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Project financing an energy revolution in the USA

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The Intergovernmental Panel on Climate Change has warned that there is significant concern that increasing manmade greenhouse gas (GHG) emissions are leading to climate change and global warming. Climate models indicate that to minimize the damage caused by global warming, governments need to limit the global temperature increase to 2°C. This requires stabilizing the concentration of GHGs in the atmosphere to 450 parts per million in carbon dioxide equivalents (CO_{2e}) by 2050. Many countries concur that the level of emissions per citizen for every country should converge by then. This will require the emissions of developed countries to decline by 50–90% by 2050. This paper examines the building and utilities sectors that account for 68% of total US GHG emissions and proposes a potential solution of adopting a carbon tax (revenues) with reinvestment (power plant construction) that reduces US emissions by 48% and building/utility emissions by 67% within 20 years. This paper then examines two potential options using a project (infrastructure) finance approach to either minimize current taxation to ease the economic burden on a slow-growing economy or accelerate emission reductions within the utilities and building sectors. The first model applies limited tax (providing economic stimulus) in years 1–10 and collects the tax from years 11 to 30 (with a peak of 2% of gross domestic product), resulting in the same emission reduction. The second model uses project finance to accelerate spending on infrastructure reducing total emissions by 58% and building/utility emissions by 81% within 20 years, resulting in a 13.2% and 36.1% emission reduction, respectively, over the base model. Due to the limited time frame to reduce emissions and minimize the impact of global warming, all three models are of value to politicians.

Keywords: Buildings, climate change, GHG emissions, project finance, utilities.

Introduction

The Intergovernmental Panel on Climate Change (IPCC), the leading climate science authority, has indicated that there is a strong correlation between increasing manmade emissions and climate change (IPCC, 2007a). The IPCC further stated that unless the world adopts a plan to reduce greenhouse gas (GHG) emissions, the global annual average temperature will increase by an estimated 2.5–7°C above pre-industrial levels by the end of this century. Climate models predict that temperature increases of 4°C increase the likelihood of irreversible impacts, and these include the extinction of 50% of species worldwide, inundation of 30% of coastal wetlands and substantial increases in malnutrition and diarrhoeal and cardio-respiratory diseases (World Development Report, 2010). Mitigation as a component of adaptation is a priority (IPCC, 2001; World Bank, 2007).

Concerning mitigation, the priority is to focus on sectors that have the greatest likelihood of success in terms of reducing emissions. For most developed and developing countries, and in particular the USA, the GHG sectors can be subdivided into (1) utilities and industry, (2) transportation and (3) buildings (commercial and residential). The allocation of emissions between these sectors results in buildings accounting for about 40% of emissions and utilities/industry as well as transportation accounting for approximately 30% each. However, this allocation uses end usage rather than the source of emission production. The allocation of emissions by source leads to the following: utilities and industry sector produce 57% of emissions, the transportation sector 32% and buildings, both

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commercial and residential, 11%, of total emissions (US Environmental Protection Agency, 2012).

Due to the significant utilities/industrial sector emissions, this paper examines a potential mitigation strategy to develop a revenue stream based on a carbon tax that replaces the existing power infrastructure, thereby reducing total emissions. This paper uses a carbon tax with reinvestment (CTR) as the base model and expands upon this concept by investigating two alternative models using project finance (PF). The first uses PF to postpone the minimization of the carbon tax for 10 years while funding a construction boom to mitigate emissions, therefore stimulating the economy (given the present weak economic climate of slow gross domestic product (GDP) growth and high unemployment). The second examines the implementation of the tax as is while also boosting investment using PF to accelerate the reduction impact on GHG emissions.

The PF solution addresses the current economic climate and the need to mitigate emissions combined with the opinion of the public who realize that something needs to be done but prefer not to spend money to adapt to potential climate change impacts. In terms of the American public, public opinion is in favour of reducing GHGs; however, there is a reluctance to spend money on an uncertain plan to achieve the goal. Sixty-two per cent of Americans favour an immediate and drastic action to reduce global warming and 68% support a new international treaty requiring the USA to reduce its carbon dioxide emissions by 90% by 2050 (Emanuel, 2007). Eighty-one per cent of Americans believe that the USA should take the lead in reducing GHG emissions, and 87% believe that the industrialized countries including India and China need to take action immediately. However, 48% are unwilling to spend additional money on gasoline taxes to achieve the goal of reducing US GHG emissions and only 18% of Americans are willing to pay 50 cents or more in additional taxes per gallon of gas to reduce emissions (Emanuel, 2007).

Climate change

To minimize the severe problems arising from climate change, nations must make a move to prevent global temperatures from rising by more than 2°C (3.6°F) above the pre-industrial levels (Monbiot, 2007). Per the IPCC, temperatures have already risen 0.74°C in the last 100 years; therefore, it is necessary to take action to prevent the average global temperature from rising more than an additional 1.26°C (IPCC, 2007d).

According to the climate models a temperature increase of up to 2°C is manageable, while an increase in excess of 2°C would result in an unmanageable and unsustainable change in the climate due to several irreversible processes causing further significant global damage. These are: (1) excess warming causing the Arctic tundra to melt releasing methane further accelerating warming (Pearce, 2005b); (2) the heating of the oceans releasing methane stored at the bottom of the oceans, further increasing temperatures (Flannery, 2005); (3) the dying of the Amazon rainforest releasing large amounts of carbon dioxide (Cowling *et al.*, 2004; Meteorological Office, 2005c); (4) inundation of aquifers by salt water in coastal cities such as Shanghai, Manila and Buenos Aires among others (Pearce, 2005a); (5) the risk of severe water shortages for 2.3 to 3 billion people (Parry *et al.*, 2001; Meteorological Office, 2005a); and (6) the death of most of the world's coral systems and ecosystems due to bleaching (Meteorological Office, 2005b).

450 parts per million (PPM)

To prevent global temperature increases in excess of 2°C above the pre-industrial levels, it is necessary to stabilize the concentration of GHGs in the atmosphere at 450 parts per million (PPM) in carbon dioxide equivalents (CO_{2e}) (IPCC, 2007c). The concentration in the atmosphere was 387 PPM in 2009 and growing at 2 PPM, per year. Current world emissions are 30 billion tons of CO_{2e} per year. Current average emissions per person are over 4 ton of CO_{2e} per year, with significant differences in per capita emissions. Australia, the USA, Canada, Germany, Sweden, China, India and Kenya are emitting 26.9, 23.5, 22.6, 11.9, 7.4, 5.5, 1.7 and 0.3 ton of CO_{2e} per person per year, respectively. To achieve 450 PPM by 2050, it is necessary to reduce average emissions to 18 billion tons of CO_{2e} per year between 2013 and 2050.

In an effort to bring developing (and keep developed) countries on board to reduce emissions, the concept of contraction and equity leading to convergence was developed, thereby granting all countries an equal allocation of emissions per capita (Meyer, 2000). Using this methodology, the goal is for each country (rich or poor) to have an equal allocation (2 ton of CO_{2e} per capita by 2050 assuming a population of 9 billion people) and therefore be responsible for achieving this goal. Contraction and convergence have gained significant support in Africa, India, China and the European Parliament, which endorsed the concept (UK Royal Commission on Environmental Pollution, 2000; Scottish Parliament, 2005).

Proposed legislation

The Kyoto Protocol was adopted in 2005 because many countries were concerned about climate change. The international treaty required the members to reduce GHG emissions to the 1990 levels by 2012. The

Obama Administration in February 2009 issued targets for overall GHG emissions, with the objective of achieving emission reductions of 14% below the 2005 levels by 2020 and total emission reduction of 83% below the 2005 levels by 2050. This requires significant emission reductions from all emitting sectors of the economy. Of primary concern is the utilities sector, which is the leading generator of GHG emissions (US Environmental Protection Agency, 2012). The utilities sector consumes fossil fuels to provide electricity to the industry, transportation and building sectors, thereby producing CO_2 emissions. Electricity generation emissions are distributed to each of the end-use sectors based on each sector's share of aggregate electricity consumption. This distribution of emissions is done using the national average mix of fuels according to their carbon intensity. Power plants produce a significant amount of GHG emissions; however, attributing these emissions to the end sectors results in buildings producing a significant amount of emissions.

Carbon tax or cap: proposed solutions to reducing emissions

Current proposals that have come forth to solve the global warming dilemma are primarily political. These proposals consist of (1) directly taxing carbon through a carbon tax applied solely to energy and (2) limiting carbon emissions by imposing a cap and requiring everyone, to varying degrees, to reduce energy consumption by the purchase of emission permits, known as a cap-and-trade.

Emission externalities

Emissions are an externality (Coase, 1960; Baumol, 1972) resulting in a social cost (global warming and climate change), and the proposals to tax carbon are a method to address this externality. An externality is a cost or a benefit not captured in the price of the good or service. In the case of GHG emissions, the externality results in a social cost (global warming and climate change), and the proposals to tax (or limit) carbon emissions attempt to address this externality. Pigou (1920) proposed the use of a tax to address externalities; this Pigouvian tax addresses the externality by incorporating the cost (of the externality) into the price of the good or service, creating an incentive to minimize the production of GHG emissions.

Cap-and-trade

Developed by Thomas Crocker in the 1960s, cap-and-trade caps emissions at a fixed level, allowing the price of emissions (CO_{2e}) to vary (Hilsenrath, 2009). Economists and politicians question whether a cap is enforceable particularly if it stopped the sales of crucial items such as electricity, gasoline or other items, creating economic harm (Hilsenrath, 2009). Many cap-and-trade proposals, including Liebermann–Warner (Lieberman and Warner, 2008) and Waxman–Markey (Waxman and Markey, 2009), have 'exit' provisions. 'Exit' provisions switch the emissions cap to a fixed carbon tax temporarily if the price of carbon rises above a pre-specified level, thereby allowing the economy to function by taxing carbon at a fixed 'reasonable' price. The Kyoto Protocol (2005) was an attempt to set binding targets for 37 countries, whereby the countries would then set up their own cap-and-trade programme to meet pre-agreed emission limits. Within cap-and-trade, there is no concept of remaining lifetime for a power plant/utility. A new (or old) power plant that exceeds specific emission levels (or quotas under cap-and-trade or similar legislation) would either need to be closed or incur significant costs to be modified. Modifying a coal power plant may not be a viable option as the only low GHG emission option is carbon sequestration and therefore shutting down may be the more economical option (Montopoli, 2012). The cost of sequestering and capturing carbon is in the range of $8000–9000 per kW, significantly exceeding the cost of building new natural gas, solar, wind, geothermal and nuclear power plants with no guarantee that the carbon will remain sequestered (Kaplan, 2008; Vincent, 2012).

Carbon tax

A carbon tax is a simple tax on total emissions at a fixed price per ton. Proposals within the literature (Mann, 2002; Waggoner, 2009; Avi-Yonah and Uhlmann, 2009) focus on applying a carbon tax to energy (coal, oil and gas), including energy imports; however, finished and intermediate goods and services that are imported are excluded as well as potentially other areas of the economy.

As with cap-and-trade, the carbon tax is applied locally within one country. While an appropriate tax would lead to the reduction of emissions, there are many problems with a global tax. Among them, does it apply equally to everyone or do some countries receive a pass similar to that received in the Kyoto Protocol. If they do, are industries allowed to move to those countries to avoid the cost of the tax, thereby giving them an unfair trading advantage? This would hurt the economy as well as employment as industry moves in greater numbers to locations without pollution and emission controls. Furthermore, who would collect the tax? If the objective is to reduce carbon production, then it is reasonable that the tax be applied to all items (Weber *et al.*, 2008).

Carbon tax with reinvestment

In response to the issues associated with the existing carbon approaches, the author proposes a hybrid to the carbon tax, namely a CTR as a solution. Revenues are used to construct carbon-minimizing power plants. The CTR would operate like a carbon tax, meaning that it would be a price per ton of carbon. For the base model, the assumption is that the CTR would start in year 1 at $5/ton of carbon emitted and increases each year by $5/ton for a total tax of $50/ton by year 10. This tax structure minimizes the impact on the economy and creates predictability for consumers and power companies in terms of energy costs. A corporation or person would be able to make an informed decision about the short-term and long-term purchases.

Unlike a traditional carbon tax that typically proposes to refund monies raised immediately (i.e. within the year they are collected), the goal of the CTR is to potentially refund monies collected over a longer time period through cheaper and cleaner energy. The process works as follows. First, funding from the CTR is used to build low- or no-carbon-emitting power plants, including but not limited to solar, wind, geothermal, hydroelectric, nuclear and other non-emitting energy sources. The tax starts low and increases consistently over time informing the market that 'dirty' power and energy will become progressively more expensive, encouraging conservation as well as the conversion from dirty to clean power plants over the next several years. Industry would be motivated to purchase energy-efficient machinery, so would the consumer, when it comes to vehicles, homes and appliances. With the externalities produced by energy taxed, there will be a dual incentive to use less energy as well as cleaner energy.

Second, once these power plants are constructed, they would be transferred to the local state public utility commissions (PUCs). We make some simplifying assumptions with the PUCs. Under the law, utilities are entitled to the recovery of their reasonably incurred expenses and a fair return on their investment (the PUC) (The PUC Rate Making Process and the Role of Consumers, 2012). The PUCs structure electricity prices based on the cost of power plant assets, transmission (distribution grid) assets and the cost (energy) to produce power. As new power plants are constructed using CTR funds (collected from taxpayers) and transferred to PUCs and utilities, the total capital invested by the utility over time is lowered, thereby resulting in lower electricity prices. This assumption would therefore refund the monies collected in taxes by providing not only cleaner, but also cheaper electricity in the future. This paper does not delve into how a transfer would occur to a PUC, but leaves this research for a future paper. This paper proposes that this issue could be resolved and the benefit passed onto consumers of having a zero-cost (pre-paid) asset incorporated into the local utility rates, thereby lowering electricity rates in the future.

Unlike other tax or cap proposals, there is no incentive to shift production either to another state or offshore. In fact, given the high level of emissions from shipping, it may be advantageous to move production locally. Under the current trade situation, there are two primary incentives to move the production of goods and services offshore; they are as follows: (1) lower wages and (2) cheaper but dirtier power/energy combined with lax emission standards. A CTR would eliminate the incentive to move production offshore for cheaper energy with lax emission standards. Our assumption here is that it is possible to structure the CTR such that all goods and services are taxed under this model, both domestic and foreign.

The purpose of the CTR presented here is not to examine the impact on world trade or to show how this could be structured to comply with World Trade Organization regulations. Rather, the purpose of this paper is to show that applying a CTR-like structure and reinvesting the monies into clean power production could potentially reduce GHG emissions significantly over a 20-year period.

Project/infrastructure finance

While modern and reliable infrastructure is essential for development (Ngowi *et al.*, 2006), it seems that it is also essential in the effort to combat climate change because current power plants produce 57% of GHG emissions (US Environmental Protection Agency, 2012), and replacing or modifying these will require significant capital. Financing to build the infrastructure in the USA or elsewhere has been volatile over the past decade and insufficient (Beck *et al.*, 2000; Kehew *et al.*, 2005; Martell and Guess, 2006; Ngowi *et al.*, 2006; Platz, 2009). However, current proposals for reducing GHG emissions to avert global warming, both cap-and-trade and carbon tax, do not take into account this potential lack of financing or funding to solve this dilemma.

PF involves the financing of long-term infrastructure, industrial projects and other public service facilities where the project is financed by raising funding today to pay for the project and using the future cash flows generated by the project to pay back the lenders and investors (Esty, 2003; Baragona, 2004). In the USA, 10–15% of total capital investment is financed on a project basis, while more than half of the capital assets costing in excess of $500 million are financed on a project basis. The most common projects financed are in the natural resource (mines, pipelines and oil fields) and infrastructure (toll roads, bridges, telecommunications systems and power plants) sectors (Esty, 2003, 2004).

A primary advantage of PF is that it is off the balance sheet (Esty, 2003). This is important not only to corporations but also to governments. A road typically needs to be financed and maintained by the local city, municipality, state or federal government. Building a road (long-term asset) usually implies that a government will finance the project. Using its regular budget implies that funding to repay the bonds would come from its general receipts. This potentially places the budget in jeopardy as the government has other obligations to its people. A revenue shortfall could result in severe budget cuts, higher interest rates and bond downgrades (raising the cost of all of the government's debt), all potentially spiralling into bankruptcy. Raising additional funding, even for a specific project, could also result in a downgrade of the government's credit rating, again resulting in additional costs (Schewel, 1998). Separating a project from the sponsor, a government or a corporation, the project as an entity may be rated, financed and operated separately, thereby allowing the project to stand on its own financially and to move forward.

In the case of a corporation, there are additional advantages. For a project built in a country with high political risk, a corporation proceeding alone faces significant risks to its capital investment once a project is completed, with expropriation and change in tax rates or policy being among them (Esty, 2001; Delecluse, 2004; Arbogast, 2008–2009). By turning to PF, the banks and investors involved in the project will require guarantees both from the corporation (as the operator) and from the government in order to ensure that their funds are returned (Rendell, 1994). This minimizes the risk of government expropriation as this could impact the government's overall credit rating and ability to raise funds on international credit markets (Robertson and Jones, 2004; Ozkan, 2006). It is common for the cash flow from the project to be controlled by the banks, ensuring payment on the debt obligations and minimizing the ability of either the government or corporation to squander funds on pet projects (Esty, 2004).

The advantage of using PF

A key advantage of using PF is that it allows a project to move forward based on future revenue generation expectations. Revenue projections (and contracts or passed law) allow for liquefied natural gas facilities, toll roads, airports and power plants to raise funds in the present to ensure a timely project being built. This creates a key advantage. With respect to a carbon tax, revenues are raised as soon as legislation is passed and signed into law. However, a carbon tax only raises revenues in the future, and those revenues cannot be spent until the revenue is collected. PF allows the funding to be raised in the present in anticipation of the future revenue stream, which creates an advantage given that designing, planning and constructing power plants require revenues to be committed in the present.

Regarding the environmental constituency, a primary concern that is expressed is that in order for a proposal to be widely accepted the impact on emissions should occur sooner rather than later. In this proposal to finance an energy revolution, this means that the sooner the low- to no-carbon power plants are built, the sooner the emission levels begin to decline. This is a systems dynamic model, whereby emissions decline as new clean energy production comes online thereby replacing older 'dirtier' power production. PF gives rise to two potential benefits, either delaying full implementation of the tax (minimizing the economic impact) or accelerating the benefits of the tax to increase the ordering of power plants by providing finance upfront, allowing the steel, cement and construction industries to get to work. The net effect is to increase production and construction while reducing unemployment and emissions. The benefits of this policy are threefold: (1) it provides a significant stimulus to the construction industry, thereby stimulating the economy; (2) it results in the production of clean power sooner, thereby reducing emissions; and (3) it leads to lower emissions, resulting in lower total taxation to achieve the end result of reducing emissions.

Modelling a CTR

To analyse the impact that a CTR would have on the emissions of the economy, a model was developed to illustrate the potential for reducing GHGs, developing funding for alternative energy sources and ensuring that the current US output of cement and steel would allow for a major investment in alternative energy sources. The model is based on using the CTR as a workable idea to not only incentivize businesses, people and governments to reduce carbon emissions by raising prices, but also fund the development of energy resources with low- to no-carbon emissions.

The model illustrates how the funding raised from the CTR is used to develop new power plant facilities while retiring older facilities that emit high carbon equivalents. The building of these facilities will require significant amounts of materials and labour. For simplification purposes and given that the recent statistics puts unemployment at 20.1% in the construction industry (Bureau, 2010), it is assumed that we have more than sufficient human capital to develop and build these facilities. This leaves the materials, which are primarily steel and cement.

Model introduction

The CTR model was developed using MS Excel 2007. This platform was selected because it allowed for pure calculations as well as an iterative process. The model is divided into three primary components: input variables, analysis calculations and output variables.

Input variables

The input variables of the CTR model include carbon emissions equivalent (domestic and total imports), fixed (annual) rate for a carbon tax on those emissions, metric tons of steel and cement needed to build four different types of power plants, and time frame for the construction of the power plants. These variables represent the emissions, tax on emissions, resulting revenues leading to orders for power plants and related demand for steel and cement.

Analysis calculations

The analysis component of the model emphasizes the prediction of the demand for cement and steel based on the rate and the time frame over which the CTR is collected. The primary components of the analysis functions include

- total revenues from the CTR applied to domestic production and imports and
- orders of power plants based on the revenues.

Output variables

The final output from the model emphasizes the total reduction in emissions as well as the amount of steel and cement needed to build the power plants based on the revenues and subsequent orders of power plants. This emphasis is realized through the following output variables:

- emissions from utilities and buildings (change as the CTR takes effect resulting in ordering and putting online the new no- or low-carbon power plant facilities, with the impact of decommissioning high-carbon power plants) and
- the total order of steel and cement, which ensures that the current industry is able to produce the volumes needed to transform the utilities sector, thereby reducing total emissions from utilities and buildings.

Data and modelling

To determine the amount of steel and cement needed to develop the alternative energy infrastructure, four types of power plants are included in the model: (1) nuclear, (2) wind, (3) solar and (4) geothermal (Peterson, 2006). The amount of steel and cement required by these facilities per megawatt (MW) of power plant capacity is given in Table 1.

Understanding the need for steel and cement to build these facilities is important for two key reasons: (1) While most of these energy sources are low-carbon emission ones, the building of these facilities, using high-carbon energy, results in high initial emissions prior to an extended period of use with almost no emissions. (2) It is necessary to determine the required amount of cement and steel to understand its impact on the current production capacity of steel and cement. Either the capacity to produce steel and cement may need to be increased and/or the number of facilities constructed may need to be limited.

If the number of facilities constructed needs to be limited due to resource constraints, then it may be necessary to either build more of one type or less of another type of facility initially with the objective of reducing total emissions. Alternatively, if there is no constraint on facilities, then it may be possible to accelerate construction to reduce emissions at a more rapid rate. In either case, a policy decision could be made to determine whether it would be better to accelerate or reduce the rate at which carbon is taxed to match cash flows or to reduce emissions based on pricing.

Flow chart of the model

The model is based on all GHG emissions being taxed. The taxes raised are used to order and construct new power plants. Once constructed, these power plants would replace the existing power plant infrastructure. This restructuring of the existing power grid leads to a reduction in total emissions, thereby resulting in future lower tax revenues. The flow chart is shown in Figure 1.

Table 1 Steel and cement amounts required per MW capacity

	Nuclear	Solar	Wind	Geothermal
Metric tons of steel	60	104	460	200
Metric tons of cement	105	108	232	71

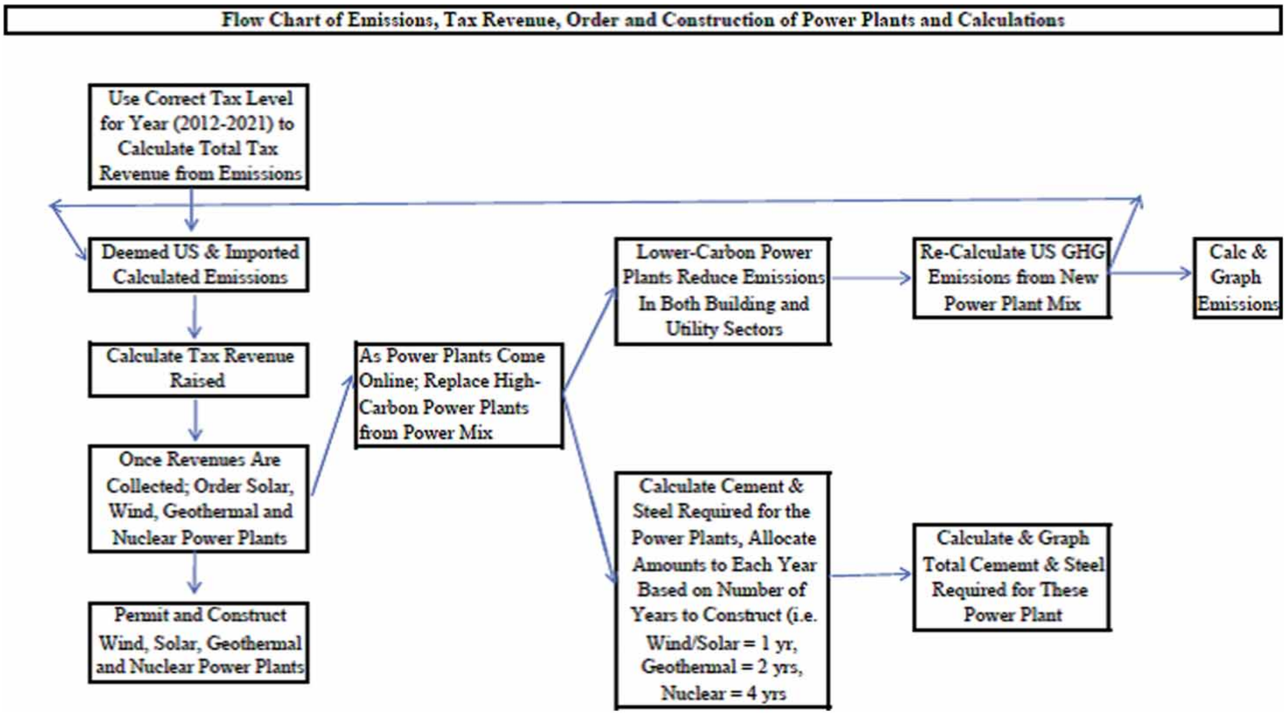

Figure 1 Flow chart of emission modelling

Applying the CTR model

With the information on material limitations (if any), it is now possible to determine the following: (1) the need for funding based on a construction schedule and material availability and (2) the need to adjust the tax on carbon to reduce emissions. Using this information, the base model incorporates the following assumptions to calculate the impact of the CTR concept. All of the cases developed herein use the following assumptions:

(1) All three cases assume that a nuclear power plant will take eight years to be built, needing a two-year regulatory approval period, followed by a four-year construction period and a two-year testing period.
(2) All three cases assume that wind and solar power plants take a total of two years to be built, needing a one-year regulatory period and a one-year construction period.
(3) All three cases assume that deep geothermal power plants take a total of three years to be built, needing a one-year regulatory approval period followed by a two-year construction period.
(4) To minimize permitting, construction and testing time, it is assumed that the government and industry can agree on standardized power plant designs, thereby eliminating uniqueness but allowing a few size differences. This is particularly important for nuclear and geothermal power plants. This process will facilitate the minimization of construction costs (standardization), allowing construction to proceed at a quicker pace.
(5) Electricity production continues to grow at approximately 2% per year. If electricity demand grows at a slower pace, a faster reduction in carbon emissions results.
(6) The base model adds the assumption that the tax structure (CTR) starts in year 1 (2013) at $5/ton. The rate increases by $5/ton each year until the carbon tax reaches $50/ton in year 10 (2022). At this point, the tax flattens and remains at $50/ton. The IPCC's Working Group II surveyed over 100 different studies of the optimal tax rate and found ranges from $3 to $95 per ton (IPCC, 2007b). The purpose of starting the tax at $5/ton is to allow time to ramp up the construction (and manufacture) of power plants, train personnel, build manufacturing capacity and reduce potential of demand-induced inflation from a lack of materials and labour. Ramping up of the tax rate allows for an accelerating construction pace and the peak at $50/ton results in a developed slower growing economy, such as that of the USA, reducing emissions significantly within a 20-year period.

CTR scenarios

Three scenarios are developed. They are the base case, using the above construction periods and projected revenue streams. This is followed by the two cases using PF. The first PF case uses PF to postpone the full implementation of the tax, thereby providing economic stimulus to the economy. The second PF case uses PF to accelerate construction, thereby further reducing total emissions. These scenarios are presented below to provide an overview of how the CTR could be successfully implemented.

Base case

The base case begins with the tax rate at $5/ton in year 1 and peaks in year 10 at $50/ton after rising by $5/ton each year. This base case uses constant assumptions regarding construction periods, namely that a nuclear power plant will take eight years to be built. Solar- and wind-powered facilities are assumed to take two years, while a geothermal facility is assumed to take three years. To avoid deficit financing, I assume that power plants are ordered only after tax revenues have been collected, which are modelled quarterly (once the carbon tax is collected, power plants are ordered). In the base case, the revenues (taxes) and spending (power plant orders) are the same. I use an estimate of 2.5% for GDP growth. As the tax rate increases from $5 to $50 per ton, revenues increase from 0.31% (2013) to a peak of 2.45% (2022) of the GDP and then decline to 1.26% (2033) of total GPD. Although the CTR is rising at $5/ton/year for the first 9 years, the increase as a percentage of GDP is at a decreasing rate because power plants are being constructed and coming online, thereby reducing total emissions, and this automatically reduces the total tax level as there are less emissions on which to collect taxes. The 8–2–3 indicates the time it takes to build the specific types of power plants, namely the nuclear (eight years), wind and solar (two years) and deep geothermal (three years) power plants.

Base case analysis

Applying this carbon tax to purchasing and building significant new power plant capacity would require significant amounts of materials and labour. The labour is definitely available as a recent Wall Street Journal (Fields, 2009) article shows unemployment at 19.1% in the construction industry (over 1.6 million construction workers joined the unemployment rolls since the start of the recession (AGC, 2011)). Furthermore, in the USA, approximately 45% of US steel capacity (World Steel Association, 2009) is unused as well as 20% of cement capacity (Goose, 2008), thereby sufficient labour, steel and cement exist to implement this policy. To simplify matters, I assume that both political parties would back this proposal as it produces more secure energy future and environmental future and creates a significant number of jobs, thereby returning funding while supporting international objectives of reducing emissions. The taxes collected during the 20-year modelling period result in a tax that averages 1.61% of GDP for the base case.

Based on the above funding, purchasing and construction of power plants, the total emissions from the power plants (and buildings) would decline as shown in Figure 2. The lighter line indicates the decline in total emissions and the darker line indicates the decline in emissions from buildings and utilities. The main consideration is that by restructuring the power sector into clean energy, it results in a cleaner building

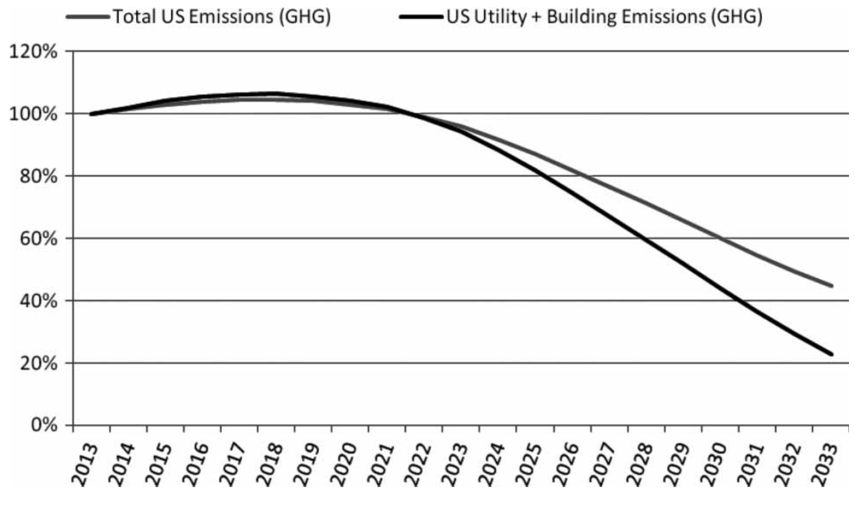

Figure 2 Base case—declining US emissions *vs.* utility and building emissions

sector. As Figure 2 shows, emissions peak in years three and four (2015/2016) and then begin to decline steadily; this process results in emissions from utilities and buildings declining by over 60% during the 20-year modelling period.

Even though total emissions for buildings and utilities would decline quite rapidly, this impact is less on the total overall emissions. Emissions for buildings and utilities decline by 77%, while the total US emissions decline by 55% in the 20-year period.

PF Case 1 (deferred tax implementation)

The first PF case is based on the current economic situation. Since the recession of 2008, the US economy has grown at a relatively slow rate. The US government has chosen on several occasions to provide a stimulus to the US economy through spending. The concept here is to tie together the need to reduce emissions with the need to stimulate the economy. This case introduces a carbon tax at a significantly reduced rate while maintaining spending in the base case. Ordering and constructing power plants provide the economy with a stimulus, achieving the goal of reducing emissions, and postpone the majority of the tax impact for 10 years. Figure 3 presents the revised tax rate.

The assumption is based on the US government using diverse funding (PF) using the legislated carbon tax to repay the bonds. Under present interest rates, I assume that the combined interest rate on borrowing would be 3.5% (Treasury Direct, 2012). The current average US government interest rate is 2.6%. The goal was for PF loans to be paid within 30 years from the start, which would be 2042. This reduced rate of tax for years 1–14 minimizes the economic drag while providing a stimulus to the economy, which averages 0.75% of GDP during this time, resulting in a more energy-efficient and cleaner economy when taxes increase from years 15 to 30 to repay the stimulus. This delay in implementing the tax does not delay the investment. The investment continues at the same pace as that mentioned above. As shown in Figure 4, spending exceeds revenues from 2013 to 2026; in 2027, revenues exceed expenditures to start repaying the financing. From 2027 to 2042, the average repayment is 0.84% of GDP. As a comparison within Figure 4, the expenditures in the first PF case (expenditures as a percentage of GDP) are equivalent to both the revenues raised and spent in the base case.

Year	Tax Rate	Year	Tax Rate
2013	$ 2.00	2023	$ 32.50
2014	$ 4.00	2024	$ 40.00
2015	$ 6.00	2025	$ 42.50
2016	$ 8.00	2026	$ 47.50
2017	$ 10.00	2027	$ 52.50
2018	$ 12.00	2028	$ 57.50
2019	$ 14.00	2029	$ 63.50
2020	$ 16.00	2030	$ 70.00
2021	$ 18.00	2031	$ 75.00
2022	$ 20.00	2032	$ 80.00

Figure 3 PF Case 1 (carbon tax structure)

PF Case 1 analysis (deferred tax implementation)

Emissions decline at the same pace as in the base case. This results in a 77% decline for the building and utility emissions and a total US emission decline of 55% in the 20-year period. The total debt due reaches a peak of $2.367 trillion in 2028 and is repaid completely by 2042. The benefit of providing a stimulus of 0.75% of GDP per year, on average, would support the economy by stimulating the construction sector as well as the related sectors would appear to be very beneficial. Note that I do not model that benefit. The tax never exceeds 2% of GDP and this was an objective to minimize the economic impact. The tax peaks in 2030 (year 18) at 1.998% and averages around 1.95% of GDP until the financing is repaid in 2042. Over the 20-year period, the tax rate in Case 1 averages 1.22% of GDP, and over the 30-year average, the tax rate averages 1.464% of GDP.

PF Case 2 (accelerated investment)

This case takes into consideration the fact that prices encourage changes in behaviour. Under the assumptions given above regarding the implementation of the carbon tax and the applicability of the tax to both domestic and imported goods and services, using the base case's tax rates would encourage organizations and consumers to alter their behaviour to include energy efficiency in their purchase decisions. This case accelerates the base case in terms of expenditures while using the base case revenues for the first 10 years. To pay for the acceleration, the tax rate does increase to $55/ton in 2022 and to $60/ton in 2029–2042 when all financing is paid. Figure 5 presents the tax rate in each year.

The accelerated spending shown in Figure 6 is compared with the carbon tax revenues. The benefit of this case is that more power plants are ordered and constructed sooner, resulting in fewer emissions and lower total taxes.

The increased spending results in a stimulus to the economy of 0.48% of GDP per year, on average, which provides a similar albeit smaller stimulus as in

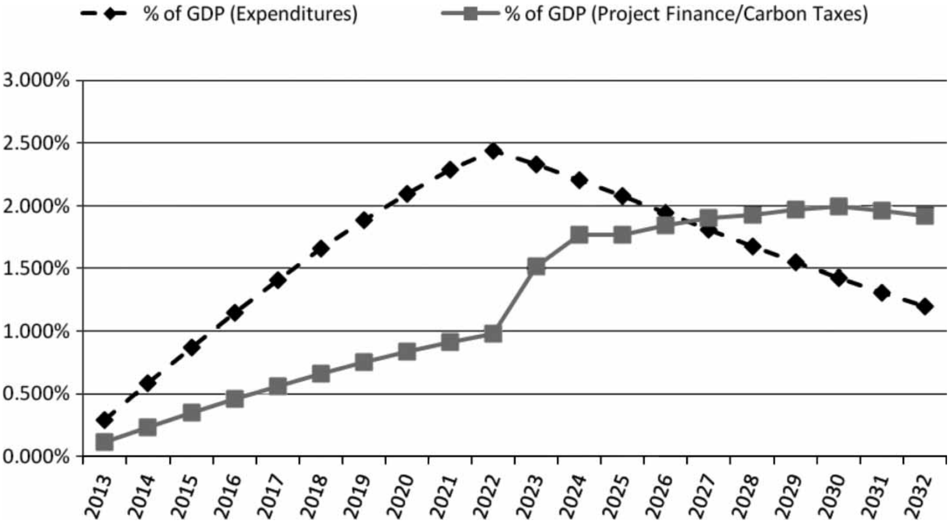

Figure 4 PF Case 1—expenditures as percentage of GDP *vs.* carbon taxes collected

the first case. Spending peaks at 2.26% of GDP in 2022 (year 10), while revenues peak in 2023 at 2.36% of GDP; both start to decline the following year. The benefit of this structure is that the taxes on carbon never exceed $60/ton. A further benefit in terms of reducing emissions is shown in Figure 7.

Compared with either the base case or the first PF case, overall emissions decline a further 13.2%, while emissions from buildings and utilities decline a further 36%. As a result, total emissions decline by 61% within the 20-year period, while emissions from buildings and utilities decline by 85% in the same period.

PF Case 2 analysis (accelerated spending)

Compared with the base case, the tax rate changes very little; however, the accelerated spending does require borrowing. Total borrowing peaks at $960.1 billion (significantly lower than that in Case 1, but provides less stimulus) in 2030 and declines to a zero balance by 2042. The tax increases in 2022 to $55 and in 2030 to $60. Although the tax rate is similar to that in the base case, the tax peak is 2.26% of GDP. Emissions decline at a more rapid rate.

Year	Tax Rate	Year	Tax Rate
2012	$5.0	2023	$55.0
2013	$10.0	2024	$55.0
2014	$15.0	2025	$55.0
2015	$20.0	2026	$55.0
2016	$25.0	2027	$55.0
2017	$30.0	2028	$55.0
2018	$35.0	2029	$60.0
2019	$40.0	2030	$60.0
2020	$45.0	2031	$60.0
2021	$50.0	2032	$60.0
2022	$55.0	2033	$60.0

Figure 5 PF Case 2 (carbon tax structure) and PF (carbon tax structure)

Analysis of results

A carbon tax with revenues applied to building a new energy (and low GHG emissions) economy would produce good results in reducing total emissions. PF can be used to improve those results either by postponing the impact of most of the taxes or by accelerating spending to build more power plants more quickly. In the case of postponing the tax impact, the benefit is that GHG emissions decline on track and taxes are postponed. For the base case, the CTR averages 1.61% of GDP over the 20-year period. The first PF case provides a stimulus of 0.75% of GDP while having a lower CTR average for the first 20 years of 1.22%. However, debt is acquired in the process and tax rates per ton of carbon do need to climb to repay the debt. In the second PF case, emissions are reduced more rapidly, which better meets the goal of 450 PPM. To do so, the average CTR for the 20-year period is 1.59%, very similar to that in the base case, but there is an initial stimulus to the economy of approximately 0.5%.

Depending on the political outcome, either of these models would provide a good solution and reduce total emissions. If the desire is to reduce emissions rapidly while stimulating the economy, then Case 2 would work very well. If the desire is to reduce emissions but provide a stimulus to the economy, then Case 1 provides a larger stimulus. If the goal is simply

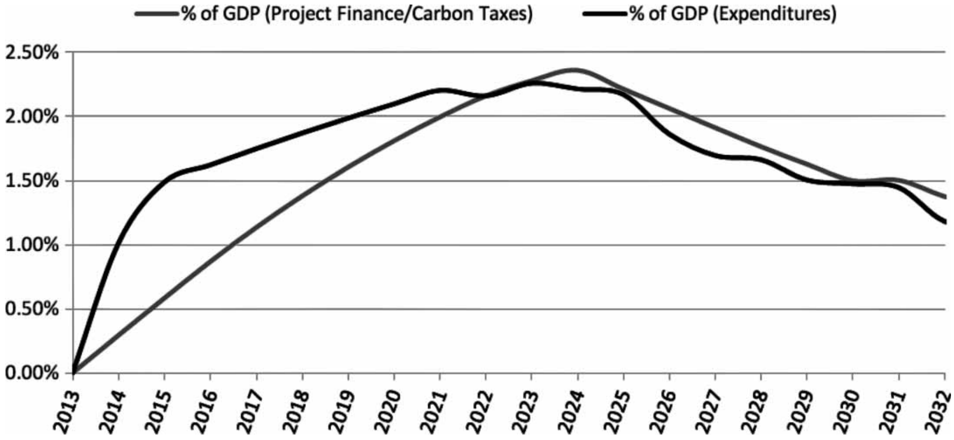

Figure 6 PF Case 2—expenditures as percentage of GDP *vs.* carbon taxes collected

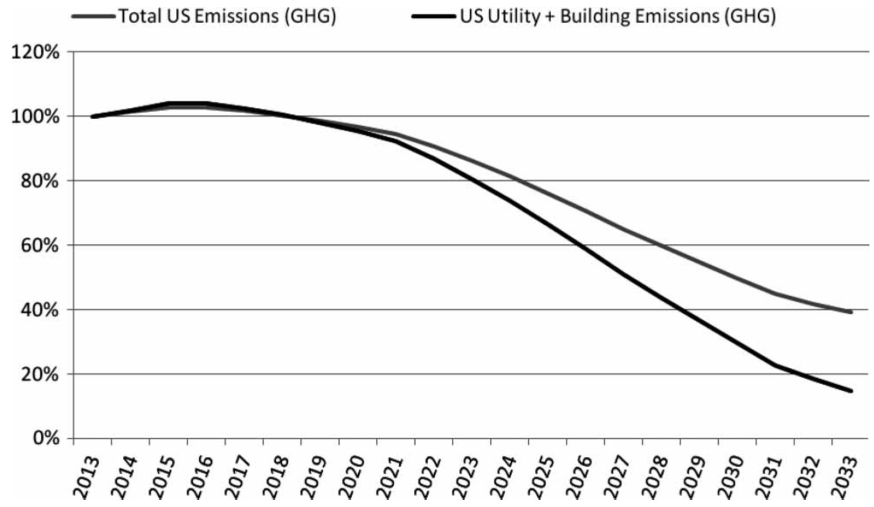

Figure 7 PF Case 2—declining total US emissions/utility and building emissions

to reduce emissions without providing any stimulus, then the base case would work.

Conclusion

By developing and building our new energy infrastructure based on nuclear and renewable power systems, we could ensure that we have the capacity to influence global events. In terms of future research, we could move forward with fuel cell- and electric-powered cars, thereby eliminating the future need to import oil. We could also use natural gas more efficiently, thereby freeing up our resources to potentially export to our friends and allies. In the process of reducing emissions, we could also create a more sustainable environment where the USA has a greater say in energy prices and significant energy imports no longer contribute to trade deficits and international debt.

In 2009, the leading global emitters met at Copenhagen to discuss reductions in global carbon emissions (National Resources Defense Council, 2009; Power, 2009). During this meeting, it was proposed that developed countries set aside $100 billion per year to assist developing nations to build clean power. Using the CTR and setting aside solely 15% of revenues raised on imported goods and services (a potential PF model for another paper) would fund 67.2 GW of new capacity for developing countries. This would represent 52% of African continent's current electric generating capacity (129.2 GW), and it would be low- to no-carbon power (EIA, 2010a, 2010b). A 50% allocation from taxes collected on imports could over the 20-year period fund 224 GW of new clean generating capacity, thereby replacing 'dirty' power plants in many countries of the world, and bring clean power to millions of people, especially once these funds are added to those from other countries that adopt this tax.

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