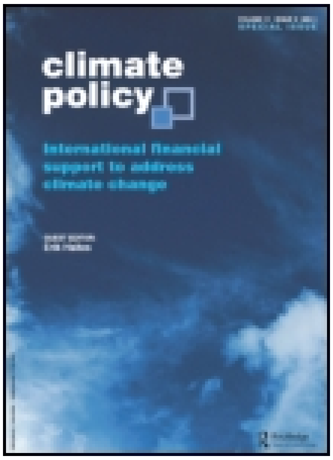

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Carbon taxes: a review of experience and policy design considerations

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synthesis article

Carbon taxes: a review of experience and policy design considerations

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State and local governments in the USA are evaluating a wide range of policies to reduce carbon emissions, including carbon taxes, which have existed internationally for nearly 20 years. In this article, existing carbon tax policies, both internationally and in the USA, are reviewed, and carbon policy design and effectiveness are analysed. Design considerations include which sectors to tax, where to set the tax rate, how to use tax revenues, what the impact will be on consumers, and how to ensure that emissions reduction goals are achieved. Emissions reductions that are due to carbon taxes can be difficult to measure, although some jurisdictions quantify reductions in overall emissions, others examine impacts that are due to programmes funded by carbon tax revenues.

Keywords: carbon tax; climate change policies; domestic policy instruments; GHG reductions; policy formation

Aux Etats-Unis les gouvernements des Etats ainsi que les gouvernements locaux sont en train d'examiner de nombreuses politiques de réduction des émissions de carbone, dont les taxes carbone qui existent dans le monde depuis presque 20 ans. Dans cet article, les politiques de taxe carbone existantes internationales ou propres aux Etats-Unis sont examinées, ainsi que la forme des politiques carbone et leur efficacité. La réflexion sur la forme comprend: quels secteurs devraient être touchés par la taxe, quel doit être le niveau de la taxe, et que faire des revenus de la taxe, quels seront les impacts sur les consommateurs, et comment garantir que les objectifs de réduction des émissions soient atteints. Les réductions des émissions dues précisément aux taxes carbone sont parfois difficiles à mesurer, même si certaines autorités font le calcul des réductions par rapport a la totalité des émissions, alors que d'autres analysent l'effet des programmes financés par les revenus des taxes carbone.

Mots clés: formulation de politique; instruments de politique domestique; politiques en changement climatique; réductions de GES; taxe carbone

1. Introduction

Carbon taxes have existed internationally for nearly 20 years. In the early 1990s, carbon taxes emerged in northern European countries, Finland being the first nation to adopt a carbon tax in 1990. Subsequently, the Netherlands (1990), Norway (1991), Sweden (1991) and Denmark (1992) implemented carbon taxes. After a lull of almost a decade, the UK began its Climate Change Levy (CCL) in 2001. In recent years, several new taxes have been introduced at the provincial or municipal levels in North America.

Interest in federal carbon policy has recently increased in the USA. The US House of Representatives passed H.R.2454 'The American Clean Energy and Security Act of 2009' (the 'Waxman–Markey Bill') in June 2009, and the US Senate introduced S.1733 'Clean Energy Jobs and American Power Act' (the 'Kerry–Boxer Bill') in September 2009. While recent federal policy has focused on carbon cap and trade policies, Congress introduced three carbon tax bills in 2009.[1] Proposals vary but all of them

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tax fossil fuel production and imports between $10 and $15 per short tonne of carbon dioxide (CO_2) in the first year, and create plans to increase the tax over time.

In the most recent wave of carbon taxes, state and local governments have become more active in adopting taxes, as either a complement to federal policies or a reaction to lack of federal leadership. Boulder, Colorado and Quebec, Canada introduced carbon taxes in 2007; British Columbia, Canada and the Bay Area Air Quality Management District (BAAQMD) in California began implementing carbon taxes in 2008; and the California Air Resources Board (CARB) proposed a carbon tax in 2009.

There is also increasing interest in combining carbon taxes with other carbon mitigation policies. Carbon cap-and-trade (C&T) systems may not cover all sectors and may be more difficult to implement in sectors without point sources (e.g. transportation); indeed, carbon taxes may be designed to work in conjunction with other carbon policies. For example, the recently proposed French carbon tax was designed to cover the sectors not addressed by the EU Emissions Trading Scheme (EU ETS).

As a policy mechanism, carbon taxes have been extensively compared with carbon C&T systems. The primary difference between the two policies is that a tax puts a price on carbon in order to reduce emissions, while a cap puts a limit on the quantity of emissions allowed, thus imputing a price. In practice, a carbon tax could be designed that functions in many ways as a carbon C&T policy, and vice versa. Some try to distinguish a carbon cap and a carbon tax based on their ability to raise revenue. However, a carbon cap could raise revenue if carbon allowances are auctioned. Both a carbon tax and a carbon cap with auctioned allowances could distribute revenue to low-income consumers. For a review of the advantages and disadvantages of an internationally harmonized carbon tax, many of which are applicable to domestic carbon taxes, see Nordhaus (2007).

Considerations in the design of carbon taxes – based on a review of experience implementing carbon taxes domestically and internationally – are discussed in this article. This article expands on the work of both Aldy et al. (2008) and Aldy and Pizer (2009). Aldy et al. (2008) discuss the design of carbon taxes at the domestic level, suggesting that the efficient near-term tax is at least $5–20 per tonne of CO_2 and that the tax should be placed on upstream sources, while Aldy and Pizer (2009) summarize the literature on the distributional impacts of carbon taxes, suggesting that recycling revenue to consumers can reduce the distributional impact. However, while both describe issues related to designing a domestic carbon tax, neither draw from the experience of existing carbon taxes.

In addition, the effectiveness of carbon tax policies and difficulties in measuring impacts are discussed. Measures of effectiveness can vary by jurisdiction and specific policy goals. While all carbon taxes are designed to reduce CO_2 or greenhouse gas (GHG) emissions, some taxes may be aggressive in their efforts to encourage changes in behaviour and consumption patterns. Other taxes may be implemented, at more modest levels, to generate revenues to support the expansion or cost-effectiveness of low-carbon technologies. The effectiveness of carbon tax policies has been evaluated based on (1) aggregate carbon emissions reductions in the jurisdiction, (2) emissions reductions that are due to tax and (3) emissions reductions from programmes implemented with tax revenue.

2. Carbon tax design considerations

Carbon taxes place a value on CO_2 emissions, thus internalizing some portion of the costs associated with their environmental impact. While all carbon taxes inherently provide this function, policy goals may vary. Carbon taxes serve primarily to reduce GHG emissions by placing a cost on emissions, but can also raise revenues to provide funding for carbon mitigation programmes or create market signals for consumers. Policy design considerations associated with implementing carbon taxes include determining the tax base, which sectors to tax, where to set the tax rate, how to use tax revenues, how to assess the impact on consumers and how to ensure that the tax achieves emissions reduction goals.

2.1. Tax base

To implement carbon taxes, governments must decide which fuels or sources to place the tax on. Most commonly, carbon taxes are placed on gasoline, coal and natural gas. Some governments, however, exempt certain industries from carbon taxes or allow those industries to pay lower tax rates.

Governments must also decide whether to place the tax on upstream or downstream sources of emissions. Taxing upstream sources may provide an administratively efficient method of tax collection, because fewer sources would need to be regulated. Applying a carbon tax upstream also ensures that all possible sources of emissions are covered when fuels are later combusted, increasing the likelihood that all emission abatement opportunities are used (Aldy et al., 2008). On the other hand, taxing downstream sources such as electricity consumption may provide a more direct signal to consumers. Although this debate is not the focus of this article, it is important to recognize the potential effects of taxing upstream, versus downstream, sources when designing a carbon tax.

When considering which sectors to tax, some governments may also be limited by their jurisdictions. For example, the BAAQMD has the authority to control air pollution for non-vehicular stationary sources. Thus the primary sectors taxed include petroleum refineries, power plants, cement plants and landfills. Table 1 summarizes the major fuels or sources on which current carbon taxes are applied in the 11 jurisdictions described in Section 3.

2.2. Tax rate

As shown in Figure 1, carbon tax rates vary across jurisdictions, in part due to their specific function. While higher carbon tax rates provide stronger signals to consumers to change behaviour, lower rates may do little to change behaviour but can still nevertheless provide funds for carbon mitigation programmes.

Some of the highest rates are seen in Europe:[2] Sweden's standard tax rate is the equivalent of $105 per metric tonne CO_2; however, the rate for industry is substantially less at $23 per metric tonne CO_2. Norway's tax on gasoline equates to $62 per metric tonne CO_2, while Finland's tax is $30 per metric tonne CO_2.

Some of the lowest rates occur in California. The BAAQMD rate is $0.045 per metric tonne CO_2, and the BAAQMD explicitly designed the tax to raise revenue to support local GHG mitigation programmes rather than to encourage behavioural change. The proposed CARB tax rate is also set comparatively low, at $0.155 per metric tonne CO_2, and is designed to generate funds to implement California's Assembly Bill 32, which sets GHG reduction goals. The CARB tax more closely resembles a cost-covering fee rather than a traditional carbon tax.

2.3. Revenue distribution

Revenues from carbon taxes are directed in different ways. Revenues can be (1) directed specifically to carbon mitigation programmes, (2) directed to individuals through measures such as reductions in income taxes, or (3) used to supplement government budgets. The choice of revenue distribution may impact the political sustainability of the tax.

State and local governments frequently direct carbon tax revenues to the carbon reduction programmes they implement. Boulder (Colorado), Quebec, and the Californian BAAQMD all use revenues for carbon mitigation programmes, while CARB has also proposed to do so.

TABLE 1 Major taxed sectors in existing and proposed carbon tax systems

	Finland	Netherlands	Norway	Sweden	Denmark	United Kingdom	Quebec	British Columbia	Boulder, CO	BAAQMD, CA	CARB
Natural gas	√	√	√	√	√	√	√	√			
Gasoline	√		√	√			√	√			
Coal	√			√	√	√	√				
Electricity	√	√			√	√	√		√		
Diesel	√		√				√	√			
Light and heavy fuel oil	√	Light only	√	√	√		√				
LPG			√	√		√	√				
Home heating oil		√		√			√				
Permitted facilities										√	√

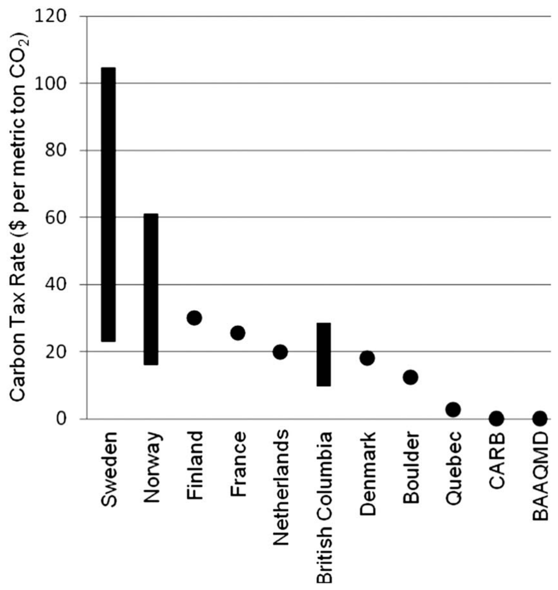

FIGURE 1 Carbon tax rates

Notes: Sweden and Norway's carbon tax rates vary depending on the taxed sector. British Columbia's carbon tax was CAD$10 ($9.55) per metric tonne CO_2 in 2008, but is scheduled to increase by CAD$5 per year to CAD$30 ($28.64) in 2012.

Some carbon tax programmes return tax revenue to customers through other means such as income tax reductions. The UK and British Columbia, Canada use this method. While Finland's approach does not earmark the carbon tax revenue, the tax is accompanied by independent cuts in income taxes (Parkkinen, 2009). These 'revenue-neutral' mechanisms, which are designed to change customer behaviour while reducing other taxes, do not raise money for government general funds or emissions reduction programmes. Research in the 1990s suggested that revenue-neutral approaches could yield a 'double dividend' through reducing emissions and also lowering existing tax distortions (Parry, 2003) that can reduce labour supply.

Cost savings are also greater when tax revenues are returned through cuts in distorting taxes (such as income taxes) rather than when they are returned in lump sums. These results have been both demonstrated by economic theory and supported by numerical simulations (Goulder, 1995). In the mid-1990s, however, another wave of research began to suggest a separate 'tax-interaction effect', which results when higher energy prices reduce real household wages and labour supply (Aldy et al., 2008). However, if the tax revenues are used to reduce income taxes, the double dividend effect may be large enough to exceed the tax-interaction effect (Bovenberg and Goudler, 1997; Aldy et al., 2008).

While revenue recycling mechanisms may be optimal from an economic benefit perspective, some carbon taxes, like those in Sweden and Norway, are used specifically to raise revenue for governments. Directing revenues to general government budgets can be easier to administer than funding carbon mitigation programmes. However, critics say that carbon taxes are simply a way of raising government revenue rather than providing environmental benefits, thus creating a tax rate that would not be economically efficient. For an efficient tax, the rate should be set equal to the marginal damage caused by carbon emissions. An alternative approach would direct revenue to programmes that address environmental impact through earmarking, thus limiting the incentive to raise taxes purely to generate more revenue (Prasad, 2008).

2.4. Impact on consumers

When designing a carbon tax, the impact on low-income households is an important consideration since a common criticism of such a tax is that it disproportionately burdens low-income households.

A carbon tax that rebates revenues can mitigate the impact on low-income households, especially if the revenues are rebated in a lump sum. Metcalf et al. (2008) evaluated three methods of rebating carbon tax revenue to consumers, and found that a lump sum per capita payment of $274 made the carbon tax progressive.

British Columbia provides a low-income 'climate action tax credit', a reduction of 5% in the first two personal income tax rates, and has proposed providing a 'northern and rural homeowner' benefit of up to $200 in 2011 (Ministry of Finance, British Columbia, 2008). British Columbia estimated the net impact of the carbon tax and other associated tax cuts for two respective family types (seniors and a two-earner family of four), and found that the tax cuts exceed the cost of the carbon tax in both cases (Ministry of Finance, British Columbia, 2008).[3]

Carbon taxes impact businesses. Businesses may prefer carbon taxes to other carbon mitigation policies, because taxes provide a certain, long-term price signal that can be incorporated into projections of operating expenses, whereas projected prices may not be as well-known with emissions caps. Energy-intensive or highly competitive industries that compete with companies in jurisdictions without taxes have expressed concerns about carbon taxes. To address concerns about the impact of carbon taxes on businesses, some jurisdictions allow certain industries to pay reduced rates. Sweden's reduced rate for industry is approximately $23 per metric tonne CO_2, while the standard rate is $105 per metric tonne CO_2. In Denmark, businesses that sign an energy savings agreement with the Ministry of Transportation and Energy can pay reduced rates. Denmark also reduced existing taxes on energy when it established a carbon tax, so that the effective tax rate is the same.

2.5. Ensuring emissions reductions

One of the key arguments against a carbon tax and in favour of a limit on emissions is that a tax does not necessarily guarantee emissions reductions. While a tax policy can be structured so that rates automatically increase if emissions reduction goals are not met, this approach has not yet been implemented. This may reflect the political challenges of passing such a tax in the first place. In fact, many of the proposed taxes are structured in ways to make them more politically feasible. Indeed revenue-neutral policies, and refunds to low-income consumers, are designed to make policies more politically appealing.

Some governments have increased their tax rates over time, but none has implemented a policy in which the tax increases automatically if emissions reduction targets are not met. British Columbia's carbon tax is set to phase in, over a four-year period, and the government has indicated that it will modify the tax over time, if necessary, to achieve carbon emissions goals. However, the tax has only recently been implemented, and there have been no attempts as yet to modify the tax rate. Governments operating GHG reduction programmes may find it easier to modify programmes than to raise taxes. The Province of Quebec publishes an annual progress report on its GHG reduction programmes. The City of Boulder increased rates in August 2009 to the maximum allowed by their ordinance, and directed the additional revenues to implement more GHG reduction programmes (City of Boulder, 2009a). The BAAQMD has indicated that it may raise fees in the future, depending on the needs of its Carbon Protection Program.

3. Carbon taxes implemented since 1990

While the first implemented carbon tax is approaching its 20th year of implementation, there have been few reviews of carbon tax policies. The contemporary literature focuses on the economic efficiency of carbon taxes compared to carbon C&T systems. In this section existing carbon taxes are examined, specifically the sectors taxed, the tax rate and the annual revenue generated (Table 2).

3.1. Finland – 1990

Finland was the first country to adopt a carbon tax. Launched in 1990, Finland's carbon tax is a separate component of Finland's excise tax on fossil fuels used for transportation or heating. The carbon tax applies to gasoline, diesel, light and heavy fuel oil, jet fuel, aviation gasoline, coal and natural gas (Ministry of the Environment, Finland, 2008a). Coal is subject to a tax of $73.97 (€49.32) per metric tonne, natural gas is subject to a reduced tax rate of $3.02 (€2.016) per MWh, and liquid fuels are taxed between $0.07 (€0.05) and $0.09 (€0.06) per litre (European Environment Agency, 2009). Commercial vessels and air traffic, as well as fuels used for electricity, are exempt. Electricity is taxed, but the rate per kilowatt-hour (kWh) does not vary according to carbon content; however, a refund is available for renewable electricity (Parkkinen, 2009). The City of Boulder also exempts wind power purchases from its carbon tax.

Initially, Finland based its carbon tax purely on carbon content but modified it to include a 60% carbon component and a 40% energy component. The energy component was a tax based on energy use in MWh rather than on the carbon content of the fuel. In January 1997, however, Finland returned to a pure carbon tax (Parkkinen, 2009, personal communication). The carbon tax was most recently increased by 13% to $30 (€20) per metric tonne CO_2 on 1 January 2008 (Ministry of the Environment Finland, 2008b). Carbon tax revenues have been approximately $750 million (€500 million) annually (Ministry of the Environment, Finland, 2008b). All revenue from the carbon tax in Finland goes directly into the general central government budget without any earmarking (Parkkinen, 2009, personal communication).

In 2000, the Finnish government estimated that, due to the carbon tax, CO_2 emissions were reduced by 4 million metric tonnes of CO_2 between 1990 and 1998. Four million metric tonnes of CO_2 represents approximately 7% of the 57 million metric tonnes of emissions recorded in 1998 (Prime Minister's Office, Finland, 2000).

3.2. The Netherlands – 1990

The Netherlands' carbon tax began in 1990 and applies to natural gas, electricity, blast furnaces, coke ovens, refinery and coal gas, coal gasification gas, gasoline, diesel and light fuel. In 1996, the tax rate was equivalent to $20 per metric tonne CO_2.

Environmentally related taxes generate a total revenue of $4.819 billion (€3.213 billion), of which the carbon tax is the majority (Netherlands Ministry of Housing, Spatial Planning and the Environment, 2004).

The Netherlands uses carbon tax revenues to reduce the general tax burden, for individuals and businesses, and to provide programmes to reduce GHGs. Part of the revenue is 'recycled' to businesses in the form of accelerated depreciation for environmental equipment and tax deductibility of energy investments (Netherlands Ministry of Housing, Spatial Planning and the Environment, Directorate-General for Environmental Protection, 2004). While this may not be the most welfare-improving way to use carbon tax revenues, the Netherlands may find this option more politically palatable.

TABLE 2 Overview of carbon tax policies

Country/ jurisdiction	Start date	Tax rate ($US unless noted otherwise)	Annual revenue	Revenue distribution
Finland	1990	$30/metric tonne CO_2 (€20)	$750 million (€500 million)	Government budget; accompanied by independent cuts in income taxes
Netherlands	1990	~$20/metric tonne CO_2 in 1996	$4.819 billion[a] (€3.213 billion)	Reductions in other taxes; climate mitigation programmes
Norway	1991	$15.93 to $61.76/metric tonne CO_2 (NOK 89 to NOK 345)	$900 million (1994 estimate)	Government budget
Sweden	1991	Standard rate: $104.83/metric tonne CO_2 (SEK 910) Industry rate: ~$23.04/metric tonne CO_2 (SEK ~200)	$3.665 billion (SEK 25 billion)	Government budget
Denmark	1992	$16.41/metric tonne CO_2 (90 DKK)	$905 million	Environmental subsidies and returned to industry
United Kingdom	2001	$0.0078/kWh for electricity; $0.0027/kWh for natural gas provided by gas utility; $0.0175/kg for LPG or other gaseous hydrocarbons supplied in a liquid state; and $0.0213/kg for solid fuel	$1.191 billion (£714 million)	Reductions in other taxes
Boulder, CO	2007	$12–13 per metric tonne of CO_2	$846,885	Climate mitigation programmes
Quebec	2007	$3.20 per metric tonne of CO_2 (CAD$3.50)	$191 million (CAD$200 million)	Climate mitigation programmes
British Columbia	2008	$9.55 per metric tonne of CO_2 in 2008 (CAD$10), increasing $4.77 (CAD$5) annually to $28.64 (CAD$30) in 2012	$292 million (CAD$306 million)	Reductions in other taxes
BAAQMD, California	2008	$0.045 per metric tonne of CO_2e[b]	$1.1 million (expected)	Climate mitigation programmes
CARB, California	proposed	$0.155 per metric tonne of CO_2e in FY 2010–11, dropping to $0.09 per metric tonne CO_2e in 2014	$63.1 million 2010–2013; $36.2 million starting in 2014, expected	Climate mitigation programmes

Notes: [a] Revenue in the Netherlands is from all environmentally related taxes, of which carbon taxes are the clear majority.
[b] CO_2e is the carbon dioxide equivalent.

The Netherlands Ministry of Housing, Spatial Planning and the Environment (2004) estimated that the carbon tax would reduce annual CO_2 emissions 1.7–2.7 million metric tonnes annually in 2000, with covered sectors reducing CO_2 emissions by approximately 5%. Due to an increase in the tax in

1999, annual CO_2 emissions are projected to be reduced by 3.6–3.8 million tonnes by 2010 and by 4.6–5.1 million tonnes in 2020.

3.3. Norway – 1991

Norway's carbon tax began in 1991. The current tax rates vary from $15.93 (NOK 89) per metric tonne CO_2 to $61.76 (NOK 345) per metric tonne CO_2 (Ministry of the Environment, Norway, 2007). Taxed sectors include gasoline, light and heavy fuel oil, and oil and gas in the North Sea. The pulp and paper industry, fishmeal industry, domestic aviation, domestic shipping of goods and the continental shelf (supply fleet) pay reduced rates. Foreign shipping, fishing in Norway, fishing in distant waters and external aviation are all exempt from the tax. Table 3 shows Norwegian carbon tax rates by taxed sector in 2007. The tax is estimated to cover approximately 68% of Norway's CO_2 emissions, or approximately 50% of Norway's GHG emissions (UNFCCC, 2006).

Norway directs carbon tax revenues to general government accounts. Using this and additional revenue from offshore drilling licenses, Norway has financed a special pension fund that contained $373 billion, or nearly $80,000 for every Norwegian, at the end of 2007 (Turner, 2008).

Norway received negative press because its GHG emissions increased by 15% from 1991, when it implemented a carbon tax, to 2008. Others justify the increase in GHG emissions by noting that Norway also experienced an increase in gross domestic product of 70% since 1990 (Abboud, 2008).

Industrial efficiency gains in Norway may have been achieved because of the carbon tax. Emissions per unit of production were 22% lower in 2003 than they were in 1991. Since 1996, emissions per unit of production have been steady or even slightly rising. Norwegian officials recognize that the carbon

TABLE 3 Norwegian carbon tax rates, 2007

	Tax rate – US$ (NOK) per litre oil and petrol (kg coal and coke or Sm^3 gas)[a]	Tax rate – NOK ($) per metric tonne CO_2
Petrol (gasoline)	$0.14 (0.80 NOK)	$61.76 (345 NOK)
Fuel oil		
Light fuel oil, diesel	$0.10 (0.54 NOK)	$36.34 (203 NOK)
Heavy fuel oils	$0.10 (0.54 NOK)	$30.79 (172 NOK)
Mineral oils, lower rate		
Light fuel oil, diesel	$0.05 (0.28 NOK)	$18.80 (105 NOK)
Heavy fuel oils	$0.05 (0.28 NOK)	$15.93 (89 NOK)
Use of gas in Norway		
Natural gas	$0.08 (0.47 NOK)	$35.98 (201 NOK)
LPG	$0.11 (0.60 NOK)	$35.80 (200 NOK)
Continental shelf		
Light fuel oil, diesel	$0.14 (0.80 NOK)	$53.70 (300 NOK)
Heavy fuel oils	$0.14 (0.80 NOK)	$45.65 (255 NOK)
Natural gas	$0.14 (0.80 NOK)	$61.22 (342 NOK)

Note: [a] Sm^3 refers to a standard cubic metre.

tax is not the only factor contributing to changes in industrial efficiency. Other factors that impact it include general technology improvements and the use of more mature petroleum fields, which provide increased energy per unit of production (Ministry of the Environment, Norway, 2005a).

Norway's carbon tax has promoted technology innovation in the form of carbon sequestration. In 1996, StatoilHydro ASA, the company operating the Sleipner gas field, began developing a CO_2 sequestration project, storing CO_2 under the sea floor. The project, which cost approximately \$200 million, has saved the company approximately \$60 million in carbon taxes each year and has stored approximately 1 million metric tonnes of CO_2 annually since 1996 (UNFCCC, 2006; Abboud, 2008). However, even though the company has increased the efficiency of its operations, its total emissions have increased due to expansions in drilling (Abboud, 2008).

3.4. Sweden – 1991

In 1991, Sweden initiated a carbon tax of \$44.37 (SEK 250) per metric tonne CO_2. Industries, including manufacturing, agriculture, co-generation plants, forestry and aquaculture, pay a lower proportion of the general level (Ministry of Sustainable Development, Sweden, 2005a). As shown in Figure 2, Sweden modified the rates so that industry paid only \$11.28 (SEK 80) per metric tonne, while other consumers paid \$45.15 (SEK 320) per metric tonne in 1993.

Revenue from Sweden's carbon tax was relatively steady from 1993 to 2000, and then gradually increased from 2000 to 2004 (Figure 3). It generated approximately \$3.65 billion (SEK 25 billion) annually in 2005–2007 (Swedish Tax Agency, 2008).[4] Sweden directs the tax revenues to the general government budget.[5]

Several studies in Sweden have attempted to assess CO_2 emissions. The Swedish Ministry of the Environment estimated that CO_2 emissions fell by about 15% between 1995 and 1990 because of the tax (Johansson, 2000). In terms of overall emissions, Sweden saw GHG emissions fall by almost 9% between 1990 and 2006. In December 2008, Sweden reported that GHG emissions have fallen by more than 40% since the mid-1970s (Ministry of the Environment, Sweden, 2008).

3.5. Denmark – 1992

Denmark's tax on CO_2 passed in 1991 and took effect in May 1992. Fossil fuels are subject to both an energy tax and a CO_2 tax. When the CO_2 tax was passed, a subsequent decrease in the energy tax was

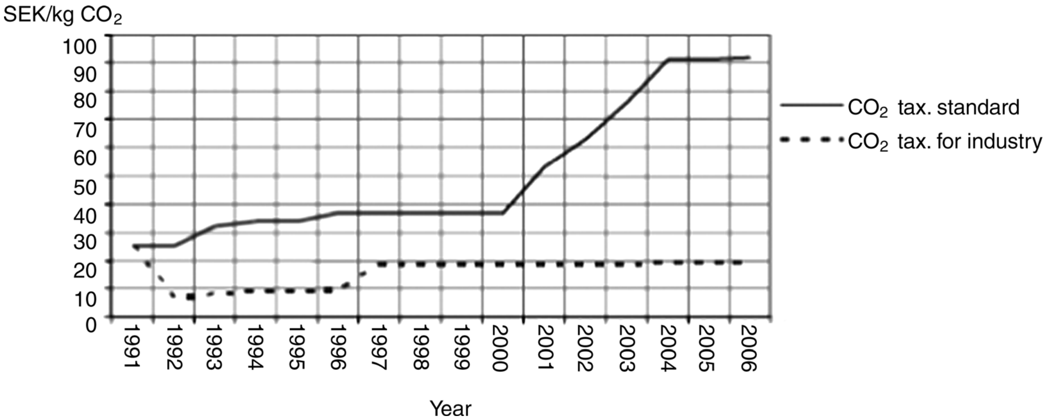

FIGURE 2 Swedish CO_2 tax rate, SEK per kilogram CO_2, nominal figures

Source: Swedish Environmental Agency and Swedish Energy Agency (2007).

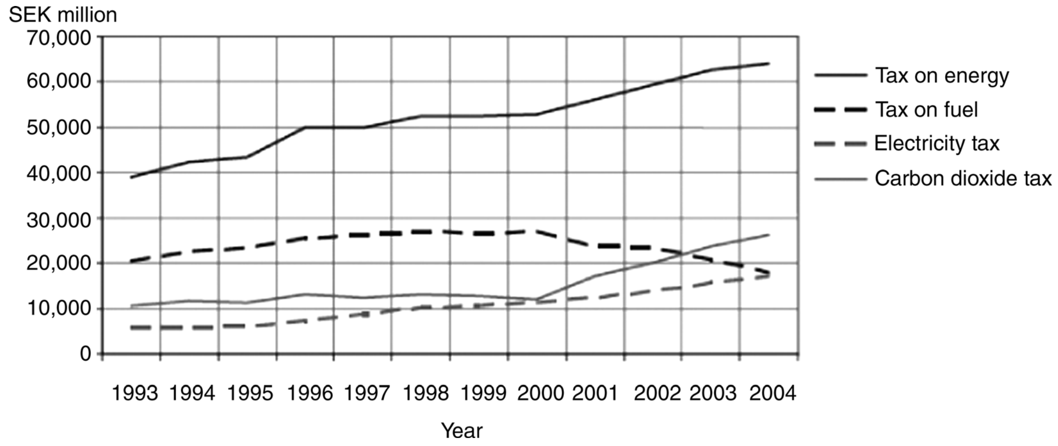

FIGURE 3 Swedish carbon tax revenues

Source: Swedish Environmental Agency and Swedish Energy Agency (2007).

included to maintain the overall tax rate. Table 4 shows the Danish energy and CO_2 tax on various fuel types. The initial tax rate of $16.91 (DKK 100) per metric tonne CO_2 was reduced to $16.41 (DKK 90) per metric tonne CO_2 in 2005. With the decrease in the CO_2 tax in 2005, the energy tax increased to maintain the overall tax rate (Speck et al., 2006). In 2008, the carbon tax rate remained at $16.41 (DKK 90) per metric tonne CO_2 emissions (Ministry of Taxation, Denmark, 2008). In 2008, the revenues from the CO_2 tax were approximately $905 million.

In Denmark, about 40% of tax revenue is used for environmental subsidies, while the other 60% is returned to industry. The government provides, approximately, a 25% reduction of the tax if a company signs an energy savings agreement with the Ministry of Transportation and Energy. Per capita emissions in Denmark reduced by 15% from 1990 to 2005 (Prasad, 2008). Industrial emissions were also estimated to have decreased by 23% during the 1990s, after adjusting for growth and market-induced industry restructuring (Enevoldsen, 2005).

3.6. United Kingdom – 2001

The UK CCL began in 2001. It imposes a tax on electricity, natural gas supplied by a gas utility, liquified petroleum gas (LPG) or other gaseous hydrocarbons supplied in a liquid state for heating, and solid fuel (e.g. coal and coke, lignite, semi-coke of coal or lignite, and petroleum coke). CCL rates only apply to industrial and commercial energy supplies to the industrial, commercial, agricultural, public and service sectors (DECC, 2009). The CCL was designed to encourage businesses to become more energy efficient and reduce GHG emissions. Table 5 shows the average CCL rates as of 1 April 2009 by fuel type.

CCL revenues in 2006–2007 were $1.191 billion (£714 million). This is far less than the estimated $2.25 billion (£1.35 billion) required to offset the 0.3% cut in National Insurance Contributions[6] implemented to make the CCL policy revenue-neutral.[7] As a result, industry as a whole has not faced higher taxes; instead, the tax burden as a whole has been reduced because the cut in National Insurance Contributions is greater than the carbon tax itself (DECC, 2009). The CCL was estimated to generate approximately $1.167 billion (£700 million) in 2007–2008 and 2008–2009 (HMT, 2008).

TABLE 4 Danish energy and CO_2 tax on various fuel types[a]

	1985	1990	1996	2000	2002	2005
Light fuel oil (€0.01/l)						
Energy tax	4.61	22.4	20.25	23.21	24.63	25
CO_2 tax			3.67	3.62	3.63	3.23
Total tax	4.61	22.4	23.92	26.83	28.26	28.23
Heavy fuel oil (€0.01/kg)						
Energy tax	5.11	25.2	22.56	26.16	27.72	28.09
CO_2 tax			4.35	4.29	4.31	3.9
Total tax	5.11	25.2	26.9	30.45	32.03	31.99
Natural gas (€0.01/nm^3)[b]						
Energy tax			0.14	21.47	27.19	27.42
CO_2 tax			2.99	2.95	2.96	2.69
Total tax			3.13	24.42	30.15	30.11
Pit coal (€0.01/kg)						
Energy tax	1.62	9.8	11.69	17.44	19.25	19.49
CO_2 tax			3.26	3.22	3.23	2.96
Total tax	1.62	9.8	14.95	20.66	22.47	22.45

Notes: [a] Tax rates expressed in national currencies have not been increased since 2002, with the result that current tax rates in real terms are slightly lower than they were in 2002.
[b] The unit nm^3 represents a normal cubic metre.
Source: Speck et al. (2006).

TABLE 5 UK CCL rates as of April 1, 2009

Sector	Tax rate
Electricity	\$0.0078 (£0.00470) per kWh
Natural gas as supplied by a gas utility	\$0.0027 (£0.00164) per kWh
LPG or other gaseous hydrocarbons supplied in a liquid state, for heating	\$0.0175 (£0.0105) per kg [\$0.0012 (£0.00076) per kWh]
Solid fuel, for example, coal and coke, lignite; semi-coke of coal or lignite; and petroleum coke	\$0.0213 (£0.0128) per kg [\$0.0027 (£0.00164) per kWh]

Source: Hatherall (2009), personal communication.

A study by Cambridge Econometrics (2005) estimated that by 2010 the CCL would reduce energy demand by approximately 15% (12.8 million metric tonnes) in the commercial and public sectors (HMT, 2008: 101).

3.7. Boulder, Colorado – 2007

Boulder, Colorado – a city of approximately 100,000 people located northwest of Denver, USA – adopted a carbon tax via a ballot initiative in 2006. The tax, collected by the investor-owned electric utility, took effect in April 2007.

Rates are set based on kWh use of electricity, with residents initially paying $0.0022 per kWh, commercial customers paying $0.0004 per kWh, and industrial customers paying $0.0002 per kWh (City of Boulder, 2009a). In August 2009, the tax increased to the maximum rate allowed by the tax ordinance: $0.0049 per kWh for residents, $0.0009 per kWh for commercial customers, and $0.0003 per kWh for industrial customers (City of Boulder, 2009a). The rates are equivalent to approximately $12–13 per tonne of CO_2. The ordinance exempts the portion of electricity that Boulder residents can voluntarily purchase as utility-provided wind power through Xcel Energy (see Chapter 3-12, City of Boulder, 1981).

Tax revenues were $846,885 in 2008, and are expected to peak at $1,609,000 in 2010 and then decrease to $1,203,000 in 2012 as fossil fuel use decreases.[8] The tax is set to expire on 31 March 2013 and an extension of it would require voter approval.

The City of Boulder uses its carbon tax revenue to fund a climate action plan that promotes energy efficiency in homes and buildings, renewable energy and reductions in vehicle miles travelled.

Boulder developed a set of guiding principles to evaluate its carbon reduction programmes. Each programme must both maximize GHG reductions and be cost-effective. The city measures cost-effectiveness in tax dollars spent per GHG tonne reduced. Programmes must also include a reasonable expectation for private investment and payback time (City of Boulder, 2009a).

Boulder's goal is to reduce GHG emissions to a level that is 7% below the level of 1990 (1,478,534 metric tonnes carbon dioxide equivalent (CO_2e))[9] by 2012, and it measures the success of the carbon tax in terms of meeting this goal.[10] Boulder estimated that its climate action strategies resulted in the following emissions reductions: 60,000 metric tonnes CO_2e in 2008 from renewable energy, 33,000 metric tonnes CO_2e annually from transportation measures, and 6,700 metric tonnes CO_2e in 2008 from energy efficiency programmes (City of Boulder, 2009b).

3.8. Quebec, Canada – 2007

The province of Quebec implemented its carbon levy in October 2007. The carbon levy is $3.20 (CAD$3.50) per metric tonne of CO_2. The level is readjusted every year based on the volume of sales.[11] The rate varies for each fuel, with the gasoline levy at $0.0076 (CAD$0.008) per litre, diesel fuel at $0.0086 (CAD$0.009) per litre, propane at $0.0048 (CAD$0.005) per litre and coal at $7.64 (CAD$8.00) per metric tonne.

According to Torys LLP (2007), the carbon levy is expected to raise $191 million (CAD$200 million) annually. Quebec deposits its carbon tax revenue into a 'green fund', which supports reductions in GHG emissions and improvements to public transportation. GHG reduction measures – with the largest projected reduction in, or avoidance of, GHG – include (Quebec, 2008) the following:

- Requiring manufacturers of light-duty vehicles to meet a GHG emissions standard, starting in 2010.
- Improving the energy efficiency in the transport of merchandise.
- Financially supporting the capture and incineration, or valorization, of landfill gas.
- Supporting manure processing and biomass.
- Supporting research and innovation for carbon sequestration.

Quebec's 2006–2012 carbon mitigation action plan – *Quebec and Climate Change: A Challenge for the Future* (Quebec, 2008) – recommends 26 actions to reduce GHG emissions and adapt to climate change. The plan is also supported by CAD$350 million from the federal trust fund for clean air and climate change. In total, the plan is expected to reduce GHG emissions by 14.6 million metric tonnes by 2012 (Quebec, 2008). GHG emissions reductions from programmes funded by the tax are estimated at 11.2 million metric tonnes by 2012.[12] If GHG emissions hold steady at 2005 levels of 92 million metric tonnes, this would represent a decrease of approximately 12%.

The government publishes an annual progress report, which enables it to refocus programme priorities, if necessary, to meet its goals (Quebec, 2008). It is unclear whether the government may choose to raise the carbon tax as part of this review process.

3.9. British Columbia, Canada – 2008

The province of British Columbia, Canada launched its carbon tax in July 2008. The tax is applied primarily to transportation fuels, natural gas and fuels used in industrial processes. It began at a level of $9.55 (CAD$10) per metric tonne CO_2 and increases $4.77 (CAD$5) per metric tonne CO_2 annually until reaching a level of $28.64 (CAD$30) per metric tonne of CO_2 in 2012.

In 2008, the carbon tax was estimated to be an additional $0.0223 (CAD$0.0234) per litre of gasoline. The tax will increase to approximately $0.0637 (CAD$0.0667) per litre in 2012. Natural gas is taxed at $0.47 (CAD$0.50) per GJ, while coke is taxed at $23.74 (CAD$24.87) per metric tonne (European Environment Agency, 2009). After being phased in, the government may adjust the tax rate depending on whether its GHG emissions targets are being met, the impacts other carbon policies are having, the actions other governments are taking and any general advice offered by its Climate Action Team (Ministry of Finance, British Columbia, 2008).

The tax base includes fuel used to generate heat for households, and industrial processes such as producing cement and drying coal. In addition, the carbon tax applies to road, rail, marine and air transportation within British Columbia. Inter-jurisdictional transportation is exempt from the carbon tax.

Carbon tax revenues for the 2008–2009 fiscal year were $292 million (CAD$306 million). The tax is expected to raise $531 million (CAD$557 million) in the 2009–2010 fiscal year, $714 million (CAD$748 million) in the 2010–2011 fiscal year and $911 million (CAD$955 million) in the 2011–2012 fiscal year.[13]

British Columbia provides a combination of tax rebates in order to make its carbon tax revenue-neutral. The government provides a personal income tax rate cut, a low-income 'climate action tax credit', a small business rate cut, a general corporate tax rate cut, and industrial and farm property tax cuts. In addition, British Columbia distributed a one-time cheque for CAD$100 to residents in June 2008.[14]

The effects of British Columbia's carbon tax are still unknown because the tax has only recently been implemented. However, the Ministry of Finance estimated that the tax would reduce emissions by 3 million metric tonnes annually by 2020 (Ministry of Finance, British Columbia, 2008).

3.10. BAAQMD, California – 2008

The BAAQMD incorporates nine counties of the San Francisco Bay Area. It established a carbon fee in July 2008, which in June 2009 was increased by 3% to $0.045 per metric tonne of CO_2e. The fee applies to GHG emissions from BAAQMD permitted facilities. The BAAQMD establishes the cost of implementing GHG reduction programmes and then sets the rate by dividing the cost by the total amount of GHG emissions from BAAQMD permitted facilities (Bateman, 2009). Approximately 780 facilities are subject to the fee (Bateman, 2009).

The GHG fee raises revenue for BAAQMD Climate Protection Program projects related to stationary sources. Funded activities include completing and maintaining a regional GHG emissions inventory, supporting local efforts to reduce GHG emissions from stationary sources, developing regulatory measures for GHG emissions from stationary sources, reviewing GHG-related documents, addressing climate issues in the California Environmental Quality Act and performing administrative activities such as updating databases and invoicing (BAAQMD, 2008).

The fee is expected to raise $1.1 million for the BAAQMD (Bateman, 2009), which may be increased in the future based on the funding needs of the Carbon Protection Program.

3.11. CARB – proposed

The CARB, under the authority of California's Assembly Bill 32 (AB 32) (the Global Warming Solutions Act of 2006), adopted a carbon fee in September 2009, designed to help California meet its GHG reduction goals, and is in the rulemaking process to institute it (CARB, 2009a).

The CARB staff proposal for the fee covers 85% of California's GHG emissions through regulation of approximately 350 sources, including large natural gas distributers and large users of natural gas, producers or importers of gasoline or diesel fuel, facilities that combust coal and petroleum coke, refineries, cement manufacturers, and electricity importers and in-state generating facilities (CARB, 2009b).

The preliminary proposed costs for the fee in the fiscal year 2010–2011 are $0.155 per metric tonne CO_2e. CARB established the fee by calculating the revenue requirement to implement GHG reduction programmes, and then dividing by the estimated GHG emissions by covered sectors. The fee was not designed to place a value on carbon high enough to change behaviour but rather to provide a continuous funding source to implement AB 32.

The fee is expected to raise $63.1 million during the first three years of implementation, in part to cover loans the programmes have received in the fiscal years of the period 2007–2010. It is proposed that the fee be reduced to $0.09 per metric tonne of CO_2 in 2014 – after loans are paid off – and generate an estimated $36.2 million per year thereafter.

The fee is not designed to change purchase behaviour but is intended to fund the administration, implementation and enforcement of GHG emissions reduction measures in the AB 32 scoping plan (CARB, 2008). In this way, the CARB fee more closely represents an administrative cost-covering fee than a traditional carbon tax. The polluting entity in this system pays to cover the costs to administer a programme to regulate emissions (see Ekins, 1999).

4. Effectiveness of carbon taxes

While the primary purpose of a carbon tax is to reduce GHG emissions, most existing carbon policies introduce no specific processes or requirements to evaluate policy effectiveness in reducing emissions, although some have attempted to assess their effects. Determining the overall impacts of a carbon tax can be challenging because many factors can affect overall carbon dioxide emissions, including economic growth levels and other programmes designed to address environmental impacts.[15] Despite the challenges that exist in determining the impact of a carbon tax, measurement, tracking and programme evaluation are important in determining the impact of the policy, especially if emissions reductions are the ultimate goal.

4.1. Evaluation of emissions benefits of carbon taxes

Jurisdictions have used a variety of metrics to determine the emission benefits of carbon taxes. One of the most rudimentary metrics for measuring carbon tax effectiveness is overall reductions in GHG emissions, which can be tracked using GHG emissions inventories at the national or local level. This metric is flawed in that it includes not only the carbon tax effects but also the effects of other carbon mitigation polices and exogenous variables such as the level of economic growth. While this metric lacks precision, jurisdictions can use it to evaluate whether they are meeting overall GHG reduction goals and to determine whether policies, including carbon taxes, should be modified accordingly.

Examining the effects of a carbon tax alone on GHG emissions would provide a more precise measure of policy effectiveness. Many governments model the effects of a carbon tax acting alone during the implementation phase of the tax. For example, the UK modelled the effect of its CCL in 2005, after the tax had been operating for four years. Determining the actual impact of a tax independently of other factors is often difficult, and most evaluations have not attempted to do so. Due to the lack of common evaluation practices, it is difficult to compare the effects of policies across jurisdictions. Table 6 summarizes evaluations of either carbon emissions levels or programme effectiveness that jurisdictions have conducted to gauge the impact of carbon taxes. For example, Sweden's emissions were reduced by almost 9% between 1990 and 2006, while in Denmark per capita emissions were reduced by 15% between 1990 and 2005.

4.2. Benefits of programmes funded by carbon tax revenues

The impacts of programmes funded by specific carbon mitigation measures can be quantified to determine programme effectiveness. With such programme evaluations, governments administering carbon taxes can change the rate, or shift funds to programmes that are more effective at reducing emissions. For example, each year the City of Boulder evaluates programmes funded through its carbon tax. In July 2009, the Boulder City Council approved an increase in the carbon tax level and targeted the additional revenue at expanding programme offerings, including energy efficiency improvements and mass transit programmes (City of Boulder, 2009a).

Estimating the impacts of individual programmes funded through a tax may be easier than estimating the impacts of the tax itself, as most programmes are targeted towards specific reductions that can be measured typically. For example, it is possible to calculate the cost, per metric tonne of CO_2e emissions, over the lifetime of the project. Boulder used such a metric and found that energy efficiency programmes provided the most cost-effective programmes. However, reductions from some programmes, such as education and outreach, may be difficult to quantify.

5. Summary and conclusions

Federal, state and local governments are increasingly interested in instituting a carbon tax as a mechanism for addressing GHG emissions. While a handful of taxes were implemented in Europe in the early 1990s, few were adopted in the interim until the resurgence of interest, in recent years, on the part of local and state governments. Since 2007, new carbon taxes have been implemented in parts of Canada and the USA, while a number of others have been proposed.

Policy designs for carbon taxes vary according to the jurisdiction's policy goals. The ultimate design of a carbon tax is subject to the political process, and is thus unlikely to match the theoretically optimal design (see del Río and Labanderia, 2009). However, existing carbon taxes highlight best practices for federal, state and local governments as they develop new carbon tax policies or reform existing ones.

5.1. Evaluating taxes and ensuring emissions reductions

Efforts to evaluate the effectiveness of existing carbon taxes have been limited. Some studies assessing carbon emissions levels in those countries that instituted taxes in the early 1990s show overall GHG

TABLE 6 Estimated emissions reductions in jurisdictions with carbon taxes[a]

Jurisdiction	Start date	Change in CO_2 emissions	Source
Finland	1990	Emissions were 7% lower in 1998 than they would have been without a tax	Prime Minister's Office, Finland (2000)
Netherlands	1990	Emissions were expected to be reduced by 1.7–2.7 million metric tonnes CO_2 annually in 2000. In covered sectors, emissions were expected to be reduced by approximately 5%	Netherlands Ministry of Housing, Spatial Planning and the Environment (2004)
Norway	1991	Emissions increased by 15% – and GDP increased by 70% – from 1991 to 2008	Abboud (2008)
Sweden	1991	Emissions were reduced by about 15% from 1990 to 1996 because of the carbon tax Emissions decreased by 9% from 1990 to 2006 Emissions decreased by more than 40% from the mid-1970s to 2008	Johansson (2000); Ministry of the Environment, Sweden (2008)
Denmark	1992	Emissions decreased by 15% per capita from 1990 to 2005	Prasad (2008)
United Kingdom	2001	Emissions decreased by more than 58 million metric tonnes CO_2 from 2001 to 2005 Emissions are expected to be reduced by 12.8 million metric tonnes CO_2 per year (15% of commercial and public sector energy demand) in 2010 because of the CCL	Cambridge Econometrics (2005) cited in HMT (2008:101)
Boulder, CO	2007	Emissions in 2007 and 2008 decreased from 2006 levels. Greatest reductions due to programmes funded by the carbon tax: ■ Renewable energy activities (60,000 metric tonnes CO_2e) ■ Transportation (33,000 metric tonnes CO_2e) ■ Energy efficiency (6,700 metric tonnes CO_2e)	City of Boulder (2009b)
Quebec	2007	Emissions were expected to be reduced by 11.2 million metric tonnes CO_2 by 2012 due to the carbon tax.	Quebec (2008)
British Columbia	2008	GHG emissions were expected to be reduced emissions by up to 3 million metric tonnes CO_2 annually in 2020 due to the tax	Ministry of Finance, British Columbia (2008)

Notes: Unless otherwise noted, decreases in emissions represent total emission reductions, not emission reductions that are due to a carbon tax.
[a] BAAQMD implemented a carbon tax in 2008 and is tracking data, but has not issued a report. CARB has proposed but not implemented a programme.

emissions reductions, with some as high as 15%. However, these studies have generally not attempted to account for the impact of other carbon mitigation policies. Reductions in carbon dioxide emissions can be undermined if a jurisdiction reduces other energy taxes when instituting a carbon tax (see Wiener, 1999), for example, as Denmark has done. This attempt at 'fiscal cushioning' may make it easier politically to implement the tax, but could result in fewer emissions reductions. Most recently, implemented carbon taxes emphasize evaluation and estimating impacts, but their effectiveness remains to be seen.

Evaluating the effectiveness of a carbon tax is essential to determining whether to modify it. While it is possible to track and adjust tax levels, over time, to meet emissions goals, most carbon taxes were not designed to adjust depending on emissions levels. In British Columbia, however, the government specified that future changes in the tax rate will depend on whether GHG emissions targets are being met, the impacts other carbon policies are having, the actions other governments are taking, as well as general advice being offered by its Climate Action Team (Ministry of Finance, British Columbia, 2008). Since the tax is new, this evaluation and adjustment has not yet been implemented. It remains to be seen whether raising carbon tax levels entails political difficulties and how progress towards emissions goals will be evaluated. However, taxes designed with tracking and adjustments in mind hold promise as another means of achieving GHG emissions reduction goals.

Ideally, the methodology for measuring emissions will be clearly articulated before the tax is implemented.

5.2. Tax base

Taxes have been most commonly applied to natural gas, gasoline, coal, electricity and fuel oils (Table 1). Most carbon taxes have exempted certain sectors or industries. Increasing the scope of coverage allows for lower-cost abatement opportunities, thus lowering the average cost of the carbon tax. However, exempting certain sources may also be a way to gain political support for the tax.

Carbon taxes have been – and can be – used to address emissions from sectors that may not be easily addressed through C&T policies due to concerns about the point of regulation or emissions tracking. For example, non-stationary sources such as vehicle emissions can be difficult to address through a C&T system.

5.3. Tax rate

Some carbon taxes have been designed to encourage behavioural change and represent cost increases for fuel use as much as $30 per metric tonne CO_2 or more. Other carbon taxes have been designed to raise revenues for specific carbon mitigation programmes and, in some cases, are implemented at levels that are not likely to drive behavioural change.

Ideally, the carbon tax rate should be based on the marginal damage caused by carbon emissions. However, estimates of the ideal carbon tax vary due to difficulties in assigning value to environmental damage, and disagreements over the appropriate discount rate for such impacts (Aldy et al., 2008). Most existing carbon taxes range between $12 per tonne CO_2 (in Boulder) and $30 per tonne CO_2 (in Finland). Carbon taxes, higher than this range, grant exemptions to certain sources or sectors. For example, Sweden's tax rate for industry is substantially less than the standard rate, while Norway's tax rate varies depending on the source of emissions. To determine whether the tax rate is set at the appropriate level, governments seeking to reform their existing tax rate could evaluate the carbon reductions resulting from their current policy and make changes as needed. Similarly, governments developing a new carbon tax could establish policies to evaluate and modify the tax rate as needed on a periodic basis.

5.4. Revenue distribution and impact on consumers

The use of revenues derived from carbon taxes varies considerably. Half of the taxes implemented to date return revenues to the government, or entities subject to the tax, to offset the burden, while the rest use revenues to fund either specific carbon mitigation programmes or government budgets. Policies in Finland and the Netherlands apply a portion of revenues for each purpose. Policies that generate revenues to the government were implemented in the 1990s, but this practice has not been adopted by any jurisdictions since Sweden implemented its carbon tax in 1991. In the more recent wave of carbon taxes (2000 to the present), revenue distribution has been used for either climate mitigation programmes or reductions in other taxes.

Directing revenues to consumers through reductions in other taxes, or direct rebates, can help correct the distributional inequity of a carbon tax. The UK and British Columbia are good examples of carbon tax policies that seek to minimize the impact on consumers. It may be useful for governments to periodically review how they direct revenues. The UK cut National Insurance Contributions by 0.3% in conjunction with the CCL. However, this reduction ended up being greater than the amount of revenue collected by the CCL. Another option would be to tie associated tax cuts, or rebates, more directly to revenues generated by the carbon tax.

5.5. Interactions with other carbon policies

Although much of the debate about a carbon tax focuses on implementing it as an alternative to a C&T system, existing carbon taxes are often combined with other carbon policies. A tax is an attractive option for addressing emissions that might be difficult to regulate through other mechanisms, such as C&T or command and control regulation. For example, Norway's carbon tax covers about 68% of CO_2 emissions, which represents more than half of its total GHG emissions. By comparison, Norway's participation in the EU ETS covers 35–40% of its GHG emissions (Ministry of the Environment, Norway, 2008). In addition to its carbon tax, Norway implemented a tax on the import and production of those GHGs (including hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs)) that have high global warming rate potentials. Emissions from these sources are expected to be halved because of this tax (Ministry of the Environment, Norway, 2005b).

Carbon taxes have generally been limited to certain sectors, working together with other carbon policies to achieve comprehensive reductions. For example, carbon taxes in Sweden address the energy and transport sectors but rely on other GHG reduction strategies to reduce overall GHG emissions. Sweden has added cross-sectoral instruments such as participating in the EU ETS, investing in research, development and local programmes, and developing policies to address the waste sector (Ministry of Sustainable Development, Sweden, 2005b).

Like Sweden, Finland participates in the EU ETS. Businesses are subject to both the EU ETS and the carbon tax. So far, Finland has allocated emissions allowances under the EU ETS free of charge (Parkkinen, 2009). It has also developed building code regulations, waste management policies and CO_2-based rates for vehicle registration taxes and annual vehicle taxes (Parkkinen, 2009).

In the UK, businesses subject to the CCL can sign climate change agreements with the government to reduce emissions and, after achieving their targets, can receive an 80% reduction in the CCL. One way businesses can meet their targets is through purchasing allowances through the EU ETS (Defra, 2005).

Experience with carbon taxes yields lessons for policy design and implementation. Policy makers must consider which sectors to tax, where to set the tax rate, how to use tax revenues, what the impact will be on consumers, and how to ensure that emissions reduction goals are achieved. Jurisdictions should also consider how to evaluate carbon tax effectiveness and adjust tax policies if emissions goals are not being met. This article is intended to draw lessons from implementation experience, which can help inform local, state and federal policy makers as they review or develop new carbon taxes, and it is hoped that it will promote further research in this field. The literature on carbon tax effectiveness is weak. Only through informed evaluation can policy makers determine the optimal carbon policy design.

Notes

1. Representative Stark (D-CA) introduced H.R.594 'Save Our Climate Act of 2009' in January 2009; Representative Larson introduced H.R.1337 'America's Energy Security Trust Fund Act of 2009' in March 2009; Representative Inglis (R-SC) introduced H.R.2380 'Raise Wages, Cut Carbon Act of 2009' in May 2009.

2. In this article, unless otherwise noted, foreign currencies have been converted to US dollars using contemporary exchange rates for the given year of revenue or expenditure. If no year of the tax or expenditure is stated, the current exchange rate is used.
3. In 2009, a two-earner family of four earning CAD$60,000 per year would pay carbon taxes of CAD$60 for gasoline and CAD$53 for natural gas heat and hot water, but would receive a personal income tax reduction of CAD$118, thus receiving a net gain of CAD$5. These figures assume 23 miles per gallon fuel efficiency and approximately 12,400 miles of driving per year. A senior couple earning CAD$30,000 per year would pay carbon taxes of CAD$25 for gasoline and CAD$70 for an oil furnace using 2,000 litres of heating oil per year. The senior couple would receive CAD$205 in personal income tax reduction, thus making the net gain for the couple CAD$110. These figures assume 19.6 miles per gallon fuel efficiency and approximately 4,300 miles of driving per year (Ministry of Finance, British Columbia, 2008).
4. It generated SEK 25.810 billion in 2005, SEK 24.743 billion in 2006, and SEK 25.088 billion in 2007.
5. Pelle Magdalinski (Swedish Environmental Protection Agency), personal communication, 9 December 2009.
6. National Insurance Contributions are mandatory contributions paid by employees and employers on earnings, and by employers on certain benefits-in-kind provided to employees.
7. Nick Hatherall (United Kingdom Climate Change and Energy Branch), personal communication, 18 September 2009.
8. Sarah Van Pelt (City of Boulder), personal communication, 9 October 2009.
9. Boulder performs GHG accounting in metric tons of carbon dioxide equivalent (CO_2e).
10. Sarah Van Pelt (City of Boulder), personal communication, 9 October 2009.
11. Robert Noel de Tilly (Senior Policy Advisor), Quebec Government, personal communication, 8 October 2009.
12. Robert Noel de Tilly (Senior Policy Advisor), Quebec Government, personal communication, 8 October 2009.
13. Anne Foy (British Columbia Ministry of Finance), personal communication, 17 September 2009.
14. Anne Foy (British Columbia Ministry of Finance), personal communication, 17 September 2009.
15. Evaluation may be easier to implement for taxes designed to raise revenues to implement specific carbon reduction programmes.

References

Abboud, L., 2008, 'An exhausting war on emissions: Norway's efforts to contain greenhouse gases move forward – and backfire', *Wall Street Journal*, 30 September 2008 [available at http://online.wsj.com/article/SB122272533893187737.html].

Aldy, J.E., Pizer, W.A., 2009, 'Issues in designing U.S. climate change policy', *Energy Journal* 30(3), 179–209.

Aldy, J.E., Ley, E., Parry, I., 2008, 'A tax-based approach to slowing global climate change', *National Tax Journal* 61(3), 493–517.

BAAQMD (Bay Area Air Quality Management District), 2008, 'Fact sheet: proposed Bay Area Air Quality Management District greenhouse gas fee schedule', 5 February 2009 [available at www.baaqmd.gov/Divisions/Planning-and-Research/ Planning-Programs-and-Initiatives/Climate-Protection-Program/~/media/6D9F5ACC2B674F698BFD77D339C3D535.ashx].

Bateman, B., 2009, 'Bay Area Air Quality Management District greenhouse gas fee schedule', presented at the Center for Climate Change webinar, 25 August 2009.

Bouvenberg, A.L., Goudler, L.H., 1997, 'Costs of environmentally motivated taxes in the presence of other taxes: generally equilibrium analyses', *National Tax Journal* 50(1), 59–87.

CARB (California Air Resources Board), 2008, 'Climate change scoping plan: a framework for change', Sacramento, CA [available at www.arb.ca.gov/cc/scopingplan/document/adopted_scoping_plan.pdf].

CARB (California Air Resources Board), 2009a, 'AB 32 cost of implementation fee regulation (HSC 38597)', Sacramento, CA [available at www.arb.ca.gov/cc/adminfee/adminfee.htm].

CARB (California Air Resources Board), 2009b, 'Proposed AB 32 cost of implementation fee regulation and proposed amendment to the mandatory reporting of greenhouse gas emissions regulation', Sacramento, CA, 25 September 2009 [available at www.arb.ca.gov/cc/adminfee/ meetings/sept25_board_presentation.pdf].

City of Boulder, 1981, 'Imposition of climate action plan excise tax in section 3-12-2', Boulder Revised Code [available at www.colocode.com/boulder2/chapter3-12.htm].

City of Boulder, 2009a, 'An ordinance amending the climate action plan excise taxes to the maximum rates set forth in section 3-12-2, B.R.C. 1981, and setting forth details in relation thereto', Ordinance No. 7657 [available at www.colocode.com/boulder2/chapter3-12.htm].

City of Boulder, 2009b, 'Community guide to Boulder's climate action plan', October 2009 [available at www.bouldercolorado.gov/files/CAP_Guide.pdf].

DECC (Department of Energy and Climate Change), 2009, 'Climate change agreements: the climate change levy', UK Government [available at www.decc.gov.uk/en/content/cms/what_we_do/change_energy/tackling_clima/ccas/cc_levy/cc_levy.aspx].

Defra (Department for Environment, Food and Rural Affairs), 2005, 'The United Kingdom's report on demonstrable progress under the Kyoto Protocol', UK Government [available at http://unfccc.int/resource/docs/dpr/uk1.pdf].

del Río, P., Labanderia, X., 2009, 'Barriers to the introduction of market-based instruments in climate policies: an integrated theoretical framework', *Environmental Economics and Policy Studies* 10(1), 1–20.

EEA (European Environment Agency), 2009, 'OECD/EEA database on instruments used for environmental policy and natural resources management', Copenhagen [available at www2.oecd.org/ecoinst/queries].

Ekins, P., 1999, 'European environmental taxes and charges: recent experience, issues and trends', *Ecological Economics* 31, 39–62.

Enevoldsen, M., 2005, *The Theory of Environmental Agreements and Taxes: CO_2 Policy Performance in Comparative Perspective*, Edward Elgar Publishing, London.

Goulder, L.H., 1995, 'Environmental taxation and the double dividend: a reader's guide', *International Tax and Public Finance* 2, 157–183.

HMT (Her Majesty's Treasury), 2008, *Budget 2008: Stability and Opportunity: Building a Strong, Sustainable Future*, HC 388, The Stationery Office, London [available at www.hm-treasury.gov.uk/d/bud08_completereport.pdf].

Johansson, B., 2000, 'The carbon tax in Sweden', in: *Innovation and the Environment*, OECD Publishing, Paris, 85–94.

Metcalf, G.E., Paltsev, S., Reilly, J.M., Jacoby, H.D., Holak, J.F., 2008, *Analysis of U.S. Greenhouse Gas Tax Proposals*, National Bureau of Economic Research (NBER), Cambridge, MA, Working Paper No. W13980.

Ministry of Finance, British Columbia, 2008, 'Budget and Fiscal Plan 2008/09-2010/11', 19 February 2008 [available at www.bcbudget.gov.bc.ca/2008/bfp/ 2008_Budget_Fiscal_Plan.pdf].

Ministry of Sustainable Development, Sweden, 2005a, *The Swedish Report on Demonstrable Progress under the Kyoto Protocol*, Ds 2005:57 [available at http://unfccc.int/resource/docs/dpr/swe1.pdf].

Ministry of Sustainable Development, Sweden, 2005b, *Sweden's Fourth National Communication on Climate Change under the United Nations Framework Convention on Climate Change*, Ds 2005:55 [available at http://unfccc.int/resource/docs/natc/swenc4.pdf].

Ministry of Taxation, Denmark, 2008, 'VAT, payroll tax and environmental taxes', 23 June 2008 [available at www.skm.dk/foreign/english/taxindenmark2008/6649].

Ministry of the Environment, Finland, 2008a, 'Detailed information on environment-related taxes and charges in Finland' [available at www.environment.fi/download.asp?contentid=85625].

Ministry of the Environment, Finland, 2008b, 'Environmentally related energy taxation in Finland' [available at www.environment.fi/default.asp?contentid=147208].

Ministry of the Environment, Norway, 2005a, *Norway's Fourth National Communication under the United Nations Framework Convention on Climate Change: Status Report as of December 2005*, T-1452 E [available at http://unfccc.int/resource/docs/natc/nornc4.pdf].

Ministry of the Environment, Norway, 2005b, *Norway's Report on Demonstrable Progress Under the Kyoto Protocol: Status Report as of December 2005*, T-1453 E [available at http://unfccc.int/resource/docs/dpr/nor1.pdf].

Ministry of the Environment, Norway, 2007, *Norwegian Climate Policy: Summary in English,* Report No. 34 (2006–2007) to the Storting [available at www.regjeringen.no/pages/2065909/PDFS/ STM200620070034000EN_PDFS.pdf].

Ministry of the Environment, Norway, 2008, 'Norwegian national allocation plan for the emissions trading system in 2008–2012' [available at www.regjeringen.no/upload/MD/Vedlegg/Planer/NAP_FINAL_ESA_260308.pdf].

Ministry of the Environment, Sweden, 2008, *Towards a Low Carbon Society*, M2008.30 [available at www.sweden.gov.se/content/1/c6/11/66/69/f7b9ac55.pdf].

Netherlands Ministry of Housing, Spatial Planning and the Environment, Directorate-General for Environmental Protection, 2004, *The Netherlands' Tax on Energy: Questions and Answers* [available at www.wind-works.org/FeedLaws/Netherlands/NLEnergytax2004.pdf].

Nordhaus, W., 2007, 'To tax or not to tax: alternative approaches to slowing global warming', *Review of Environmental Economics and Policy* 1(1), 26–44.

Parkkinen, T., 2009, Personal communication 8 October, 2009, Ministry of the Environment, Finland.

Parry, I., 2003, 'Fiscal interactions and the case for carbon taxes over grandfathered carbon permits', *Oxford Review of Economic Policy* 19(3), 385–399.

Prasad, M., 2008, 'Taxation as a regulatory tool: lessons from environmental taxes in Europe', in: E. Balleisen, D. Moss (eds), *Government and Markets*, Cambridge University Press, Cambridge, UK, 363–390.

Prime Minister's Office, Finland, 2000, *Environmental and Energy Taxation in Finland: Preparing for the Kyoto Challenge,* Summary of the Working Group Report [available at www.vnk.fi/julkaisut/julkaisusarja/julkaisu/fi.jsp?oid=130600].

Quebec, 2008, *Quebec and Climate Change: A Challenge for the Future. 2006–2012 Action Plan* [available at www.mddep.gouv.qc.ca/changements/plan_action/2006-2012_en.pdf].

Speck, S., Andersen, M.K., Nielsen, H.Ø., Ryelund, A., Smith, C., 2006, *The Use of Economic Instruments in Nordic and Baltic Environmental Policy 2001–2005*, TemaNord 2006:525, Nordic Council of Ministers, Copenhagen [available at www.norden.org/da/publikationer/publikationer/2006-525].

Swedish Environmental Agency and Swedish Energy Agency, 2007, *Economic Instruments in Environmental Policy*, Report 5678, Swedish Environmental Agency, Stockholm [available at www.energimyndigheten.se/Global/Engelska/News/620-5678-6_webb.pdf].

Swedish Tax Agency, 2008, *Taxes in Sweden: An English Summary of Tax Statistical Yearbook of Sweden* [available at www.skatteverket.se/download/18.69ef368911e1304a625800017687/10409.pdf].

Torys LLP, 2007, 'Quebec government to implement carbon tax', *Torys Climate Change Bulletin*, 12 June 2007 [available at www.torys.com/Publications/Documents/PublicationPDFs/CCB2007-6.pdf].

Turner, C., 2008, 'The carbon cleansers', *Canadian Geographic*, October [available at www.canadiangeographic.ca/magazine/oct08/feature_norway_carbon_tax.asp].

UNFCCC (United Nations Framework Convention on Climate Change) Compliance Committee, 2006, *Report of the Centralized in-Depth Review of the Fourth National Communication of Norway*, CC/ERT/2006/8 [available at http://unfccc.int/files/kyoto_protocol/compliance/plenary/application/pdf/cc-ert-2006-8_report_of_centralized_idr_of_nc4_of_norway.pdf].

Wiener, J.B., 1999, 'Global environmental regulation: instrument choice in legal context', *Yale Law Journal* 108, 677–800.