Understanding Marginal Abatement Cost Curve in Turkish Economy on The Way to Reduce of Greenhouse Gas Emission[1]

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Abstract

This paper examines the possibility of reducing greenhouse gas emissions in Turkey and estimates its costs in a number of sectors of the economy. The main output of this paper is introduced as a "marginal cost reduction curve" or MACC for Turkish economic sectors. A MACC is a graphical representation of the extent of emissions reductions that can be achieved through carbon pricing made in different rates across the economy, and the benefits or costs associated with reducing emissions per ton.

In order to build the MACCs for Turkish economy, it is used computable general equilibrium(CGE) model. The scenarios of the model is to run the model under different constraints corresponding to various carbon taxes, such as $1, $5, $10, $25, $50, $75, and $100 per ton of carbon emission. For each carbon tax set, the model obtains the corresponding national carbon reduction levels. The levels of mitigation have been identified as a function of carbon taxes for the economy.

Keywords: Carbon tax, Greenhouse Gasses, CGE model, Turkey

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1. Introduction

According to data from the Turkish Statistical Institute, Turkey's greenhouse gas emissions increased 110% in the period 1990-2013. In the same period, annual per capita emissions rose from 4 tones to 6 tones, increasing by 53 percent. The increase in emissions is largely due to fossil-based energy sources, and emissions from electricity production have increased by about 2.5 times, while the share of electricity generation in total emissions has reached 25 percent from 15 percent.

The 195 Participants of the United Nations Framework Convention on Climate Change (UNFCCC), including Turkey, were in negotiations in Paris on December 2015 and ratified the Paris Treaty. The Paris Treaty covers the objectives of the highest greenhouse gas emissions as soon as possible to maintain the temperature rise above the industry level below 2°C and to make efforts to limit the increase to 1.5°C. The UNFCCC invited the Parties to submit their nationally agreed contributions (INDCs) in the intended manner prior to the COP21 negotiations, which represent the objectives and actions in the post-2020 period. The key tools for achieving this goal are the Nationally Determined Contribution Value (INDC), which is presented to the UNFCCC by individual states prior to the beginning of the conference. In these documents, countries are obliged to elaborate their climate change mitigation plans and to provide specific greenhouse gas reduction targets between 2020 and 2030. The Turkish INDC had a commitment to reduce greenhouse gas emissions by 21% compared to the business as usual (BAU).

Turkey's target for greenhouse gas reduction is to reduce emissions by 2030 compared to the baseline scenario by 21% by means of prioritization of interventions in renewable energy, industrial efficiency, transport, buildings and agriculture. In the official INDC of Turkey, shown in Figure 1, it is seen that the amount of carbon dioxide equivalent greenhouse gas estimated to reach 1 billion 175 million tons in 2030 according to the baseline scenario is targeted to be kept at 929 million tones in the same year.

Nevertheless, despite this struggle and national contribution, the forecast made seems to indicate a warming that would exceed the dangerous 2°C threshold. Some recent studies indicate that efforts will be made to limit the temperature increase under the catastrophic levels.

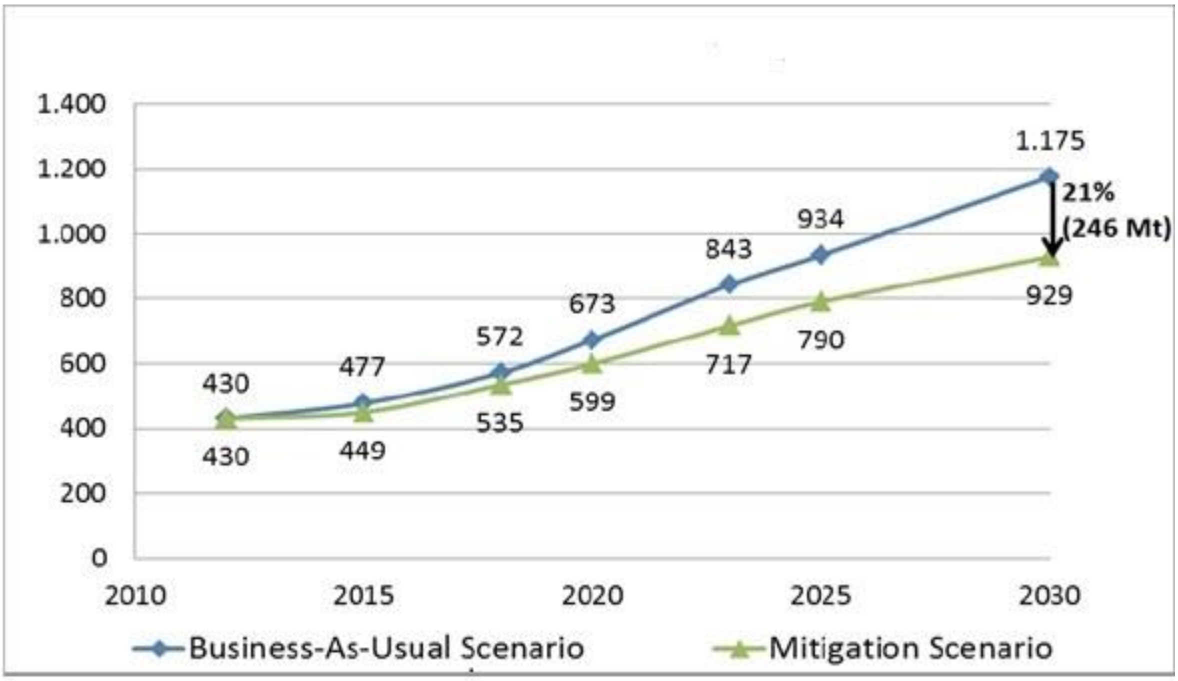

Figure-1: Turkey's target for greenhouse gas reduction by 2030

As a result of this obligation, new policies, such as various carbon pricing options, will gradually grow on the global agenda in the coming years. Using carbon pricing options provides the most cost-effective way to mitigate climate change and can help meet or potentially overcome mitigation commitments for countries. The main policy options of mechanisms for carbon pricing are the carbon taxation and Emission Trading Systems (ETS). While the basic function of both policy options is the same, the methods used in pricing are completely different (Bavbek, 2016).

However, this paper focuses only on carbon taxation of policy options, as the issue of this study is to obtain and understand marginal abatement curves for the Turkish economy, which show emission reduction rates corresponding to each carbon tax. Policy makers fighting global warming and climate change are faced with finding affordable means to reduce carbon emissions in line with the legal targets committed to reduce greenhouse gas emissions. For this purpose, marginal abatement cost curves (MAC) curves are often used to demonstrate the technological and economic feasibility of climate change mitigation. A MAC curve is a graph showing the marginal cost of emission reduction (the cost of the last unit) for emission reduction in different quantities.

In the literature, the cost curves for reducing emissions are quite long, even back to the early 1980s. After the first world oil crisis (1973), studies focused on energy supply and security have also made it necessary to form consumption and cost curves. The initial work in this area began with Meier (1982) by developing initial cost curves (US$/kWh) to reduce electricity consumption. These cost curves have been developed by many researchers such as Blumstein and Stoft,(1995), Rosenfeld et al.(1993), Sitnicki et al.(1991), Mills et al.(1991), Jackson(1991), Difiglio and Duleep(1990), Olivier et al.(1983). Moreover, such curves are widely used to assess the pollution costs of air pollutants. Rentz et al. (1994) assess the abatement cost for SO2. McKinsey & Company's work on MAC and the results of these studies[2] have become an increasing focus of interest for many researchers and policy makers.

MAC curves played an important role in the UK in shaping the climate change policy for government. (eg Pye et al., 2008, Blok et al., 1993). In many regions and countries, for example, Ireland(Kennedy, 2010) and European Union Bloc and others, 2001) and California (Sweeney et al., 2008) contributed to policy implementations. MAC has also been used in theoretical assessments of emission reduction and innovation (Downing and White, 1986; McKitrick, 1999; Bauman et al., 2008).

2. Modelling Approach and Emission Accounting

This section focuses on the question of how to generate MAC by using computable general equilibrium model. Where mitigation actions are not defined engeneosuly in the model, the only way to reduce emissions is to reduce emissions due to substitution (Kiuila, 2011). In the CGE literature abatement cost was modeled implicitly Kiuila and Sleszynski (2003), Conrad (2002), Xie and Saltzman (2000), Schmutzler and Goulder (1997), (Bergman (1991), and Robinson et al. (1994), In these models, the reduction cost was determined by the average pollution cleanup rate. The disadvantage of such an approach is that it does not explain the effects of price changes introduced by policy reforms.

CGE model can be divided into two broad categories: top-down and bottom up models. In this study we use top-down energy extended version of GTAP model named as GTAP-E.

Like the GTAP model, the GTAP-E model is a multi-regional global equilibrium model that represents the global economy. A representative in each region maximizes consumer benefit and special demand and production are modeled using different functional forms. The distinguishing feature of this model from other models is the assumption of a global banking sector that mediates global trade and transportation margins and is mediated by global savings and consumption. In addition, the model also includes the flexibility differential (CDE) function in private home preferences.

GTAP-E (Burniaux and Truong 2002) is an energy-environment version of the standard GTAP model that allows companies to change fuels and factors for production and consumption behaviors of private households and the government sector. In addition to the standard macroeconomic

[2] Between 2007 and 2009, McKinsey published 14 cost curves for different countries (McKinsey & Co., 2009 and 2010), as well as a global cost curve (Naucle´r and Enkvist, 2009).

results, GTAP-E addresses the implications of changes in energy-environment policy strategies in terms of both energy and environmental indicators. The main difference in GTAP-E is the inclusion of substitution possibilities in production and consumption, and a more detailed definition of substitution possibilities in different energy sources. In the GTAP-E model energy added for both production and consumption was added. An important element of the energy supplementation of the capital is considered complementary.[3]

The GTAP-E model replaces the standard GTAP database with millions of tonnes of carbon, replacing fossil fuel-derived CO2 emissions, including commodities and vehicles. Energy products include coal, crude oil and natural gas, refined petroleum products, electricity and gas production and distribution. CO2 emissions for electricity are equal to zero and equal for all other energy consuming products.

It is assumed that CO2 emissions in the model are produced by energy consumption of firms, government and private households as well. These direct emissions are taxed without distinction between sources of energy products. It is assumed that emissions are proportional to usage. For example, emissions from firms' usage of domestic product (gco2fd) is assumed to equal to the growth rate of firms' usage of domestic product.

$gco_2fd_{i,j,r} = qfd_{i,j,r}$

Total CO_2 emission can be calculated by summing for all users, regions and commodities:

$$CO_{2r,i} \; x \; gco_{2r,i} = \sum_{j,PROD\_COMM} CO2IFi,j,r \text{ x } gco2fmi,j,r + CO2DFi,j,r \text{ x } gco2fdi,j,r + CO2DGi,r \text{ x } gco2gdi,r + CO2IGi,r \text{ x } gco2gmi,r + CO2DPi,r \text{ x } gco2pd(i,r) + CO2IPi,r \text{ x } gco2pm(i,r)$$

In this equation, CO_2DF refers to the emission from firms' usage of domestic product and gco_2fd refers to the emission changes of firms due to domestic product use. CO_2IF refers to the emission from firms' usage of imports, gco2fm refers to the emission changes of firms due to imported product use. CO_2DP refers to the amount of emissions from private consumption of domestic product, gco_2dp refers to the emission changes of households due to domestic product use, CO_2IP refers to the amount of emissions from private consumption of imported product, and gco2ip refers to the emission changes of household consumption due to imported product use. CO_2DG refers to the amount of emissions from government consumption of domestic product, and gco2dg refers to the emission changes of government consumption due to domestic product use. CO_2IG refers to the amount of emissions from government consumption of imported product, gco_2fm is the emission changes of government consumption due to imported product use.

[3] See more detail Keller(1980) and Koetse et al.(2008)

3. Results

Before running the model to obtain results, we should design the scenarios of the model and closure of the model. It is assumed that it is not allowed to emissions trading between countries or regions. In order to generate MACC we schok the carbon taxes for example 1$, 5$, 10$ and so on, we then obtain the corresponding value of change in the amount of emissions from all agents. To do this in model we choose the carbon tax rate (NCTAXB) exogenous is exogenous and emission constraints by making the country or region-level power of emissions purchases (pempb) is endogenous. However, NCTAXB is exempt from the nominal tax rate, and if the initial carbon tax rate differs from zero, the model is not homogeneous in prices. For this reason, we have to define RCTAX, which is also a reel carbon rate variable at the country level. We can easily define the real tax rate as the nominal tax rate deflated by the income disposition price index in the model. The first column of Table-1 indicates the number of carbon taxes ($ per tone of emissions) imposed Turkish economy. These values also indicates values of shocks in model and second column of Table-1 gives the corresponding value of growth rate of emissions.

Table 1: Carbon taxes and corresponding change in
emissions in Turkish economy with respect to increasing carbon taxes

Carbon taxes	Growth emission
0	0
1	-1,04
5	-4,41
10	-7,49
25	-13,42
50	-20,82
75	-25,81
100	-29,84

Source: Simulations results

Figure-2 indicates the MAC curve for Turkish economy indicating the change in amounts of emissions for varying amounts of carbon taxes defined as marginal cost (the cost of the last unit) of emission abatement. According to the MACC, which is shown in Figure-2, when we impose 1 dollar of carbon tax per 1 ton of emissions to the Turkish economy, the emission rate decreases by 1.04 percent. It can also decrease by 7.49 percent for 10 dollars, 20.8 percent for 50 dollars and 20.9 percent for 100 dollars.

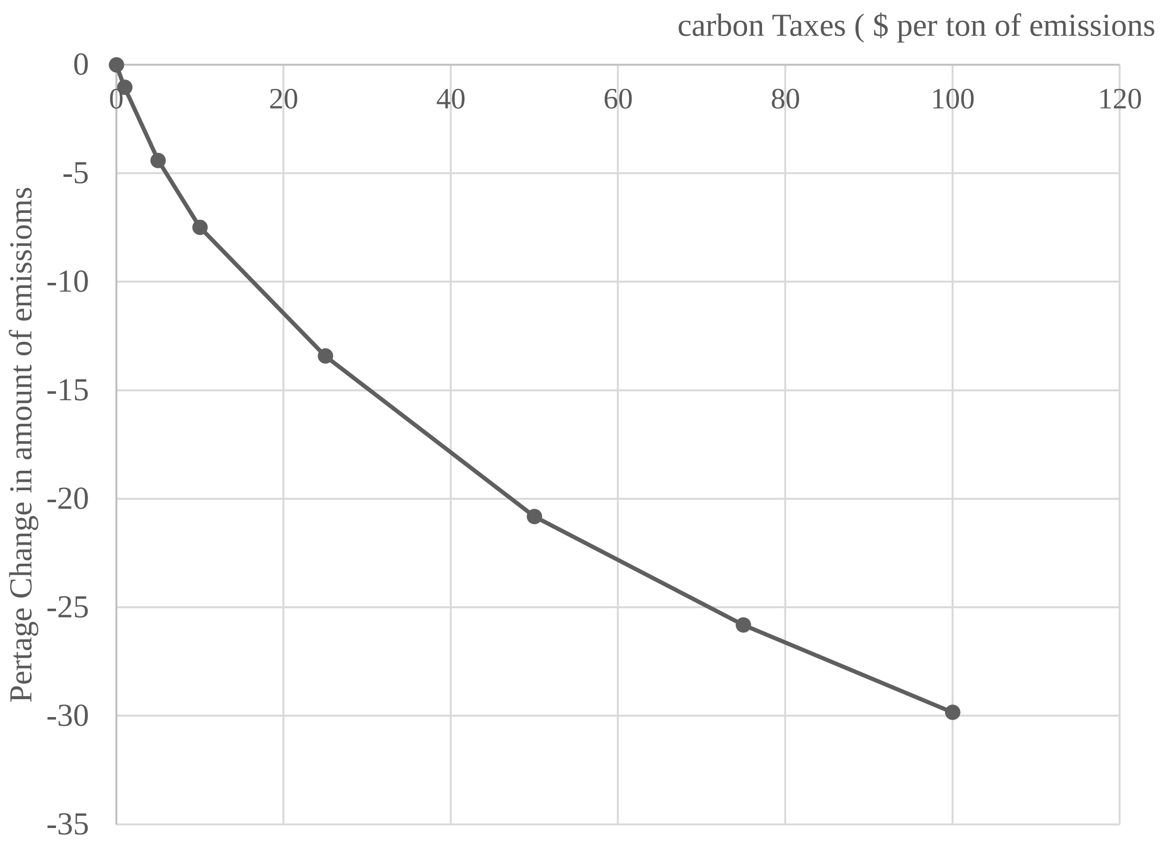

Figure-2: MAC curve for Turkish economy

Moreover, the slope of Figure-1 (percent reduction in emission amount of increase in carbon tax per ton of emission) indicates the carbon intensity of Turkish economy. Since this study only covers the Turkish economy, no comparison can be made as to whether its carbon intensity is less than in other countries.

As in most developing countries, coal is main responsible for carbon emissions in Turkey. Even though coal represented 28% of the Turkey's Total Primary Supply (TPES) in 2015 it accounted for approximately 42% of carbon emissions due to the it's heavy carbon content per unit of energy released. The coal is followed by gas with 31 percent and oil with 27 percent. Compared to gas, coal is nearly twice as emission intensive on average. Default carbon emission factors from the 2006 IPCC Guidelines: 15.3 tC/TJ for gas, 15.7 to 26.6 tC/TJ for oil products, 25.8 to 29.1 tC/TJ for primary coals[4].

It is therefore possible to see in Table 2 that the greatest reduction in the emission increase rates resulting from the consumption of fossil fuels calculated by the model for each carbon tax increase

[4] See Table1.3 at 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 2 Energy available from http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html

is in coal. For example, when a carbon tax of 25 dollars per ton is applied, the emission reduction rate from coal is 29 percent, while it is 10 percent for natural gas and 2 percent for petroleum products.

Table-2: Percentage change in growth in emission by fuels with respect to increasing carbon taxes

Carbon Taxes($/ton)	Percentage change in growth in emission by fuels				
	Coal	Crude oil	Natural Gas	Petroleum Products	Gas Distribution
1	-2,18	-0,71	-0,43	-0,09	-0,37
5	-8,73	-3,52	-2,52	-0,44	-1,81
10	-14,32	-6,89	-4,92	-0,89	-3,51
25	-28,49	-15,22	-9,78	-2,18	-8,02
50	-36,78	-25,45	-15,69	-4,18	-14,15
75	-44,11	-32,5	-20,71	-6,12	-19,11
100	-49,5	-37,9	-25	-8	-23,3

Source: Simulations results

Table-3 gives the value of some major macroeconomic indices in the case of an increase in carbon tax. Accordingly, if the carbon tax increases, the GDP price index increases while the real GDP decreases. In other words, carbon taxation is a constraint on economic growth. For example, a $5 carbon tax per tone of carbon emissions would reduce the GDP price index by 0.02 percent while the real GDP would decrease by 0.09 percent. If the tax is levied at $ 25, the price index increases by 0.04 percent while the real GDP declines by 0.25 percent.

Table 3 also reports macroeconomic costs of implementing carbon taxes as a percent change in per capita income for households and associated changes in terms of trade. As the increased carbon tax increases domestic prices, it also reduces consumer utility while worsening the terms of trade. For example, the $10 carbon tax lowers the consumer benefit by 0.09 percent, while the terms of trade deteriorate by 0.03 percent against Turkey. When the tax is raised by $100, consumer utility decline by 1 percent while the trade leads worsen by 3 percent.

Table 3: Percentage change in some major macroeconomic indices with respect to increasing carbon taxes

Carbon Taxes($/tone)	Percentage change in some major macroeconomic indices			
	reel GDP	GDP price index	Utility	Terms of trade
1	-0,009	0,003	-0,009	0,002
5	-0,04	0,02	-0,04	0,02
10	-0,09	0,04	-0,09	0,03
25	-0,25	0,04	-0,25	0,03
50	-0,48	0,07	-0,51	0,05
75	-0,74	0,08	-0,8	0,07
100	-1,01	0,10	-1,09	0,08

Source: Simulations results

The effects of increasing carbon tax on the output of the Turkish economy sectors can be seen in Table-4. The sector most affected by tax is the coal sector. 10$ carbon taxes per tone of emissions reduces the output of the coal sector by about 25 percent. Accordingly, coal-fired power generation is also reduced by about 10 percent. Accordingly, coal-fired power generation is also reduced by about 10 percent. As the substitution effect of rising coal prices in crude oil and natural gas production is more dominant, there is a slight increase in the output of these sectors. However, the production of natural gas power plants takes place in the tableland as one of the decreasing sectors after coal. On the other hand, the heavy industrial sector is decreasing in response to the increasing carbon tax.

On the other hand, the production of wind power-based electricity generation and hydroelectric power plants is increasing from renewable energy sources competing for fossil fuel-based electricity generation for each carbon tax increase. The output of agriculture, forestry, fishery and processed food is also decreasing with increasing carbon tax.

Table 4: Percentage change in sectoral output with respect to increasing carbon taxes

Sectors	Percentage change in sectoral output by Carbon taxes			
	$10/tone	$25/tone	$50/tone	$100/tone
Grains crops	-0,07	-0,16	-0,35	-0,75
Livestock and Meat Products	-0,03	-0,08	-0,21	-0,52
Forest	-0,2	-0,33	-0,52	-0,82
Fishing	-0,05	-0,14	-0,33	-0,78
Processed food	-0,02	-0,05	-0,14	-0,36
Text textiles and clothing	0,07	0,28	0,54	1,02
Light manufacturing	-0,06	-0,05	-0,1	-0,2
Heavy manufacturing	-0,71	-1,58	-2,96	-5,4
Coal mining	-24,84	-45,91	-60,36	-74,17
Oil mining	0,74	2,09	4,05	7,4
Gas mining	3,3	16,7	47,55	136,91
Refined oil products	-1,05	-2,41	-4,5	-8,44
Coal-fired electricity	-9,67	-13,39	-23,05	-33,34
Oil-fired electricity	0,77	-5,04	-8,36	-14
Gas-fired power	-5,71	-10,28	-14,94	-22,48
Hydroelectricity	5,52	6,84	9,02	10,68
Wind power	5,28	5,74	7,16	6,85
Other fired power	4,1	2,13	1,24	-2,62
Electricity distribution	4,06	1,35	0,39	-3,76
Gas distribution	-12,48	-26,53	-42,2	-59,56
Water	-0,12	-0,31	-0,57	-1,12
Construction	-0,58	-1,4	-2,64	-4,88
Transport and communication	-0,17	-0,44	-0,78	-1,54
Other services	0,02	0,05	0,04	-0,03
Capital goods	-0,62	-1,46	-2,81	-5,2

Source: Simulations results

4. Conclusion and Policy Recommendations

In this article, marginal reduction cost curve of Turkish economy is obtained by using the general equilibrium model. The MAC curve was generated by calculating the rate of change in emissions, which is the indigenous variable, by shocking the model of the exogenous variable carbon tax (1 $, 5 $, 10 $, ..., $ 100) at increasing rates. In addition, changes in major macroeconomic variables are calculated for each carbon tax. According to this, carbon tax primarily increases the GDP price index directly, reducing the real GDP. Increasing domestic prices worsen the terms of trade and reduce consumer benefits due to rising costs. In the Turkish economy, carbon tax mainly reduces the output of gas distribution and energy intensive sectors, mainly coal.

Economic development is usually a policy objective pursued by Turkish government because of the potential benefits of it on the overall social welfare and infrastructure levels. However, economic development usually leads to an increase of energy consumption. Turkey's energy consumption pattern mostly relies on the types produced by fossil fuels, imported natural gas, and coal resources, and these are important sources of greenhouse gases emissions. Considering the outcomes of environmental indicators, greater coal use leads to more possibilities of global warming (greenhouse gases), and production of air pollutants. On the other hand, energy and environmental policies may have a negative and constraining impact on economic growth and social welfare, therefore requiring careful assessment of the impacts of different policies and the trade-offs at stake between different policy objectives.

Recent economic growth in Turkey has significantly improved social welfare and infrastructure levels, as well as increased energy consumption. Although Turkey has been improving her levels of electricity supply and increasing the share of renewable sources in the electricity generation mix in her efforts towards economic growth, coal production will also rise due to the exploitation of new lignite extraction areas. Moreover, the electricity generation sector has been a major emission source in Turkey, mainly due to the use of coal and natural gas in power plants. As one of the developing economies, the assessment of the effects of increasing indigenous coal share in electricity generation mix on key economic and environmental indicators of turkey is key to provide tools for planners and decision makers on the road to the Paris Agreement entered into force in 2016.

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