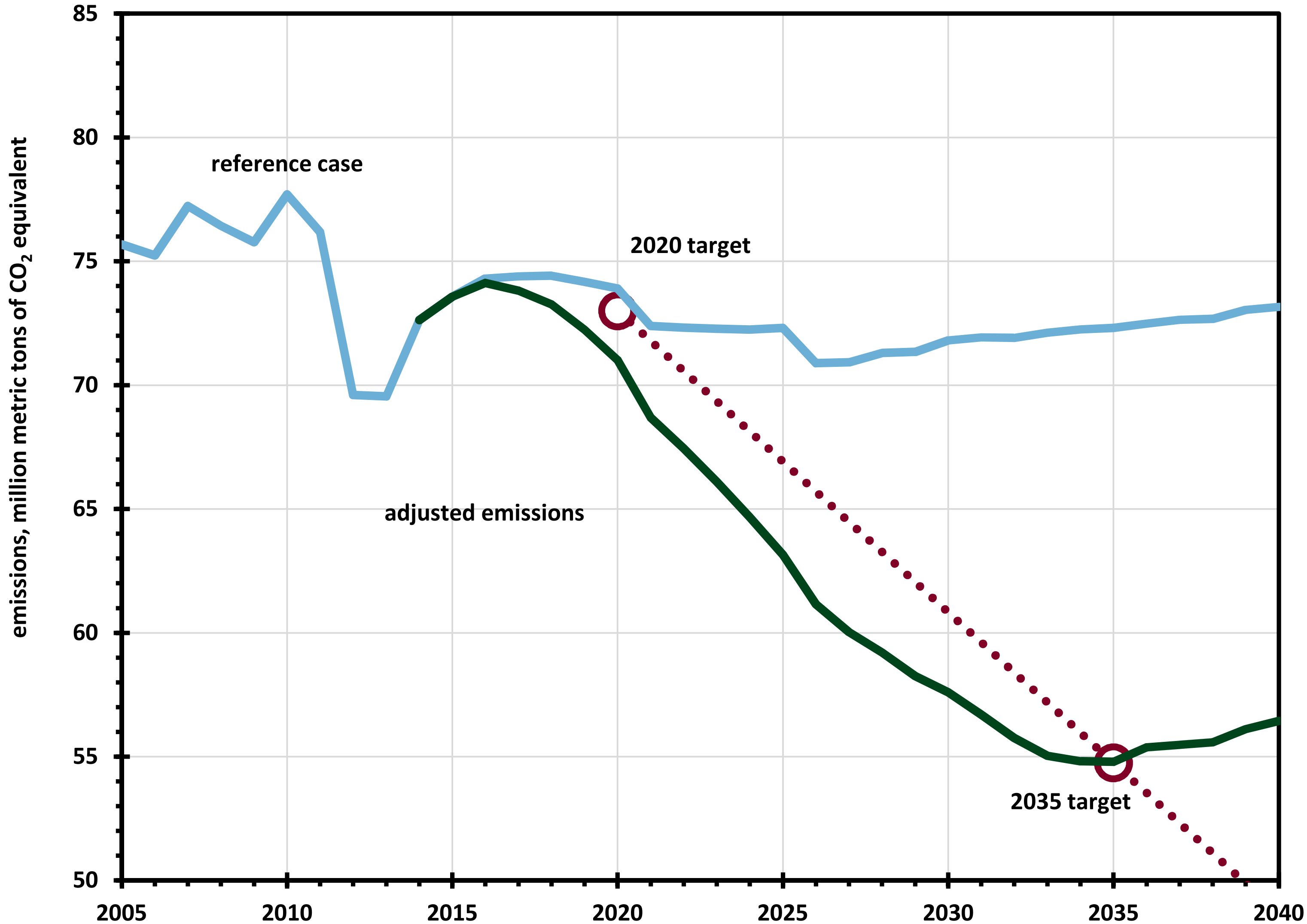
1. Can Washington state reach the 2020 and 2035 GHG emission targets with a BC style carbon tax of $30/MT?
2. What tax rate is necessary to reach the state's 2035 emission target?
3. Can complementary GHG reduction policies help keep the carbon tax rate at a manageable level?
4. How does the situation change if industrial process emissions are included in the model?

Example 1: GHG Emulating the B.C. Tax Scheme



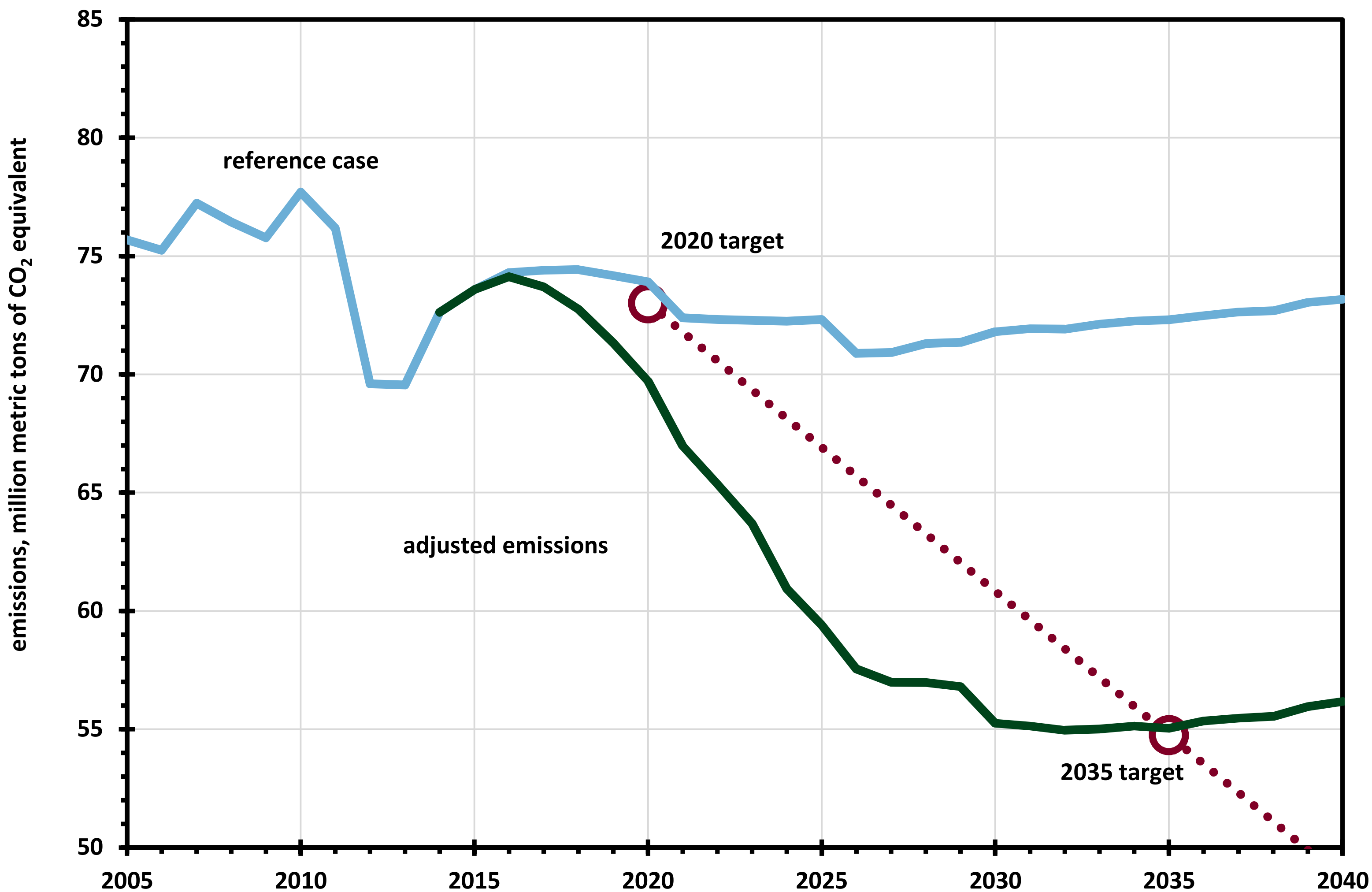
AEO 2014 Pacific region reference case prorated to WA, plus WA fuel pricing, and Centralia phase-out.

Example 2: GHG Emissions with Tax of $125/MT



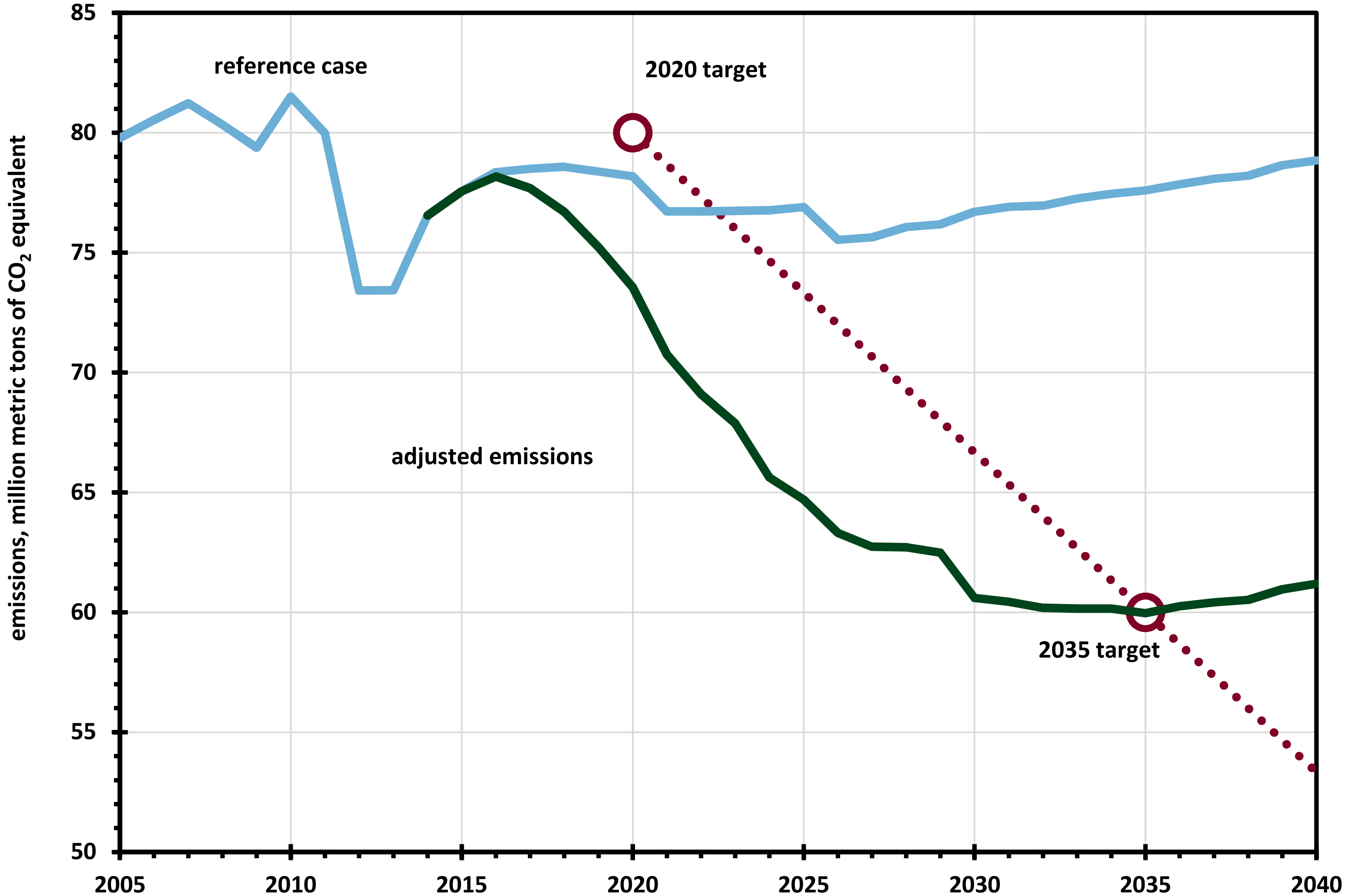
Same baseline conditions as previous slide

Example 3: Tax of $60/MT Plus Complementary Policies



Complementary policies: Increased utility energy efficiency (0.3%/yr.), 25 cents/gal. fuel tax increase, LCFS (10% AFCI), Colstrip phase-out by 2030 and accelerated EV adoption.

Ex. 4: Include Ind. Process Emis., Tax of $40/MT, Complementary Pol.



Complementary policies as with previous slide, but include industrial process emissions: emissions reduced 10% over 20 years, except semiconductor, electric power, which are reduced 20% over 20 years, and ODS emissions which are reduced 70% over 20 years.

Discussion

Discussion: Impact of other GHG policies

- Relying solely on a carbon tax requires a large tax: \$175/MT, (ex. not shown) to reach the state's 2035 goal,
- Incorporating one existing state GHG policy reduces the necessary carbon tax: \$125/MT w/Centralia phase-out.
- Adding future complementary GHG policies reduces the necessary carbon tax further: \$60/MT
- Broadening CTAM to include non-energy GHG emissions reduces the necessary carbon tax yet further: \$40/MT
- Using a more aggressive technology adoption forecast would result in a lower 2035 carbon tax rate
- Users should create plausible complementary policies and consider interactive effects

Discussion: Further Work

- Continue monitoring price elasticity literature,
- More refined simulation of elasticity stickiness,
- Improve WA energy demand and price forecasts,
- Evaluate the interactive effects of a carbon tax and complementary policies,
- Incorporate the upcoming EPA Clean Power Plan into electricity forecast,
- Consider developing scenarios with more rapid technology development/adoption.

Questions

Contact Information

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Some of the materials covered in this presentation come from the Keibun's research work at the University of Washington, the Washington State Department of Commerce, and Deloitte Tohmatsu Consulting, Co., Ltd.

The End

Extras

Background: Landmark BC Carbon Tax

- \$10/tCO_2 beginning July 1, 2008
- \$5/tCO_2 annual increment
- \$30/tCO_2 cap reached July 1, 2012
- \$1.1B revenues (FY2013 est.)
- Tax offsets
  - 60% to business
  - 40% to households
- Low income tax credit

Background: Landmark B.C. Carbon Tax

Start in 2008 at $10/MT → Increase $5/MT per year → 2012 $30/MT

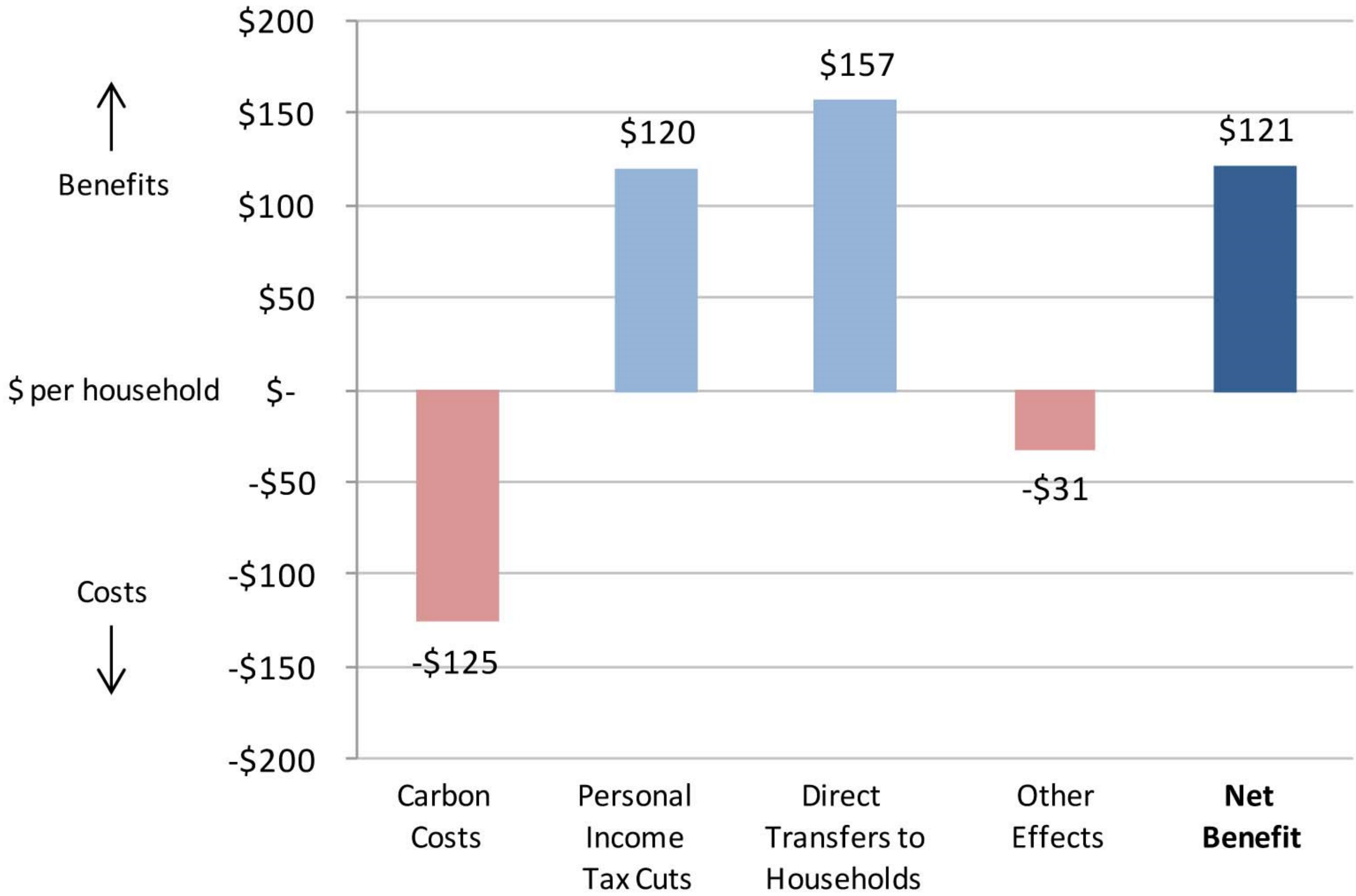
Per-capita petroleum consumption:

	2008/09	2009/10	2010/11	2011/12	2008-12 Total
BRITISH COLUMBIA	-5.4%	-3.6%	-2.4%	-7.1%	-17.4%
REST OF CANADA	-3.4%	-0.7%	3.9%	1.7%	1.5%
DIFFERENCE	-2.1%	-3.0%	-6.3%	-8.8%	-18.8%

- **2008-11 per capita GDP re 2007:**
  - **BC, -0.15%**
  - **rest of Canada, -0.23%**
  - **Conclusions muddied by the recent global recession, consumption growth in Alberta.**

Source: Elgie & McClay 2013 (Sustainable Prosperity)

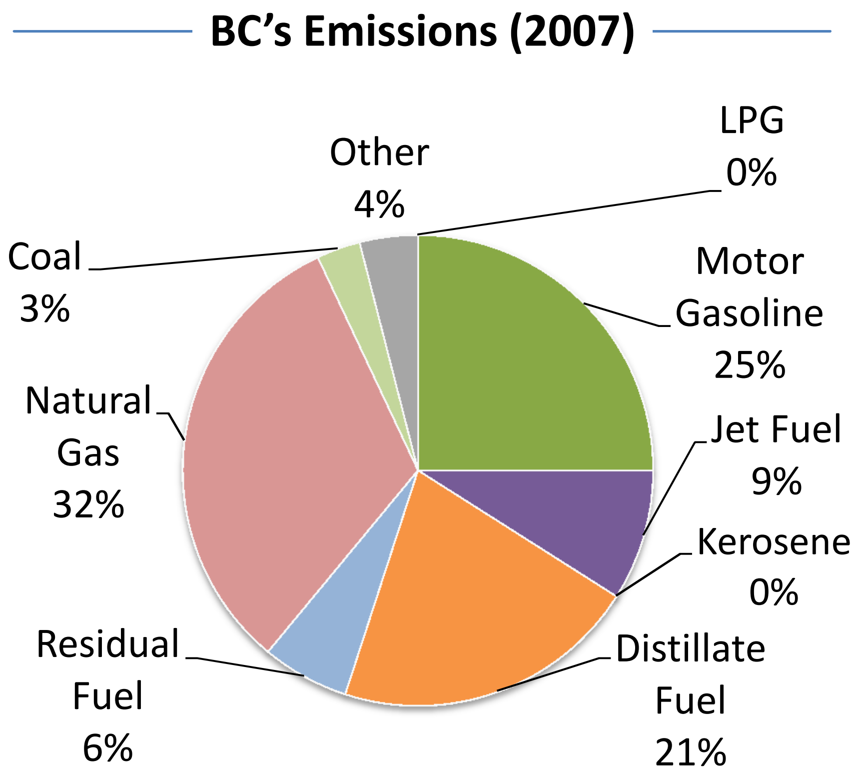
Background: Impact to Households

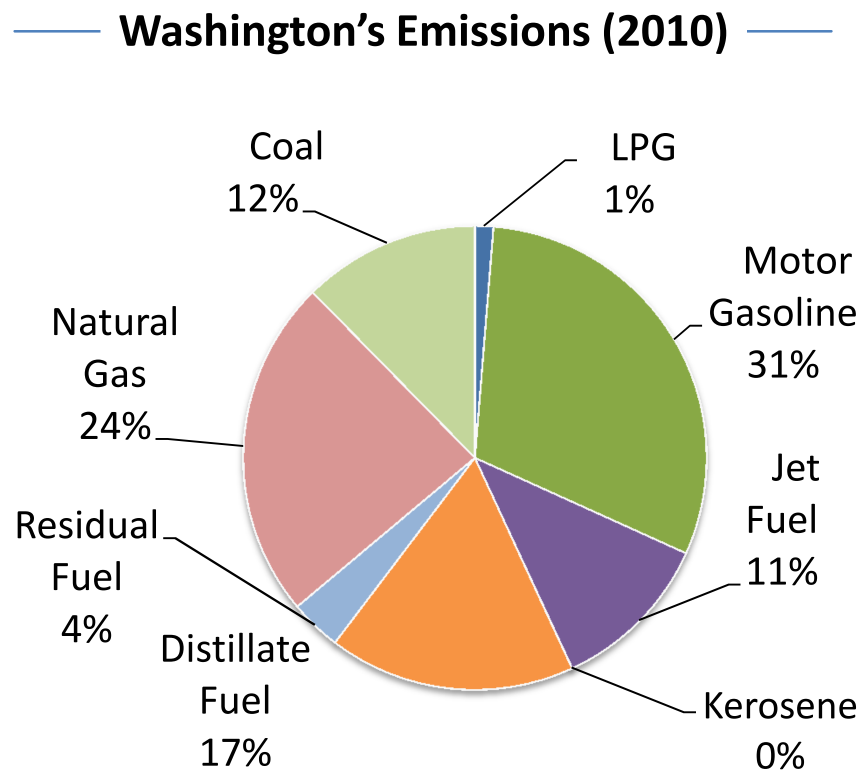


Source: Melton & Peters 2013 (Navius Research)

Discussion: WA vs. BC emission sources

- Washington State has similar energy consumption patterns and GHG emission breakdowns.
- Washington State has taken steps to reduce its GHG emissions over the past decade and has watched with interest as British Columbia has implemented its carbon tax.
- This study shows the forecasted impacts of a carbon tax in Washington State using the Carbon Tax Analysis Model (CTAM) developed at the WA Dept. of Commerce.





Sources: EIA (2010a), Canadian Industrial Energy End-use Data and Analysis Centre (2011)

Background: BC Carbon Tax

- British Columbia adopted a revenue-neutral carbon tax at CAN$10/t$CO_2$ in 2008.
- The rate was raised by CAN$5/t$CO_2$ annually, capped at CAN$30/t$CO_2$.
- The revenues are used to offset individual and corporate income tax.
- Some revenue is directed to low income families who are impacted more heavily.

BC's Revenue Recycling Scheme

(in million CAN$)	'08/'09	'09/'10	'10/'11
Carbon tax revenues	-338	-631	-880
Personal tax cuts	121	216	333
Low income refundable tax credit	104	145	146
Reduce bottom two tax bracket rates by 2% for '08, by 5% for '09	113	230	244
Additional personal income tax rate cuts	0	40	157
Business tax cuts	121	216	333
Reduce general corporate rate to 11% ('08)	75	128	133
Reduce general corporate rate to 10.5% ('10) and to 10% ('11)	0	6	73
Reduce small business corporate income tax rate to 3.5% ('08)	46	79	82
Reduce small business income tax rate to 3% ('10), to 2.5% ('11)	0	3	45
Total tax cuts	338	631	880

Source: BC Ministry of Environment (2008)

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