ENERGY POLICIES FOR CARBON DIOXIDE EMISSION REDUCTION

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Keywords: Fossil fuels combustion, carbon dioxide, CO_2 emissions, reduction measures, national policy instruments, international cooperation mechanisms

Contents

Summary

Energy policies for carbon dioxide emission reduction aim to reduce the rate of fossil fuels combustion by diminishing the carbon intensity and energy intensity associated with electricity, heat, and fuels production and consumption and by reducing the demand for energy and transport services originating from fossil fuel burning.

A wide range of technical and non-technical measures is currently available for such reductions. Energy supply-side measures reduce carbon emissions directly from the stages of electricity and heat production, as well as fuels burning in transport vehicles. Energy demand-side measures abate emissions indirectly by inducing lower rates of energy consumption in the industrial, residential/commercial, and transport sectors, as well as reducing demand for energy and transport services.

Five groups of national policy instruments are available for the implementation of these measures: government designed and implemented projects, direct regulations—standards, licenses, and bans; economic instruments—taxes, subsidies, emission trading, and deposit refund systems; information and communication policies; and voluntary agreements. The 1997 Kyoto Protocol has also provided for the possibility to improve the cost efficiency of emission reduction at the international level by means of three cooperation mechanisms: joint implementation projects, clean development mechanisms, and international emission trade in the form of quotas or permits. Each

category of measures for emission reduction can be implemented through a certain set of policy instruments and mechanisms, some of which can be simultaneously deployed while others are less or non-compatible and require a selection to be made.

Policy instruments and mechanisms have different emission reduction effectiveness, cost efficiencies, innovation stimulation potential, and impacts on the international competitiveness of economic actors, and this will influence their selection in energy policy packages. In addition, the composition and stringency of national energy policies will depend on the technical and economic potential to achieve emission reductions domestically, the presence and level of targets, and the extent to which social and economic policies are developed to control population and economic growth.

1. Introduction

This article offers a comprehensive view of the measures that can lead to the reduction of energy-related carbon dioxide (CO_2) emissions as well as the national policy instruments and international mechanisms that can induce their implementation. The measures presented pertain to the reduction of carbon intensity, energy intensity, and demand for energy services and transport services associated with the activities of fossil fuels combustion and energy consumption. The article discusses the types of policy instruments governments may choose from in the design of national energy policy packages and the international cooperation mechanisms that could be used to complement the national efforts for emission reduction.

At the same time, the groups of measures that may be expected to be implemented under each policy instrument and mechanism are mentioned. Finally, the possibilities to combine the different national policy instruments are discussed and a brief overview is offered in terms of their relative environmental effectiveness, cost efficiency, innovation stimulation potential, and impacts on international competitiveness of affected economic actors. The article concludes with some general considerations on the role that energy polices may play in climate change abatement.

2. Sources of Carbon Dioxide Emissions and Focus of Energy Policies

The main anthropogenic sources of CO_2 emissions are fossil fuels combustion, industrial processes, and land-use change represented in the first column of Table 1. Fossil fuels are responsible for CO_2 emissions both directly—through the combustion of fuels—and indirectly—through the consumption of secondary forms of energy. The activities resulting directly in CO_2 emission release are the production of electricity and heat, and the combustion of fuels in non-electric transportation such as road, air, and water-based transport. The activities and technical entities that use energy in its secondary form—electricity or heat—can be grouped into three consumption sectors: the industrial sector, the residential/commercial sector, and the electric-transport sector.

The industrial sector is generally considered as including manufacturing, agriculture, forestry, and mining activities. The residential and commercial sector refers to buildings and facilities of commercial entities. The electric-transport sector includes rail and urban electric public transport. But certain industries are also direct sources of CO_2

emissions. The main industrial processes generating CO_2 emissions are the production of lime and cement, aluminum, coke and iron, hydrogen, and ammonia for fertilizers. The change in land-use patterns also constitutes an anthropogenic source of CO_2 emissions, especially through deforestation.

Activities generating CO_2 emissions directly		**Consumption sectors**
Fossil fuels combustion	Electricity and heat production	Industrial sector
		Residential and commercial sectors
		Electric transport sector
	Transportation (non-electric)	
Industrial processes	Lime, cement, aluminum, coke and iron, hydrogen, and ammonia production	
Land-use change	Deforestation	

Table 1. Anthropogenic sources of CO_2 emissions

It is estimated that the combustion of fossil fuels accounts for 80% of the CO_2 emissions originating from human activities in industrialized counties. In this context, energy policies for the reduction of CO_2 emissions can be regarded as the array of policies that have as a direct or indirect effect the reduction of the rate of fossil fuels combustion. The activities and sectors at which energy policies can be targeted for CO_2 emission reduction are represented on gray background on Table 1.

3. The Challenge Facing Energy Policies

The composition and strength of energy policies depend on the targets for CO_2 emissions reduction. The setting of targets for CO_2 abatement is a complex task because of the high uncertainties related in particular to the range and magnitude of climate change effects, resilience of natural ecosystems, and consequences for human beings—for different degrees of global average temperature increase.

Assuming that there were no uncertainties about climate change impacts, and that the levels of temperature increases and associated time intervals for which ecosystems and humans can adapt naturally were known, the CO_2 atmospheric concentration level necessary for stabilization could have been calculated, together with the optimal stabilization year. In a science-driven process of climate stabilization, this could have supported the setting of the long-term target for emission reduction. Based on this, the necessary profile of annual CO_2 emissions (gigatonnes of carbon (GtC) per yr) could have been derived for the period between the reference year and the stabilization year and, along this curve, intermediary targets could have been set.

Further, provided that there was full international commitment for target setting and achievement, various combinations of measures and policies pertaining to the energy, social, and economic spheres could have been designed so as to achieve a profile of annual carbon emissions that overlaps the emission profile recommended by scientists. Such an ideal, science-driven process of energy-related CO_2 emission reduction for climate change control supported by full international cooperation and prioritization of environmental goals in relation to goals, such as social and economic development, is represented in Figure 1 with dashed arrows.

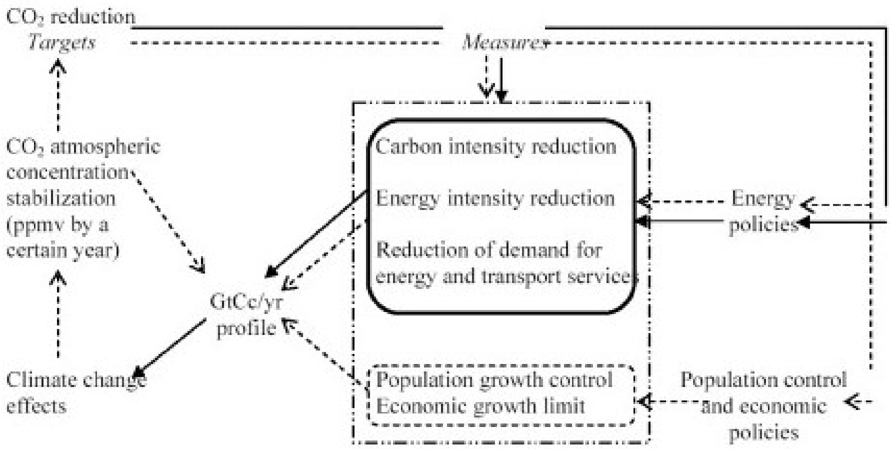

Figure 1. The ideal science-driven process and the politically driven process of climate change abatement

In practice, however, there is still considerable scientific uncertainty over the sensitiveness and vulnerability of natural ecosystems and humans to climate changes. The "tolerable" CO_2 atmospheric concentration, the "right" target, and CO_2 emission reduction profile cannot be calculated with a satisfactory degree of certainty. Against this background, and also because CO_2 emission reduction has extensive and long-running implications for social and economic development, target setting is expected to remain a primarily politically driven process.

The reduction of CO_2 emissions from fossil fuels burning can be achieved through policy intervention in five main areas:

- Reduction of carbon intensity of energy fuels and production
- Reduction of energy intensity of industrial and transport activities, as well as of end-use technologies and appliances in the residential/commercial sector
- Reduction of demand for energy and transport services
- Control of population growth
- Limitation of economic growth

Energy policies for the abatement of CO_2 emissions are directly concerned with the reduction of carbon intensity, energy intensity, and demand for energy and transport services. Nevertheless, the composition and stringency of energy policies packages depend very much not only on the level of targets, but also on whether—and the extent to which—policy actions are undertaken to control population and economic growth. But the debates on birth control and the "appropriate" rate of economic growth have always been highly controversial and policy intervention at these levels is less likely to be accepted. Consequently, the reduction of CO_2 emissions from fossil fuel burning can be more realistically expected to rely on strong energy policies that need to be continuously adjusted according to the forecasts for population and economic welfare increase and changes in target levels. In this context, CO_2 emission reduction for climate change abatement can be expected to follow the flow of the continuous arrows in Figure 1.

4. Technical and Non-Technical Measures for the Reduction of Energy-Related Carbon Dioxide Emissions

4.1. Classification of Measures

Fossil fuel combustion occurs in two distinct categories of activities: 1) electricity and heat production and 2) fuel burning in non-electric transport means (Figure 1). In the first case, the source of carbon emissions is different from the point where energy will be consumed, even if the two sites are located in immediate proximity. In the second case, the source of emissions and the point of energy consumption form a unitary technological entity, such as a road vehicle or airplane. This distinction is important because the technical approaches for CO_2 emission reduction are fundamentally different.

For each of the two categories of fossil fuel combustion, the CO_2 reduction measures can be divided in two groups: supply-side and demand-side measures. The supply-side measures for the first case envisage the reduction of the carbon intensity of electricity and heat production. In the second case, supply-side measures refer to the reduction of the carbon intensity of fuels and the decline in the energy intensity of vehicles. On the demand side, CO_2 abatement measures refer to the reduction of energy intensity of end-use technologies, appliances, and devices for industrial, residential, and commercial applications, reduction of demand for energy and transport services, as well as decline in transport fuel demand. The suggested classification of measures is represented in Table 2. The distinction between supply-side and demand-side measures is relevant from the standpoint of the types of policy instruments and international cooperation mechanisms that can be deployed for their implementation.

<table>
<tr><th>Supply-side measures</th><th colspan="2">Demand-side measures</th></tr>
<tr><td rowspan="3">1. Electricity and heat production
* Reduction in carbon intensity of electricity and heat</td><td>Industrial sector</td><td rowspan="2">* Reduction in energy intensity of end-use technologies, devices, appliances.
* Reduction in demand for energy services</td></tr>
<tr><td>Residential / commercial sector</td></tr>
<tr><td>Electric transport</td><td>Infrastructure and fleet enlargement considered desirable</td></tr>
<tr><td>2. Transport (non-electric)
* Reduction in carbon intensity of fuels
* Reduction in energy intensity of vehicles</td><td>Non-electric transport</td><td>* Reduction in demand for transport services based on non-electric vehicles
* Fuel demand reduction</td></tr>
</table>

Table 2. Classification of measures for CO_2 emission reduction from fossil fuel combustion

As can be seen in Table 2, there is a two-track approach for emission reduction:

technical and non-technical. Technical measures are those concerned with the reduction of carbon intensity and energy intensity. Non-technical measures are those concerned with the reduction of demand for fuels, energy services, and transport services. The next five sub-sections provide in the form of tables the technical and non-technical measures that can lead to CO_2 emission reduction for the two types of fossil fuel combustion activities and for the three sectors of energy consumption.

4.2. Supply-Side Measures—Production of Electricity and Heat

The production of energy assumes a chain of activities formed by fuel extraction, fuel combustion, and transport of the secondary form of energy—electricity or heat. During the extraction phase, CO_2 emissions are released, especially from natural gas and oil wells. Techniques have been developed for the capture and storage of flaring CO_2 and they are already in use in some developed countries. However, they are still expensive, which impedes for the time being their worldwide diffusion.

The largest potential for CO_2 reduction in the chain of energy production lies, however, at the level of fossil fuel burning in power plants or boilers for electricity and heat production. The measures generally discussed in the literature are increased conversion efficiency and co-generation, shift to lower-carbon fuels, de-carbonization of flue gases or fuels accompanied by CO_2 storage, deployment of renewable energy resources, and use of nuclear energy (see *Energy Efficiency and the Switch to Renewable Energy Resources*).

4.3. Supply-Side Measures—Non-Electric Transport

The transport sector—including all types of transport modes—contributed 21% to global CO_2 emissions from fossil fuel combustion in 1990. The largest contribution came from road vehicles with a share of 82% in the transport sector emissions, while aircraft had a share of 12%. The supply-side measures for the reduction of CO_2 emissions are concerned with the improvement of fuel quality and vehicle efficiency so that, for a given demand of transport services, the CO_2 emissions released for the satisfaction of that demand are smaller. The technical measures for such improvements that are most frequently mentioned in the Intergovernmental Panel on Climate Change (IPCC) publications have been listed on Table 3. The numbers in brackets represent the technical potentials for energy intensity reduction without radical changes in vehicle performances or design.

Supply-side areas of intervention	**Measures for CO_2 emission reduction from fossil fuel combustion for non-electric transport means**
Fuel quality	Road vehicles * More efficient fuels currently available: Diesel, methanol from natural gas, reformulated gasoline, compressed natural gas, liquefied petroleum gases (10%–30% emission reduction per km) Ethanol and methanol from wood, liquid hydrogen (12–13 times less CO_2 equivalent emissions per km)

	Aircraft * Alternative fuels: liquid natural gas, liquid hydrogen (effects of shift not quantified yet; may be cost effective only in the long term) Water transport * Complement energy requirements through wind turbines (10%–20%)
Vehicle efficiency	Road vehicles * Reduction of vehicle and engine weights (15%–30%) and sizes * Improved engine efficiency (15%–30%) and operating systems (3%–10%) * New types of engines (e.g. two-stroke engine (10%), gasoline direct injection engine (10%–25%), lean-burn gasoline injection (10%–20%), Stirling engines, hybrid engines, battery electric vehicles) * Vehicle design for the reduction of air resistance (15%–30%, up to 80%) and rolling resistance (2%–3%) * Less energy intensive technologies and materials for vehicle manufacturing * Reduced emissions during vehicles disposal phase Aircraft * More efficient engines based on current models (5% per year up to 2010) * New engine concepts (20%–25%) * Controlling environmental impacts of innovations: supersonic designs promise high energy intensities and are expected to boost traffic intensity Water transport * Improvements in engine efficiency (5%–10%)

Table 3. Measures for CO_2 emission reduction for non-electric transport modes (*Source*: Adapted from R.T. Watson, M.C. Zinyowera and R.H. Moss, eds., *Climate Change, 1995: Impacts, Adaptations, and Mitigation of Climate Change* (Cambridge, U.K.: Cambridge University Press, 1996) and R.T. Watson, M.C. Zinyowera and R.H. Moss, eds., *Technologies, Policies and Measures for Mitigating Climate Change* (Geneva: IPCC, 1996))

4.4. Demand-Side Measures—Energy Consumption by Industrial Activities

In 1990, industrial activities accounted for 45% of CO_2 emission from fossil fuel combustion, having the largest share in energy consumption. The most energy-intensive industries are metal industries—iron and steel, aluminum, copper; chemical industries; pulp and paper; construction materials; and food industry. Literature overviews suggest a wide array of measures that can be used for energy consumption reduction in these sectors. They have been summarized in Table 4 and can be grouped into four categories:

- Replacement of production technologies by more efficient ones already technically available

- Product innovations and production technology innovations
- Energy management systems for minimization of energy losses and exergy-efficiency improvements through heat recovery and re-use
- Recycling of intermediate or end-use products, and material substitution

Industrial activities	**Measures for reduction of energy consumption**
Steel industry	Use of more efficient production technologies (e.g. electric arc furnaces) Innovative production technologies (e.g. changing the source of carbon from coal to chemical organic wastes or tires) Improved exergy efficiency (heat recovery and use for processes with lower heat demand) Recycling intermediate and end products; material substitution
Aluminum and copper	Recycling—may lead to 8 to 10 times less energy consumption
Chemical industry	Innovative production technologies for the reduction of energy requirements for chemical transformations Product innovations: products that reduce the use of or replace the currently used raw materials—natural gas and petroleum; material substitution Innovations in recycling technologies (especially for plastics) Standardization (especially for plastics)
Pulp and paper	Recycling Improved energy efficiency
Construction materials	Use of more efficient production technologies already available (e.g. dry-process kilns for cement production) Innovations in production technologies (especially needed for cement and brick production) Product innovations (lighter materials to reduce transport-related energy consumption; material substitution; new materials) Inter-industry recycling and material substitution
Food industry	Technological innovations in the fields of food refrigeration, processing, and packaging Energy management systems and improved energy-efficiency

Table 4. Measures for the reduction of energy consumption in the most energy-intensive industrial sectors

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Biographical Sketch

Valentina Dinica is a senior researcher at the Center for Clean Technology and Environmental Policy, University of Twente, The Netherlands. Her academic background includes engineering studies, public administration, and environmental policy. In 2003, she received her Ph.D. for a study on the consequences of different configurations of economic support systems for the support of renewable electricity technologies on the market diffusion of these technologies. Since 2003, she has been a postdoctoral researcher on public policy implementation.