Carbon Pricing
Solution to Climate Crisis Caused by Carbon Dioxide Emissions

March, 2015

Milsa Vijayadharan
Global Energy Network Institute (GENI)
Milsadhaneep02@hotmail.com

Under the supervision of and edited by

Peter Meisen
President, Global Energy Network Institute (GENI)
www.geni.org
peter@geni.org (619) 595-0139

Table of Contents

1. Introduction 4
1.1 Greenhouse Effect 4
1.2 Carbon Dioxide (CO_2) 5
1.2 Solution to Climate Crisis Through Carbon Pricing 7
2. Combustion of Fossil Fuels 8
2.1 Combustion Energetics of Fossil Fuel**s** 8
2.2 Composition of Different Types of Fossil Fuels 9
2.3 Energy Content of Fossil Fuels 10
2.4 Carbon Dioxide Emission by Fuel Type 10
3. World Energy Consumption 12
3.1 Various Strategies for Pricing Carbon **13**
Carbon Tax 13
Carbon Fee and Dividend 16
Cap-and Trade 19
4**.** Factors to be considered in Developing a Carbon Pricing Pla**n** 23
4.1 Global Carbon Price 23
4.2 Revenue Neutral Carbon Pricing 23
4.4 Private investments in Clean Energy Technologie**s** 23
4.5 Combining Carbon Pricing with Supplementary Policie**s** 24
4.6 Midstream Carbon Pricing for Electricity 25
4.7 Carbon Pricing complimented by Biofuel Subsidy 25
4.8 G20 can Promote Action on Climate Change 26
5 Bibliography 27

Table of Figures

Figure 1: Enhanced Greenhouse Effect Natural and Human 5
Figure 2 Emissions of Greenhouse Gases Worldwide (1990 to 2005) 6
Figure 3: Increased CO_2 Emissions Since the Industrial Revolution 7
Figure 5: Composition of Crude oil 9
Figure 6: Composition of Coal 10
Figure 7: Energy Content of Fossil Fuel 10
Figure 8: Pounds of CO_2 Emitted Per million Btu of Energy for Various Fuels 10
Figure 9: World Energy Consumption by Source 2012 12
Figure 10:U.S Primary Energy Comsuption Estimates by source, 1950-2011 13
Figure 11: The Carbon Tax Cycle 15
Figure 12: Carbon Fee and Dividend 18
Figure 13: Cap-and-Trade 20

Abbreviations

CO_2: Carbon dioxide

G20: Group of Twenty leading economies

H/C: Hydrocarbon

KJ: Kilojoule

LGH: Liquefied natural gas

1. Introduction

1.1 Greenhouse Effect

Greenhouse effect is the process by which Earth is kept warm enough to sustain life. When sunlight reaches Earth's surface some of this energy is absorbed and rest is reflected back into space. Due the presence of greenhouse gases (GHG), this energy from the sun cannot freely leave the planet. Greenhouse gases, such as carbon dioxide (CO_2), Methane (CH_4), and Nitrous oxide (N_2O), water vapor traps some of the sun's heat before it can escapes into space. Greenhouse gases act as a blanket and keep the earth warm. Greenhouse effect can be sketched as follows:

Sun's Radiation → absorbed by Earth → some re-radiated to space as heat → some trapped by the atmosphere

The warming effect is intensified by the increase in the amount of greenhouse gases in the atmosphere. Since the industrial revolution began around 1750, greenhouse gas emissions have increased due to human activities, such as burning of fossil fuel. The increased greenhouse gas emissions contribute to a warmer climate causing many changes in the atmosphere around the world, on land and in the ocean. The process is called global warming. The figure below illustrates natural greenhouse effect and human enhanced greenhouse effect.

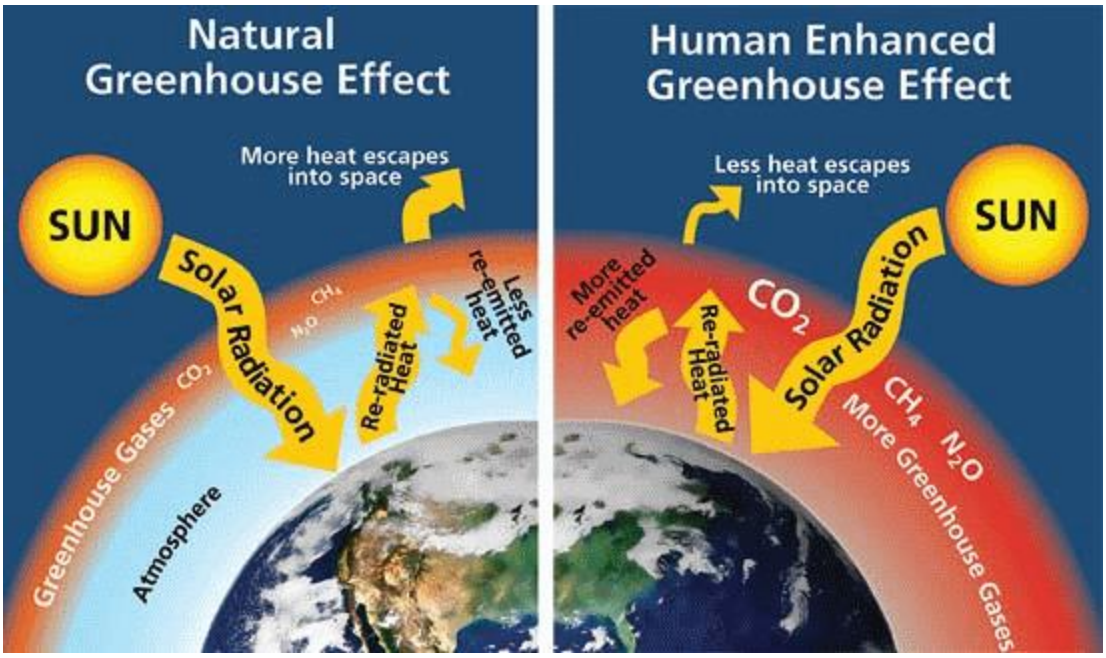

Figure 1: Enhanced Greenhouse Effect Natural and Human
Source: Will Elder, National Park Service

1.2 Carbon Dioxide (CO_2)

Carbon dioxide is one of the chief greenhouse gases responsible for global climate change. According to the Intergovernmental Panel on Climate Change carbon dioxide is the most important of the greenhouse gases increased by human activities.

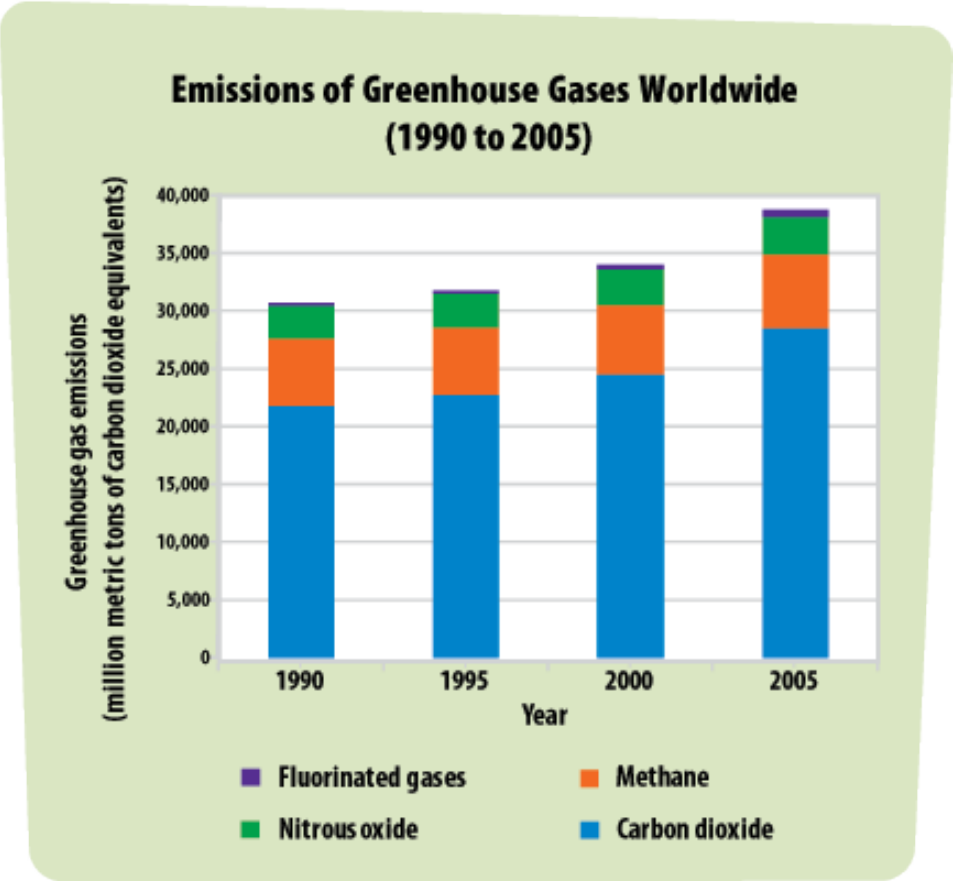

Figure 2 Emissions of Greenhouse Gases Worldwide (1990 to 2005)
Source: U.S Environmental Protection Agency**,** Climate Change Indicators (2012).

Carbon dioxide is produced mainly due to burning of fossil fuels, such as coal, oil and natural gas in cars, power plants and industries. Ice core samples taken from pre-industrial era shows that atmospheric carbon dioxide levels measured about 280 parts per million. The current carbon dioxide level in atmosphere is 400 parts per million.

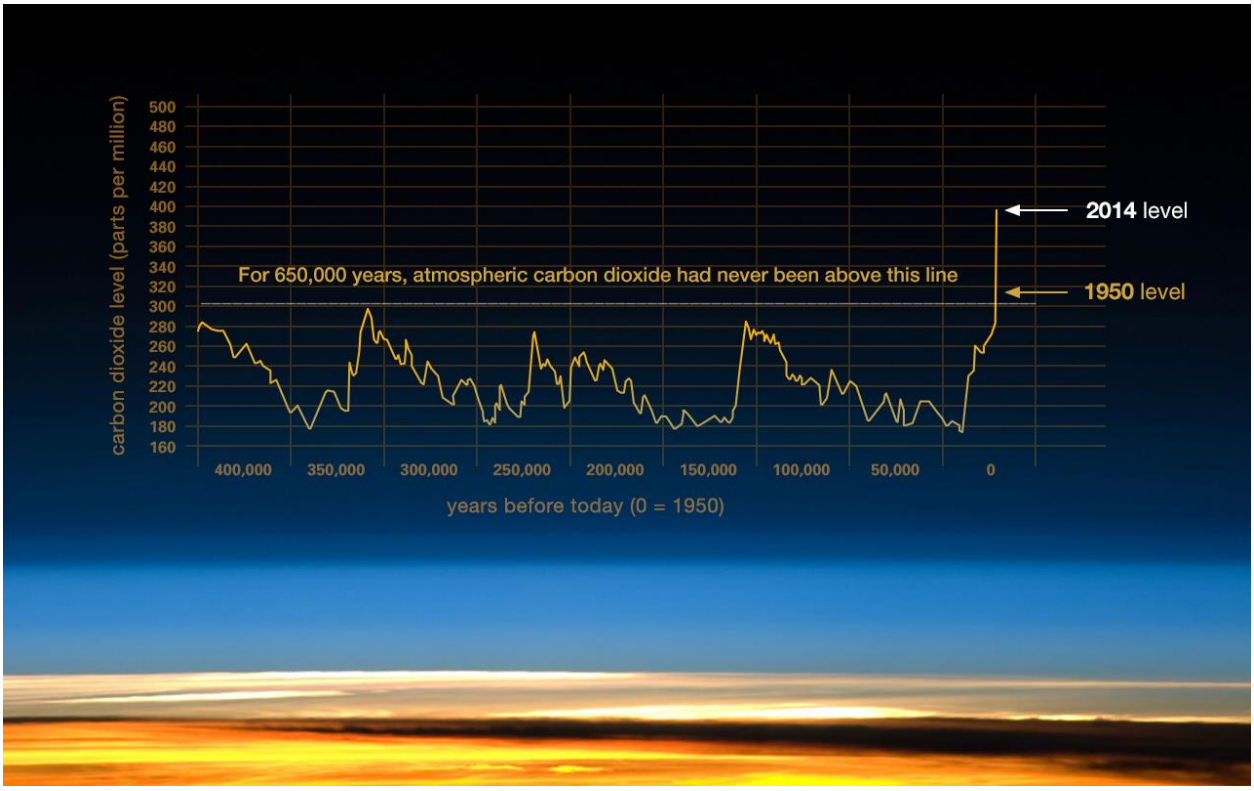

Figure 3: Atmospheric CO_2 Increases since the Industrial Revolution Based on Comparison of Atmospheric Samples of Ice Cores and Recent Direct Measurements
Source: NASA Global Climate Change, *Vital Signs of the Planet: Facts*/

1.2 Solution to Climate Crisis Through Carbon Pricing

Since CO_2 is the main greenhouse gas responsible for global warming, the most efficient way to halt it would be to reduce CO_2 emissions caused by human activities The preferred method to reduce human induced CO_2 emissions by most economists is to charge those who cause CO_2 emissions. The charge that must be paid to emit one ton of CO_2 into the atmosphere is called carbon price. CO_2 emissions imposes a cost on society, this social cost of carbon (SCC) is not reflected in the market price of the fossil fuels responsible for the rising CO_2 concentration in the atmosphere. A carbon pricing system to account for the damage caused by the emissions will discourage use of fossil fuels.

2. Combustion of Fossil Fuels

Combustion is a reaction of fossil fuels with oxygen. This is the burning process. Fossil fuels are composed mainly of hydrocarbons (molecules containing primarily carbon hydrogen bonds). During the combustion reaction, hydrocarbon molecules are converted into carbon dioxide and water. Energy is released as heat during this reaction. In other words, energy is first absorbed to break carbon-hydrogen or carbon-carbon bonds of the hydrocarbon and then energy is released when carbon and hydrogen combines with oxygen to produce carbon-oxygen and hydrogen-oxygen bonds forming carbon dioxide and water. The difference in energy absorbed during bond breaking and bond making equals the amount of heat released during a combustion reaction.

Combustion reaction of methane: $CH_4 + 2\ O_2 = CO_2 + 2\ H_2O$

Combustion of 1 mole of methane releases 810 KJ of energy.

2.1 Combustion Energetics of Fossil Fuels

The amount of energy released depends on the number of hydrogen atoms attached to the carbon in the hydrocarbon, the more hydrogen per carbon in a hydrocarbon the lower the oxidation state and the more energy will be released during the combustion reaction.

Hydrocarbons can be divided into following categories:

- **Saturated:** Saturated hydrocarbons contain only single bonds between all carbon atoms.
- **Unsaturated:** Unsaturated hydrocarbons have double or triple bonds between carbon atoms, so the number of carbon-hydrogen bonds is lesser in unsaturated hydrocarbon as compared to saturated hydrocarbon. The carbon is in more oxidized state in an unsaturated hydrocarbon, combustion of unsaturated hydrocarbon produces less energy meaning that to produce the same amount of energy, more unsaturated hydrocarbon must be burned releasing more carbon dioxide into the atmosphere.
- **Aromatics:** Aromatic hydrocarbon molecules have a specialized ring structure where bonds between carbon atoms are an intermediate between single and double bonds. The carbon to carbon bond energy of the aromatics is very high.

H/C Ratio of Different Fossil Fuels

Energy Source	H/C Ratio
Natural Gas	4/1
Petroleum	2/1
Coal	1/1

2.2 Composition of Different Types of Fossil Fuels

Hydrocarbons

- **Natural gas:** Natural gas primarily consists of methane. In a molecule of methane, one carbon atom is attached to four hydrogen atom; H/C ratio is 4/1 in methane.
- **Petroleum:** Petroleum has large hydrocarbon content. Petroleum molecule consist of multiple CH_2, units, H/C ratio is 2/1

Composition of Crude Oil

Element	Percent Range
Carbon	83 – 85%
Hydrogen	10 – 14%
Nitrogen	0.1 – 2%
Oxygen	0.5 – 1.5%
Sulfur	0.5 – 6%

Figure 4: Composition of Crude Oil
Source: The Encyclopedia of Earth, *Petroleum Crude Oil*

Coal

Coal is composed primarily of carbon along with hydrogen, sulphur, oxygen and nitrogen. Low ranked coal, such as peat and lignite, has low carbon content. For example, peat has only 20-25% carbon. High rank coal, such as bituminous coal, has higher carbon content. For example, that is 65-85% carbon. So, the combustion of bituminous coal results in higher CO2 emission as compared to low rank varieties.

Composition of Coal

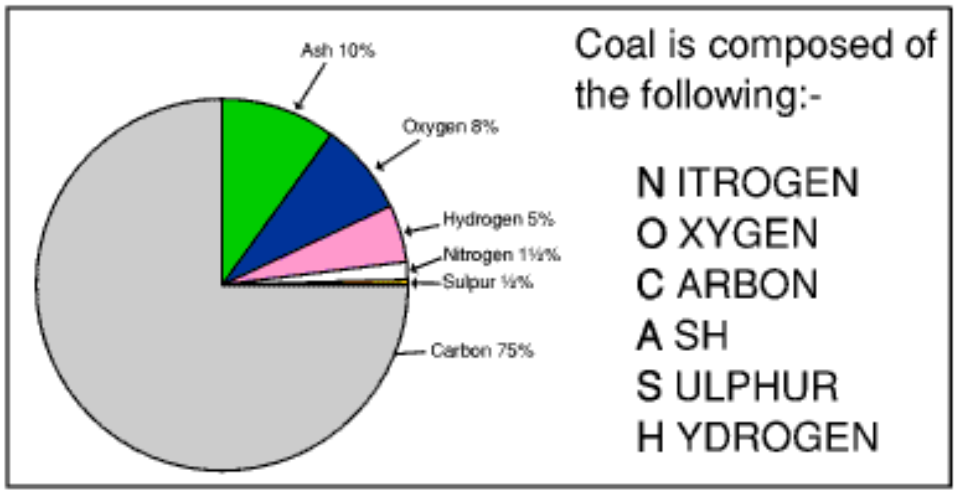

Figure 5: Composition of Coal
Source: Northampton and Lamport Railroad – MIC: *Fuel and Combustion*

2.3 Energy Content of Fossil Fuels

	H/C ratio	Energy Content (KJ/g)	CO_2 Released (mol/10^3 KJ)
Natural gas	4/1	51.6	1.2
Petroleum	2/1	43.6	1.6
Coal	1/1	39.3	2.0

Figure 6: Energy Content of Fossil Fuel
Source: Western Oregon University, *Energy from Fossil Fuels*

The energy content of coal is lowest compared to natural gas and petroleum.

2.4 Carbon Dioxide Emission by Fuel Type

Fuel Type	CO_2 Emission	Fuel Type	CO_2 Emission
Coal (bituminous)	205.7	Diesel fuel & heating oil	161.3
Coal (lignite)	215.4	Gasoline	157.2
Coal (subbituminous)	214.3	Propane	139.0
		Natural Gas	117.0

Figure 7: Pounds of CO2 emitted per million Btu of energy for various fuels
Source: U.S. Energy Information Administration.

Energy efficiency of fossil fuels is inversely proportional to its carbon dioxide emission.

Energy efficiency of different fossil fuels: Natural gas > Petroleum > Coal

Carbon dioxide emission by different fossil fuels: Coal > Petroleum > Natural gas

3. World Energy Consumption

Today, the world depends mainly on fossil fuels to satisfy its energy demands. Oil, coal and natural gas account for 33%, 30% and 24% respectively of the total consumption. Only 9% of energy comes from renewable sources.

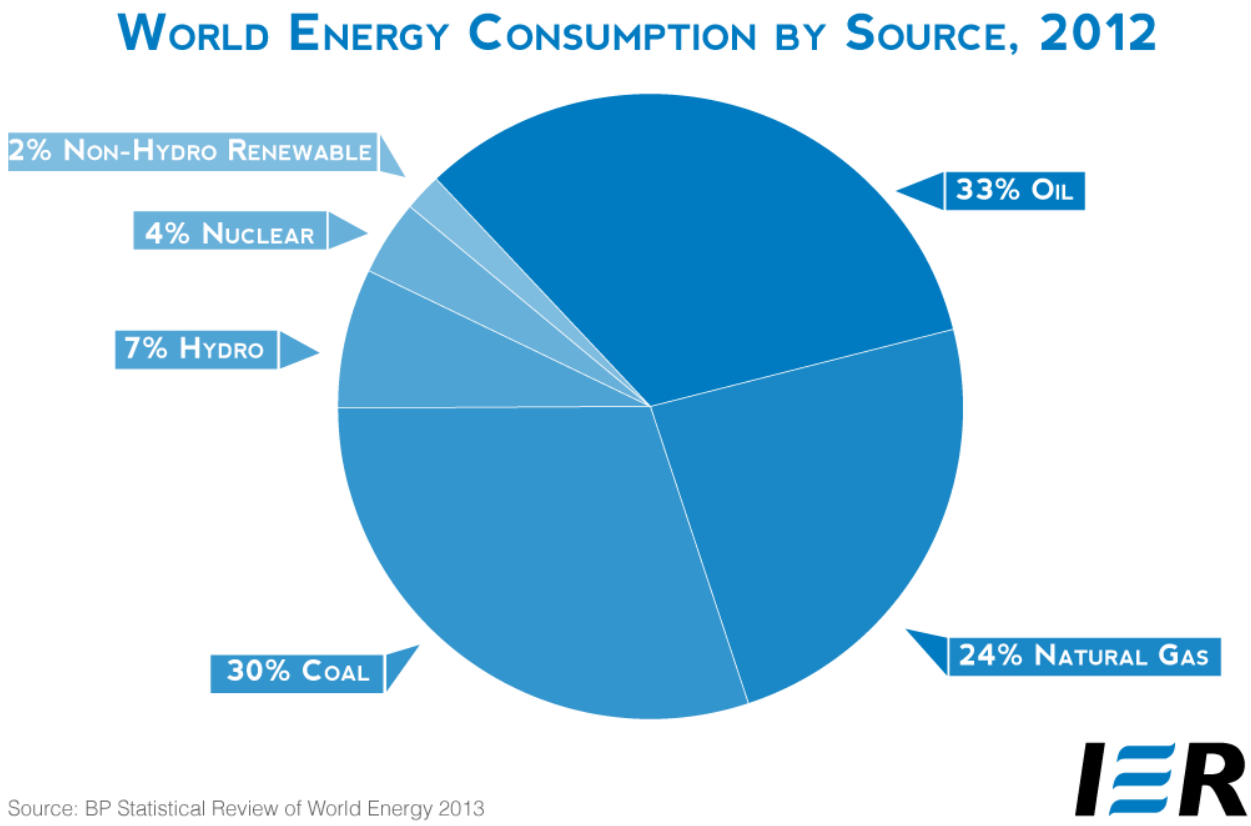

Figure 8: World Energy Consumption by Source – 2012

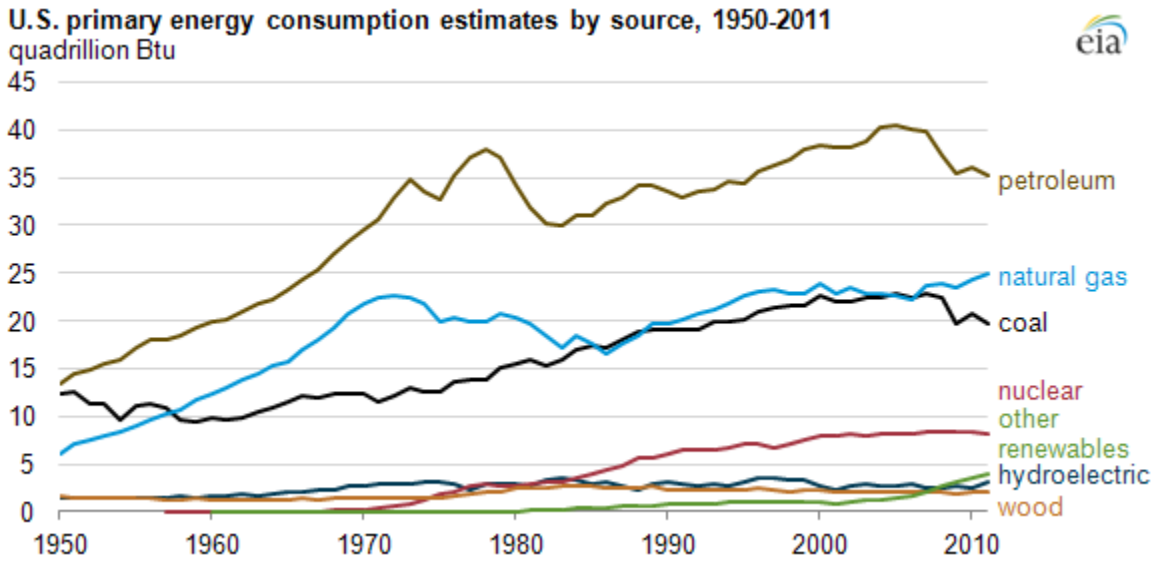

Figure 9:U.S Primary Energy Consumption Estimates by source, 1950-2011
Source: U.S. Energy Information Administration, Annual Energy Review

3.1 Various Strategies for Pricing Carbon

Depending on each country's circumstances and priorities, different strategies can be used to price carbon.

Carbon Tax

The carbon tax is a form of carbon pricing. It is a tax levied on the carbon content of the fuels and can be used to achieve reductions in CO_2 emissions. The revenue collected from the tax can be returned to the public to protect them from the rising cost associated with the carbon tax. A carbon tax can begin at a low value and increase each year. The idea is that polluters will pay for each ton of carbon they release into the atmosphere. The carbon tax is a type of pigovian tax which is a tax applied to a market activity that is generating negative externalities -- the cost suffered by the society. A good or process has a negative externality if the cost to society is greater than the cost consumer is paying for it. This market failure can be corrected by setting a pigovian tax equal to negative externalities. Burning of fossil fuels releases large amount of CO_2, which is associated with global warming and adverse climate impacts that are borne by society. The cost of these impacts on society is not included in the price of fossil fuels. A carbon tax will help to include these costs in the market price of fossil fuels. It can be done in several ways:

- **Upstream:** The upstream carbon tax on fossil fuel is applied when the fuel enters the economy; for example, at Coal mine mouth, gas wellhead, refineries, and port of

entry. Such a tax would be based on the carbon content of the fossil fuel. The advantage is that the number of sources directly subjected to tax will be minimized.

- **Midstream:** A midstream carbon tax is applied at the point of production, for example, at the power plant.
- **Downstream:** A downstream carbon tax is applied at the point of consumption. Then Implementation of downstream carbon tax is difficult due the large number of emission sources.
- **Combined approach:** The combined approach or hybrid strategy covers emissions from different sectors in a different manner. For example, transportation fuel could be taxed upstream at the point of extraction or midstream at the refinery. Coal could be taxed downstream at the power plants and specific industrial sectors.

In a revenue neutral carbon tax scheme, all the revenue collected from the tax is returned directly to the taxed economy, either through an equivalent reduction in other existing taxes like personal income and business income tax cuts or through direct payments to taxpayers in the form of rebate checks. Depending on the structure used, the carbon tax scheme can be referred as "revenue-neutral carbon tax" or a "carbon tax shift" or a "carbon fee and dividend."

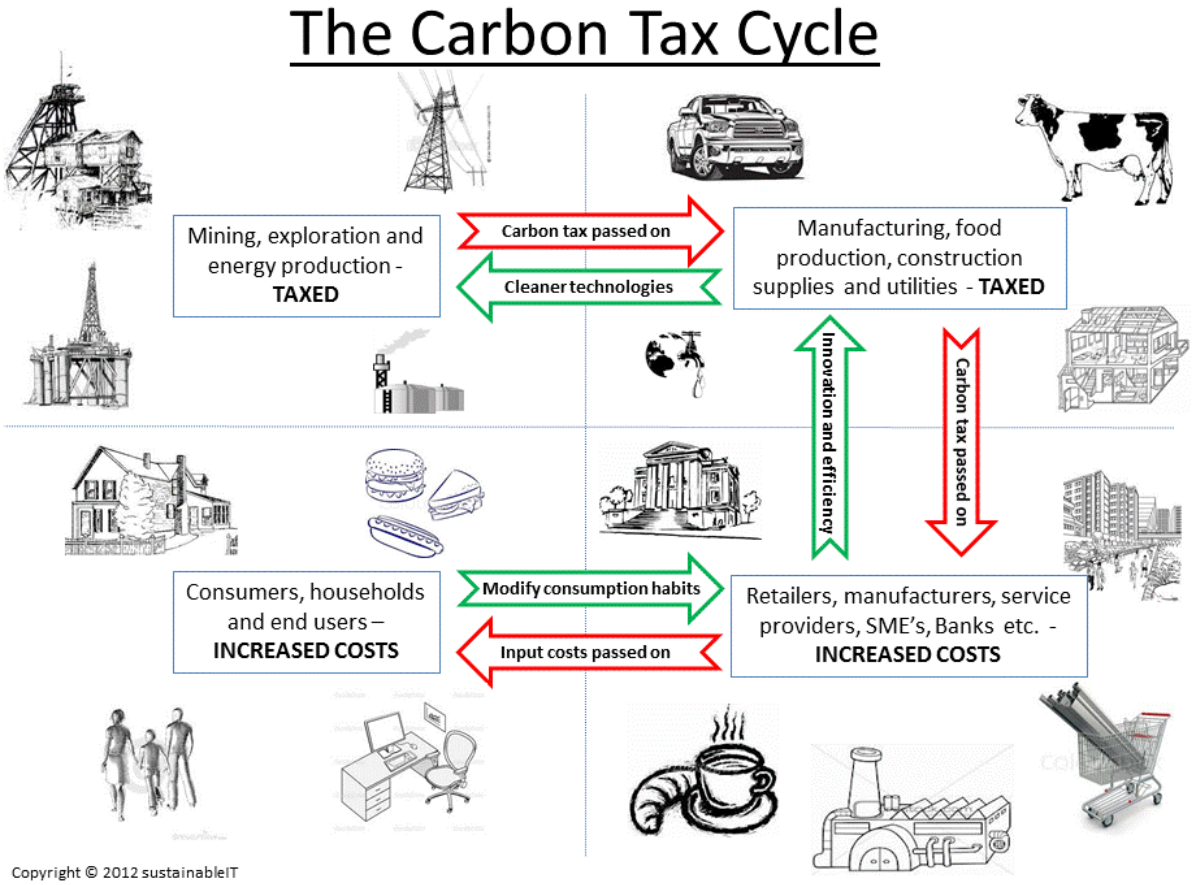

Figure 10: The Carbon Tax Cycle
Source: *The Carbon Report*

British Columbia's Carbon Tax

British Columbia implemented a revenue neutral carbon tax in July 1, 2008. British Columbia's carbon tax started at C$10 a ton of CO_2 emissions on 2008 and increased to it by C$5 each year until it reached $30 a ton of CO_2 in 2012. That is equivalent to 7 cents per liter or 25 cents per gallon of fuel. The tax has stayed at $30 a ton of CO_2 since 2012. Currently, British Columbia's government levies a fee of 30 Canadian dollars for every metric ton of carbon dioxide equivalent emissions resulting from burning fossil fuels including gasoline, diesel, natural gas and coal. BC's carbon tax is designed to be revenue neutral:

- Personal income taxes were reduced.
- Corporate and small business taxes were reduced.
- Low income households receive lump sum transfers,

All British Columbia residents receive **Climate Action Dividend** check and a **low income climate action tax credit** was introduced to offset the impact of carbon taxes paid by low income individuals or families. The carbon tax also helps people save lot of money by changing their habits like driving less or buying fuel efficient vehicles.

BC now has lowest personal income tax rate in Canada and one of the lowest corporate tax rates in North America. Fossil fuel consumption of BC and greenhouse gas emission of BC has decreased. Since the carbon tax came in BC fossil fuel use has dropped by 16%. GDP is up compared to rest of Canada.

The carbon tax has helped change the way people use energy in BC, it increased the awareness about climate change and the need to reduce carbon dioxide emissions.

Pros and Cons of Carbon Tax

Pros

- Carbon dioxide emissions will be reduced; polluters will be required to pay a high amount of tax.
- Energy efficient engines will be encouraged that does not emit large amount of carbon dioxide.
- Electrical power plants will be encouraged to use green sources to produce electrical energy.

Cons

- Businessman will move their business to other countries which do not promote carbon tax.
- Higher tax payment will encourage people to produce carbon dioxide secretly.

Carbon Fee and Dividend

Carbon Fee and Dividend is a policy proposal created by Citizens' Climate Lobby. Carbon Fee and Dividend imposes a progressive fee on carbon emission. An initial fee of $15/ton on the CO_2 content of fossil fuel shall be imposed. The fee shall be imposed upstream at the point of extraction and collected at the point where they enter the economy. This mechanism is designed to be revenue neutral, all the fees collected is returned to households. 100% of the revenue collected from carbon fee will be held in a Carbon Fees Trust Fund and returned to households

as monthly dividend. If this policy is enacted people may receive more money than they will pay for increased energy costs.

Citizen's Climate Lobby advocates a border adjustment by imposing a fee on all the products imported from countries where there is no carbon fee, along with that industries exporting goods to such countries shall be receive rebate to create a fair competitive environment. This will motivate other countries to adopt similar carbon pricing system.

A study from REMI shows that a Carbon Fee and Dividend will reduce the CO_2 emissions by 50% in 20 years. The revenue collected will create economic stimulus and will add more jobs. Carbon fee and Dividend with 100% revenue return will create over two million jobs within nine years and there will be an increase in employment in labor intensive industries.

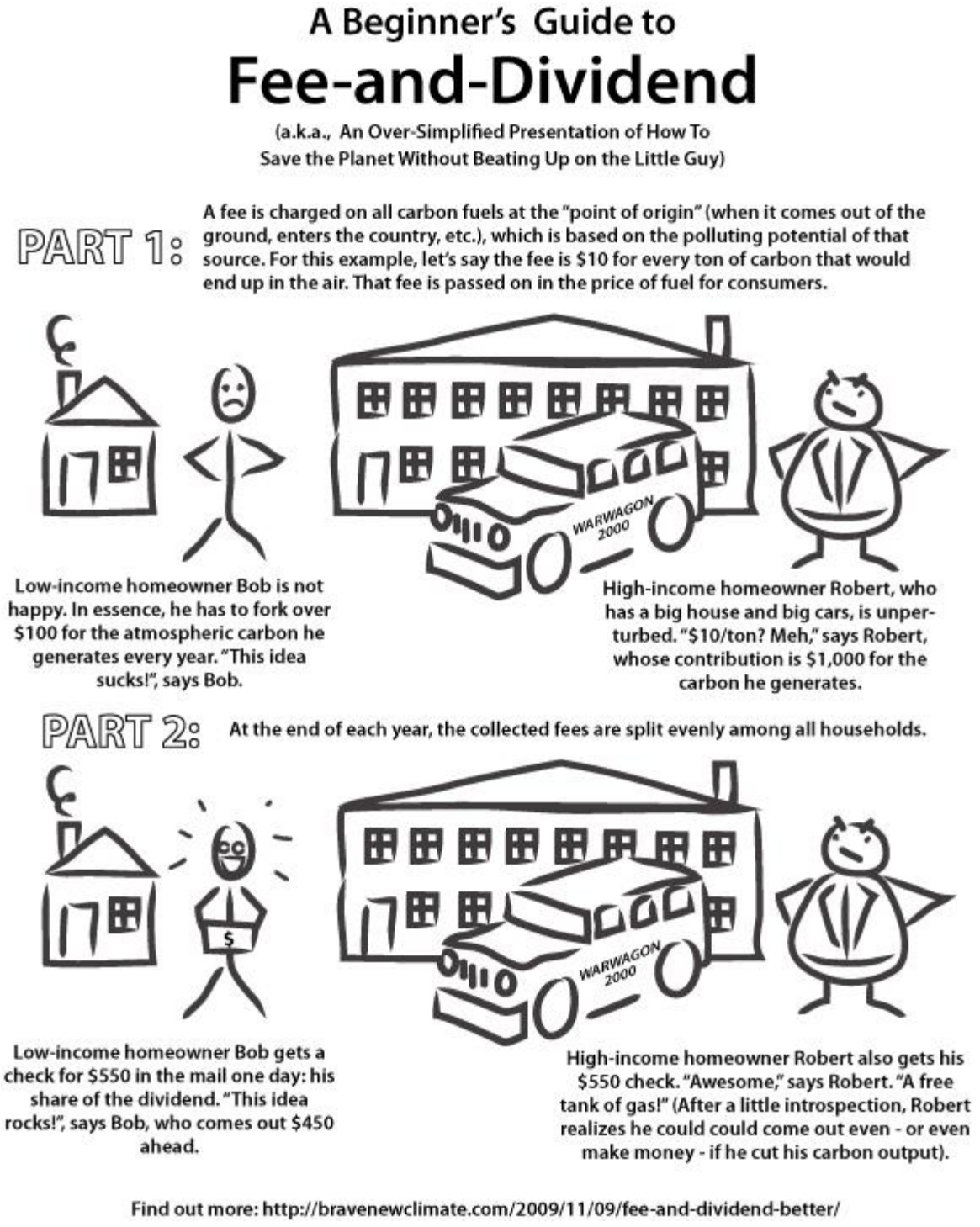

Figure 11: Carbon Fee and Dividend
Source: *DemocraticUnderground.com*

Pros and Cons of Carbon Fee and Dividend

Pros

- Carbon Fee and Dividend is a simple and transparent approach to put a price on carbon emissions.
- Firms trying to relocate to other counties which do not have a carbon fee will be discouraged as their products will be subjected to import fees.
- The dividend will increase income.
- Households will be free to make choices about their energy usage and a demand for low-carbon products will be created.
- Investments in alternative energy will be motivated.

Cons

- Investors in energy companies may lose share value.
- The rate of job growth in the areas heavily dependent on fossil fuel extraction and processing may slow down.

Cap-and Trade

Cap is the limit on CO_2 emissions which is lowered over time to reduce the amount of CO_2 released into the atmosphere. Under cap and trade system companies are allowed to trade (or sell) their unused limit to other companies that are struggling to reduce emissions or failing to comply. In this system, the governing body will set a cap on allowable emissions. Emission allowance is then distributed or auctioned that total the cap. Companies that do not have enough allowance will reduce emissions or buy allowance from companies that have unused allowances. Companies with extra allowance can sell or bank them for future use.

The cap must be strict but feasible to reduce emissions over time. If the cap is set too high then this scheme will not be effective in reducing emissions. If the cap is set too low then the allowances will be overpriced. If the price of allowance is too high then additional credits can be released to stabilize the price.

The cap-and-trade system is based on the argument that it is easier to control emissions if government is not telling polluters how to clean up their act. Instead, polluters are given chance to make a profit by being smarter. When a cap on emission is imposed, each company starts the

year with a certain number of allowances. The company can decide how to use its allowance, it can switch to cleaner fuels, or restrict output, or buy a scrubber to cut emissions. If it doesn't use up all its allowance, the company can make money by selling extra allowance. Each year cap will be lowered and the allowance will get costlier.

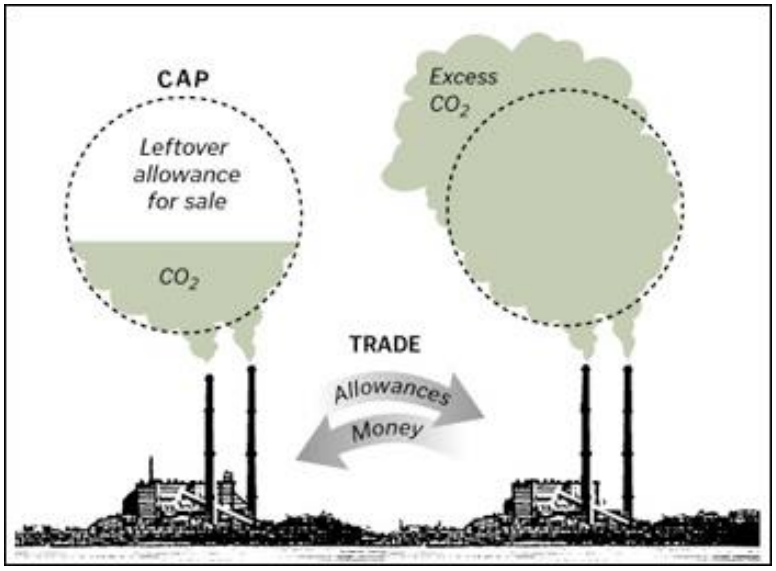

Figure 12: Cap-and-Trade
Source: *First carbon solutions*

California Cap-and-Trade Program

On September 27, 2006, California enacted the *Global Warming Solution Act* (AB 32) to reduce California's greenhouse gas emissions to 1990 levels by 2020. This roughly represents a reduction from 507 to 427 million metric tons of CO_2 equivalent. To achieve a reduction in emissions AB 32 authorized California Air Resources Board (CARB) to establish a market based cap-and-trade regulation. California's cap-and-trade program officially began on January 1, 2013. A cap with a specific number of allowances is set forth. Allowances are either given for free or sold at auction to regulated businesses by the state. The total number of allowances distributed every year decreases, California's cap declines every year. For example, from 2013 to 2014, from first to second year the cap, carbon was reduced by 3 million metric tons of emissions. This cap-and-trade program in California now covers fuel retailers. Fuel retailers can either purchase permits for the carbon emissions or switch to low carbon fuels.

Certain industries are caped under this cap-and-trade program – electricity suppliers, large industrial sources and transportation fuel providers. Auctions for allowances are held quarterly,

The California Air Resources Board held eight jurisdiction specific quarterly greenhouse gas emissions allowance auctions between November 2012 and August 2014. The success of these auctions is the evidence that the California Cap-and-Trade Program is well-constructed, strong and adaptive policy.

In a comprehensive analysis report of California's Cap-and-Trade Program by the Environmental *Defense Fund* shows that in the five auctions of 2013 vintage allowances, every allowance available for sale was purchased. This shows a healthy interest from market participants. Across all five auctions of 2013 vintage allowances there have been 142 unique qualified bidders, 40 companies have registered for four out of five auctions and 33 companies have registered for all five auctions.

On January 1, 2014, the California Cap-and-Trade Program and Quebec Cap-and-Trade System were officially linked and California Air Resources Board and Quebec Ministry of Sustainable Development, Environment and the Fight against Climate Change will hold joint greenhouse gas allowance auctions. The first joint Cap-and-Trade auction will be held on November 19, 2014.

Pros and Cons of Cap-and –Trade

Pros

- Most supporters believe that carbon cap-and-trade is the fastest and cost effective way to reduce regional emissions.
- Cap-and-trade provides a certainty about the quantity of emissions as it cannot exceed the cap.
- Companies that can reduce their emissions at low cost can do so and sell their extra allowances to companies who cannot reduce their emissions.
- By auctioning emission credits, government can make profit and the increased governmental revenue can be used to develop energy efficient alternatives or to make energy more affordable to low income families.

Cons

- By allowing companies to trade emission allowances, heavy polluters will postpone expensive changes required to meet future emission standards.

- With cap-and-trade permits are given for free initially, this is known as grandfathering. It is not good for society as it deprives government of valuable revenues.
- Trading will allow companies who have been polluting to continue because it is possible to purchase cheap offset or carbon credits instead of switching from fossil fuels to renewable energy.

4. Factors to be considered in Developing a Carbon Pricing Plan

4.1 Global Carbon Price

A uniform global carbon price based on the principle that the polluters pay will be a cost effective way to reduce greenhouse gas emissions. A global carbon price would encourage businesses to adjust their investments and innovations towards renewable energy technologies and would also encourage people to spend less on high carbon products.

4.2 Revenue Neutral Carbon Pricing

All the revenue collected from carbon pricing should be returned to taxpayers to protect them from rising energy costs. Revenue collected can be returned to citizens through dividends, rebates and/or reducing other taxes. This feature will protect households from rising energy costs, inject billions into the economy; spur innovation; allow people to make independent choices about energy usage; and create demand for low carbon products at consumer level.

4.3 Border Tax Adjustments

A tax should be levied on imported goods, based on the emissions associated with their production. Consumers will pay for the carbon associated with the goods they purchase, regardless of where the goods where produced. This will encourage consumers to buy low carbon substitutes. Industries should receive rebates for exporting to countries without carbon pricing. This will prevent firms from escaping to non-compliant nations to avoid high energy costs because their products will be subjected to import fees.

4.4 Private investments in Clean Energy Technologies

Private investors are uncertain about the adoption of new technology because they are unable to accurately predict the future cash flow from their investment. They tend to invest in less risky projects where cash flows are more predictable. Carbon pricing can change the end market for renewable energy. Carbon pricing will favor renewable energy technologies that are already in commercial scale. For early stage technologies, alternative fiscal renewable energy policies are required to reach commercial scale. Carbon pricing, along with technology-specific renewable energy policies such as feed-in tariffs, direct investment, tax exemptions, accelerated depreciation rates and renewable energy standards, will guarantee renewable energy investors an end market for their product.

4.5 Combining Carbon Pricing with supplementary Policies

Carbon pricing will discourage the use of fossil fuels and encourage the development of renewable sources of energy and encourage low carbon choices. A well designed carbon pricing system can correct the market failure to account for the pollution caused by fossil fuel combustion, but it must be supplemented by other policies. Carbon pricing alone will not ensure the deployment of existing and new improved renewable energy technologies. A set of complimentary energy policies are required to avoid dangerous climate change impacts.

Best Renewable Energy Policies

- **Feed-in tariff (FIT)** - Feed-in tariff is a policy mechanism designed to encourage investments in renewable energy technologies. Under this scheme, people who install an electricity generating system from renewable sources, such as roof-top solar photovoltaic system, wind turbines etc., are eligible to get paid for the electricity they generate from the utility even if they use it themselves and provide surplus electricity to the grid. The pay or compensation given to renewable electricity producers for the electricity provided to the grid depends on the cost of generation of each technology (for example solar PV tends to receive higher rates than other technologies). Most U.S contracts are long term (10 – 20 years) which assures the owners of a stable long term revenue stream.
- **Renewable Portfolio Standard (RPS):** The Renewable Portfolio Standard program, also known as Renewable Electricity Standard, requires electricity supply companies to produce certain amount of energy from renewable energy sources, such as wind, solar, biomass and other alternatives to fossil and nuclear electric generation. RPS mandates will enable increase in generation of electricity from renewable sources. RPS program has been adopted in 33 U.S states and District of Columbia. RPS is most successful in stimulating renewable energy projects when combined with the federal production tax credit. RPS programs vary from state to state in terms of eligible resources and technologies, program structure, enforcement mechanisms and application. There has been an increase in the amount of electricity generated through renewable resources over the past few years due to availability of federal tax incentives and state RPS programs.

- **Net Metering:** Net metering is a policy designed to encourage private investments in renewable energy. Net metering allows solar energy system owner receive credits for the extra electricity they add to the grid.
- **Financial Incentives-** Grants, loans, rebates, and tax credits are provided in some states to encourage renewable energy development.

4.6 Midstream Carbon Pricing for Electricity

Coal is considered to be the dirtiest fossil fuel. Coal provides 40% of the world's electricity needs. It is the first source of electricity generation. Coal creates more pollution the than oil, natural gas and gasoline when burned. Energy content of coal is less compared to petroleum and natural gas (refer to Section 2); so, to produce same amount of energy more coal has to be burned compared to other fuels. Pounds of CO_2 emitted per million Btu of energy by coal is higher than other fuels (refer to Section 2). By reducing the use of coal amount of carbon dioxide emitted into the atmosphere can be drastically reduced. Dramatic policy action is needed to stop the increasing use of coal. By putting a price on carbon dioxide emissions and increasing it every year will persuade utilities to shift from coal to renewable energy sources.

A Midstream Carbon Pricing System for electricity is placed at the point of production making power plants pay for each ton of carbon dioxide they emit. A midstream carbon tax or a cap-and-trade with a ceiling price will be a good regulatory approach to reduce the use of coal for electricity generation. Carbon pricing supplemented with renewable energy policies will result in successful deployment of renewable energy technologies and enable shifting the flow of finance from high carbon coal to clean renewable energy sources.

4.7 Carbon Pricing complimented by Biofuel Subsidy

The transportation sector accounts for about 30% of total emissions in United States, thus reducing emissions from the transport sector is crucial to reduce overall emissions. Biofuels have lower carbon intensity compared to gasoline, so carbon emission can be reduced by increasing the amount of biofuels used in transport sector. Biofuel subsidy can reduce the emission by displacing gasoline by biofuels. Biofuel subsidies can be complimented by a fuel carbon pricing system and the revenue collected can be used to finance biofuel subsidy. A carbon price on transportation fuel will reduce driving and encourage shift to biofuels.

Effect of Carbon Pricing on Natural Gas Use

Natural gas is less carbon intensive fossil fuel (refer to section 2). For a low carbon price, natural gas is likely to replace coal and oil. As the price increase gradually natural gas may be displaced by renewable energy as power plants fueled by renewable energy do not emit carbon dioxide. Increased domestic natural gas production will help in reducing carbon dioxide emissions but exporting natural gas will have opposite effect. Exporting LNG requires liquefaction, transport and then re-gasification, which is a highly energy intensive process. LNG export is 15% more energy intensive than natural gas produced and consumed domestically. LNG export is also associated with greater upstream emissions of fugitive methane and carbon dioxide. New policies and technology will be required to prevent accelerated warming by fugitive methane from increased natural gas use internationally.

4.8 G20 can Promote Action on Climate Change

The G20 has proved to be the most effective forum for international economic cooperation and decision making. It can serve as an effective forum for global economic governance. The G20 countries are responsible for 80% of global greenhouse gas emissions. If all the G20 countries decide to respond to climate change and unsustainable use of natural resource, an environmentally safe transformation of world economy is possible. All G20 countries should commit to end support for fossil fuels and invest in renewable energy and energy efficiency. Poor countries need funding so that they can make a low pollution pathway to development, G20 finance ministers should develop a climate finance roadmap.

5 Bibliography

Archived Auction Information and Results, *Air Resources Board, California Environmental Protection Agency,* Retrieved November 6 2014
http://www.arb.ca.gov/cc/capandtrade/auction/auction_archive.htm

EPA, "A Students Guide to Global Climate Change", Retrieved September 25, 2014
http://www.epa.gov/climatestudents/basics/today/greenhouse-gases.html

Hsia-Kiung, Katherine; Reyna, Emily; O'Connor, Timothy. "Carbon Market California*" A Comprehensive Analysis of Golden State's Cap-and-Trade Program* Year One 2012-2013. Environmental Defense Fund, Retrieved October 28 2014
http://www.edf.org/sites/default/files/content/ca-cap-and-trade_1yr_22_web.pdf

Jenkins, Jesse. "When Politics Constraints Carbon Pricing, Part 2: 6 Tips for Improving Climate Change Policy", *The Energy Collective*, July 24 2014, Retrieved December 28 2014
http://theenergycollective.com/jessejenkins/442661/politics-and-climate-policy-part-2-how-improve-politically-constrained-carbon-pr

Mooney, Chris. "Here's why B.C.'s Carbon Tax is Super Popular – and Effective," *Climate and Energy*, March 27 2014, Retrieved October 12 2014 http://grist.org/climate-energy/heres-why-b-c-s-carbon-tax-is-super-popular-and-effective/

NASA, "Global Climate Change: Vital Signs of the Planet", Causes, Retrieved September 15, 2014 http://climate.nasa.gov/causes/

"The G20 and Climate Change", WWF Australia, Retrieved January 5 2015
http://www.wwf.org.au/news_resources/g20/

U.S. Energy Information Administration, *Today in Energy*, Retrieved October 8, 2014
http://www.eia.gov/todayinenergy/detail.cfm?id=9210

Western Oregon University, The College of Liberal Arts and Sciences, Energy From Fossil Fuels.htm, Retrieved October 4, 2014
https://www.wou.edu/las/physci/GS361/Energy_From_Fossil_Fuels.htm