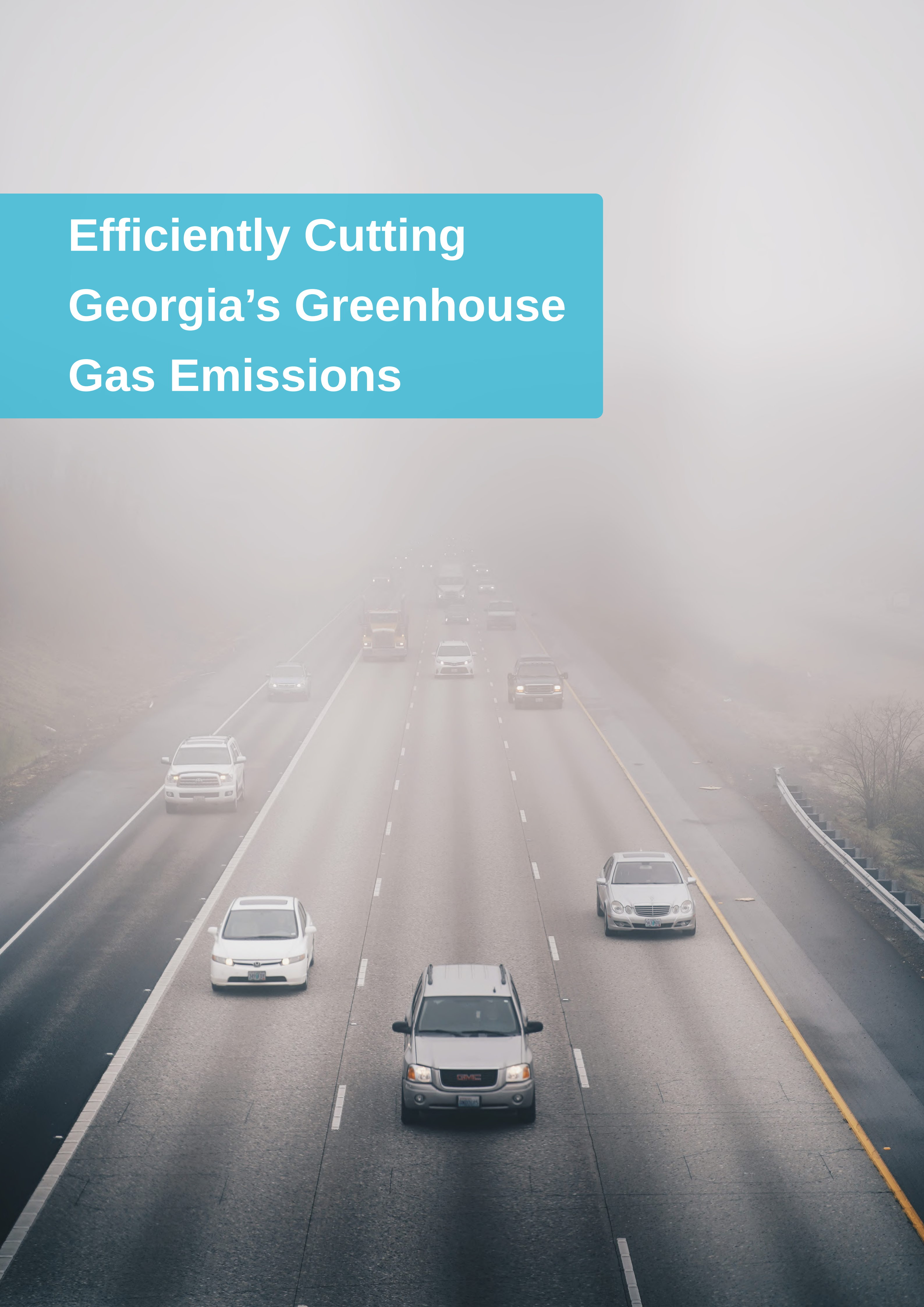
# Efficiently Cutting Georgia's Greenhouse Gas Emissions



A Comparative Statics Analysis of Alternative Strategies to Achieve the National Objectives and Targets set in Georgia's Climate Strategy and Action Plan using ISET-PI's Climate Policy Analysis (ICPA[1]) *computable general equilibrium model*.

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[1] The model was developed by the Energy and Environment Policy Research Center (EEPRC) at ISET Policy Institute, thanks to the financial support of the Swedish International Development Cooperation Agency (SIDA). The EEPRC is one of the five thematic research centers at ISET-PI.

# FOREWORD

ISET Policy Institute's Climate Policy Analysis (ICPA) model is a *computable general equilibrium* (CGE) model calibrated with data from the economy, physical energy flows, and energy-related emissions. The method is well suited for comparing the ability of different policy frameworks to reach given greenhouse gas (GHG) emission targets, and their impact on the welfare of Georgian households, since it tracks policy costs and price changes arising in different parts of the economy and it also highlights how these affect the ability of households to afford consumption. As such, this report details the ICPA model and provides an example of what it can offer the policy debate.

## Comparative statics analyses with CGE models

Comparative statics analyses in economics involve the comparison of two equilibria that differ only by some exogenous parametrization (e.g., the specific setting of policy instruments). They assume that economic agents and markets, in each parametrization, have had time to adjust to the respective situation when the comparison occurs. Thus, comparative statics is a tool for assessing long-term outcomes of policies that have been announced and phased in well in advance, and it cannot say anything about the transition to these respective long-term outcomes.

CGE models solve for market equilibria between economic sectors, households, and the government. The different agents within the model take market prices as given and adjust their behavior (supply and demand of market goods) such that their objectives (profits or consumption utility) are maximized.[2] Households can own production factors such as natural resources, labor, and capital, and derive income from providing these factors to production sectors at market prices. They spend their income on savings (buying an "investment good") and consumption from which they derive utility. Sectors use production factors along with each other's outputs as intermediate inputs and transform them into their sector-specific output. International trade allows sectors to provide their output to either the domestic market or export it to other countries. Domestic markets, on the other hand, can choose between a domestically produced variety or its imported equivalent. The final demand for produced goods is made up of household consumption, governmental consumption, and investment. The government typically keeps real consumption constant and finances it with revenue from indirect taxes, tariffs, and by transferring money between households and the government (direct taxes).

Different levels of factor mobility can be implemented in a CGE model: capital, labor, and resources can exist in sector-specific varieties, or they are assumed to be homogeneous goods that can be employed in all sectors and switch back and forth without friction. The specification of homogeneous goods is consistent with the view that the approach of comparative statics takes: well-informed on policies and market prices, all agents (and investors in particular) have had time to adjust their investments, demands, and supplies such that (i) their objectives have been optimized and (ii) markets clear.

In cases where policy changes are announced well in advance,[3] comparative statics is a good way to analyze and compare different policy options. For evaluating the climate policy strategy of Georgia this proves a reasonable tool. Emissions targets for 2030 are already being discussed now (2021) and the policies for reaching them are likely to be phased in gradually until 2030 (and will remain in place beyond 2030). Carrying out such comparative statics using a CGE model allows for a comparison of policy options for reaching given targets in terms of their impact on different economic sectors and in terms of changes in welfare that households derive from the consumption they can afford.


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[2] Perfect competition and free market entry and exit are commonly assumed, together with the assumption that all firms have access to the same range of technologies (production functions), which results in constant returns to scale in sectoral production activities.

[3] Or if policies (e.g., tax rates or emissions targets) change only gradually – that is, slowly compared to investment cycles.

# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| **BAU** | Business as usual |
| **BUR** | Biannual Updated Report |
| **CES** | Constant Elasticity of Substitution |
| **CET** | Constant Elasticity of Transformation |
| **CGE** | Computable General Equilibrium |
| **COM** | Covenant of Mayors |
| **ICPA** | ISET Policy Institute's Climate Policy Analysis |
| **EEC** | European Energy Community |
| **EEPRC** | Energy and Environment Policy Research Center |
| **ETH Zurich** | Equivalent Educational Qualifications Zurich |
| **EU** | European Union |
| **GAMS** | The General Algebraic Modelling System |
| **GDP** | Gross Domestic Product |
| **GHG** | Greenhouse Gas |
| **GoG** | Government of Georgia |
| **GTAP** | Global Trade Analysis Project |
| **INDC** | Intended Nationally Determined Contribution |
| **ISET-PI** | International School of Economics at Tbilisi State University-Policy Institute |
| **LEDS** | Low-Emission Development Strategy |
| **LF-LEDS** | Long-term Low Emission Development Strategy |
| **LULUCF** | Land Use, Land Use Change, and Forestry |
| **NAMA** | Nationally Appropriate Mitigation Action |
| **SAM** | Social Accounting Matrix |
| **SEAPs** | Sustainable Energy Action Plans |
| **TNA** | Technology Needs Assessment |
| **UNFCCC** | United Nations Framework Convention on Climate Change |
| **VA** | Value-added |

# TABLE OF CONTENTS

Foreward - - - 2

1. Policy Context - - - 5

2. Institutional Framework - - - 5

3. Specific Actions Previously Undertaken - - - 6

4. Future Steps - - - 7

5. The CGE Model for the Evaluation of Georgian Climate Policy - - - 9

6. Conclusion - - - 20

7. Recommendations - - - 21

References - - - 22

# 1. POLICY CONTEXT

Over recent decades, Georgia has been participating in several international initiatives designed to combat climate change:

In 1994, Georgia joined the United Nations Framework Convention on Climate Change (UNFCCC), thus taking the obligation to monitor greenhouse gas emissions and take measures to help abate greenhouse gas concentration levels in the atmosphere. Within the framework of the convention, the country committed to producing National Communication Documents and periodically submitting them to UNFCCC.

In 2010, Georgia joined the Copenhagen accord. While the Georgian government at the time declared that Georgia would "take steps to achieve measurable, reportable, and verifiable deviation from the baseline scenario supported and enabled by finance, technology, and capacity building."

In 2016, the EU Association Agreement entered into force. The Association Agreement once more stressed the need for cooperation when addressing climate challenges; through the joint pursuit of climate change mitigation, adaptation to climate change, carbon trade (carbon emission trading), and the redefinition of industrial policies in light of such challenges, alongside the development of clean technologies.

In 2015, under the Paris Agreement – together with other 194 countries – Georgia committed to developing initiatives that halt the increase of global temperatures to under 2 °C of pre-industrial levels (preferably 1.5 °C). Within the treaty, countries are obliged to restrict the amount of greenhouse gases (GHGs) emitted from human activity to the same levels that trees, soils, and oceans can absorb naturally between 2050 and 2100. The agreement envisages a review of each country's contribution to GHGs mitigation every five years, and it encourages wealthy nations to assist poor countries in climate change adaptation and in the implementation of renewable energy sources. From 7 June 2017, Georgia's obligations to the Paris Agreement on climate change officially came into force. In the same year, Georgia started to develop national sustainable development goal indicators and targets that are closely related to the reduction of greenhouse gas emissions.

Finally, on 1 July 2017, Georgia became a full member of the European Energy Community (EEC), and it took the responsibility to synchronize its national legislation with the EU energy acquis, within a strictly defined timeframe.[4] Among the main commitments associated with EEC membership includes the promotion change mitigation measures, like energy efficiency and renewable energy sources. The Ministry of Economy and Sustainable Development of Georgia, in partnership with other stakeholders, thereafter engaged in the preparation of laws and national action plans on energy efficiency and renewable energy.

# 2. INSTITUTIONAL FRAMEWORK

The Government of Georgia (GoG) is responsible for ensuring that international commitments are respected, while climate change policies are developed and enforced by the Ministry of Environmental Protection and Agriculture (hereafter the ministry).[5] In particular, one structural unit of the ministry, the Department of Environment and Climate Change, and its subunit, the Climate Change Division, are obliged to coordinate and prepare every strategically important document related to climate change.

Additionally, an independent non-commercial legal entity (under Georgian public law) within the structure of the ministry, the Environmental Information and Education Centre, is responsible for the creation of a unified environmental database and its dissemination to the public. The centre, with the assistance of independent experts, prepares the National Greenhouse Gas (GHG) Emissions Inventory report.

The implementation of international and national commitments, alongside strategies and action plans, are overseen and coordinated by the Interagency Council on Climate Change, which was established in January 2020 by the Georgian government. The council is chaired by the Minister of Environment and Agriculture and consists of nine members,[6] and two advisory bodies – the coordination group of the Covenant of Mayors and technical working groups.[7]

[4] Energy Community Homepage

[5] Resolution of Government of Georgia – on the approval of the statute of the Ministry of Environment Protection and Agriculture of Georgia, N112, 6 March 2018.

[6] The Minister of Internally Displaced Persons from the Occupied Territories, Labour, Health and Social Affairs of Georgia; the Minister of Finance; the Minister of Economy and Sustainable Development; the Minister of Education, Science, Culture and Sports; the Minister of Regional Development and Infrastructure; the Executive Director of the National Statistics Office of Georgia; the Chairman of the Government of the Autonomous Republic of Adjara; the Chairman of the Government of the Autonomous Republic of Abkhazia; and the Chairman of the Coordination Group of Municipalities Signing the Covenant of Mayors.

[7] Scientific institutions, technical and expert groups, non-governmental organizations, and other stakeholders are involved.

# 3. SPECIFIC ACTIONS PREVIOUSLY UNDERTAKEN

Georgia has been engaged, under coordination of the ministry, in UNFCCC internal implementation processes since 1996. In 1999, Georgia's Initial National Communication Document, which included the results of the first national inventory of greenhouse gas emissions and a discussion of the necessary policy measures for climate change mitigation, was presented to the secretariat in fulfillment of commitments to the UNFCCC. The Second National Communication Document was prepared between 2006-2009 and was submitted in 2009, while the third and the latest National Communication Document, for 2012-2015, was approved in 2015. The document included a national inventory of greenhouse gases; climate change mitigation and adaptation measures – with a focus on the three regions most vulnerable to climate change (Ajara, Upper-Svaneti, and Kakheti); and Georgia's Climate Change Strategy until 2025. The main objective of the strategy was to identify concrete ways to mitigate ecosystem vulnerability and the abatement of GHGs from emitting sectors.

Furthermore, under the aforementioned international agreements, Georgia took the responsibility to introduce other initiatives towards climate change mitigation at the national level, such as the development of a Low-Emission Development Strategy (LEDS), a Biannual Update Report (BUR), a Nationally Appropriate Mitigation Action (NAMA) plan, a Technology Needs Assessment (TNA), and a Long-term strategy for 2020-2050. Moreover, the country planned to facilitate the establishment of the Covenant of Mayors (COM) and to develop its Intended Nationally Determined Contribution (INDC).

Work on the Low Emission Development Strategy (LEDS) for Georgia started in 2013, and the draft version of the document was submitted to the ministry in 2017. The goal of the strategy was to ensure the transition towards lower emissions and to build a sustainable path for Georgia's economic and social development. While the long-term Low Emission Development Strategy (LF-LEDS) has not yet been approved.

The country also pledged to elaborate periodically on a second strategically important document that monitors actions taken in the field and reveals further constraints, gaps, and needs for climate change action: the Biannual Update Report on Climate Change. The first report was submitted in 2016 and the second in 2019.

Georgia was actively engaged in the preparation of NAMA projects and within their implementation process. Within the framework of this initiative, NAMAs on adaptive sustainable forest management in the Borjomi-Bakuriani forest district; on the efficient use of biomass for equitable, climate-proof, and sustainable rural development; and on low carbon buildings were carried out.

Furthermore, Georgia completed its TNA in 2012. The report highlighted several technologies with the potential to significantly reduce GHG emissions, such as efficient wood stoves, innovative construction technologies – including integrated building designs, energy-efficient materials, and construction practices – and residential and commercial solar water heaters.

The first INDC was submitted to UNFCCC in 2015. The country voluntarily took the obligation to reduce GHG emissions unconditionally by 15% (with a further conditional 10%) compared to the business as usual (BAU) scenario. Since the ratification of the Paris Agreement (2017), Georgia has an obligation to update its INDCs every five years. The second updated INDC draft, with a more ambitious mitigation plan, has already been elaborated by the ministry and was published for public discussion in June 2020. The Ministry of Environmental Protection and Agriculture also elaborated drafts of the 2021-2023 Climate Action Plan and the new 2021-2030 Strategy in December 2020.

Finally, the updated fifth inventory of greenhouse gas emissions for 2017 is also planned for publication this year.

The updated INDC Strategy for 2021-2030 and the new greenhouse gas inventory are expected to be incorporated into the Fourth National Communication Document, with publication intended by the end of 2021.

Under the framework of the agreement with the energy community, certain obligations have already been fulfilled. In December 2019, the Georgian parliament adopted a law promoting the generation and consumption of energy from renewable sources, as well as the Georgian 2019-2020 National Energy Efficiency Action Plan. The law aimed to create legally binding incentive schemes for the promotion and consumption of renewable energy. The Action Plan on the other hand aimed to optimize energy consumption in the country and to support the decline of energy consumption and emissions, relative to the BAU scenario. Although the draft version of the National Renewable Energy Action Plan for 2020 has been elaborated, it has not yet been adopted. While in May 2020, Georgia further approved the law on energy efficiency and the energy efficiency of buildings.

Besides actions at a national level, local initiatives have also been taking place. Since 2010, the mayors of large Georgian cities have been joining the EU "Covenant of Mayors" initiative, which monitors the inventory of greenhouse gases in the country. Sustainable Energy Action Plans (SEAPs) have moreover been elaborated by municipalities within the framework of the Covenant of Mayors. Currently, 24 towns or municipalities are part of the initiative committing to reducing $CO_2$ emissions by at least 30% by 2030. While 10 municipalities have already submitted SEAPs, suggesting that emission reductions are largely from the transport, public, and domestic sectors.

According to the third National Communication Document, 33 mitigation projects were implemented; with total funding of 128.9 million USD over the 2009-2014 period. Considering project distribution by sector, two hold the lead in terms of the number of completed projects and financing (around 60% of total funding): the energy and transport sector (13 projects with a total financing of 93 million USD) and forests and biodiversity sector (seven projects with a total financing of 31.5 million USD).

Based on the Second Biannual Report on Climate Change, and a preliminary investigation conducted by the ISET-PI energy and environmental policy research center, roughly 80 projects on mitigation have been identified, with an approximate budget of 1772.41 million USD between 2015-2020.[8] Furthermore, the highest shares in this instance were within the energy[9] and transport sectors (53 projects in total), while the remaining projects were distributed among industry, agriculture, waste, and land use change and forestry (LULUCF).

# 4. FUTURE STEPS

Despite substantial investments in climate change mitigation, the country is still far away from the final target committed to the UNFCCC. Consequently, a new draft of the 2030 strategic plan and the 2021-2023 Action Plan have both been developed.

The long-term vision for the Climate Strategy and Action Plan envisages, by 2030 compared to 1990 levels,[10] a 35% reduction in total GHG emissions for all major economic sectors affecting climate change mitigation.

To achieve its given targets, the Climate Strategy and Action Plan sets out the following sectoral objectives and targets:

**Objective 1:** Reduce greenhouse gas emissions in the energy generation and transmission sector by 15% by 2030, compared to the baseline scenario;

**Objective 2:** Reduce greenhouse gas emissions in the transport sector by 15% by 2030, compared to the forecasts under the baseline scenario;

**Objective 3:** Promote the development of low-carbon approaches in the building sector through climate-friendly and energy-efficient technologies and services, in order to reduce greenhouse gas emissions compared to the baseline scenario;

**Objective 4:** Promote the development of low-carbon approaches in the industrial sector through climate-friendly and energy-efficient technologies and services, to reduce emissions by 5% by 2030, compared to the baseline forecasts;

**Objective 5:** Promote the development of low-carbon approaches in the agricultural sector through climate-friendly and energy-efficient technologies and services, to reduce the greenhouse gas emissions by 2% with respect to the baseline scenario;

**Objective 6:** Promote the low-carbon development of the waste sector through climate-friendly and energy-efficient technologies and services;

**Objective 7:** Increase the carbon sequestration capacity of the forestry sector by 10% by 2030, compared to 2015 levels.[11]

These objectives will help ensure a minimum emission reduction of around 11% in 2030, compared to the baseline scenario (30.89 MT $CO_2$ eq. excluding LULUCF). Therefore, by 2030 emissions should equal 27.5 MT $CO_2$ eq. The sectoral targets (hereafter category-specific targets) and emissions are presented in Table 4.1 below:

[8] 1524.63 million USD, 278.8 million EUR, and 10 million GEL at the 2020 average EUR/USD and GEL/USD exchange rate.

[9] It is noteworthy that the majority of energy projects were the construction of hydro power plants, with total costs of roughly 1381.15 million USD.

[10] Total emissions by 2030 should not exceed 29.25 MT $CO_2$ eq.

[11] The objective is not incorporated in the model.

### Table 4.1. Direct greenhouse gas emissions (GHGs) in different sectors

| Sectors | 1990 Direct Emissions (MT $CO_2$ Equivalents) | 2015 Direct Emissions(MT $CO_2$ Equivalents) | 2030 Base Case Scenario Direct Emissions (MT $CO_2$ Equivalents) | 2030 Goal Direct Emissions(MT $CO_2$ Equivalents) |
|---|---|---|---|---|
| **Energy Generation and Transmission** | 19.86 | 3.65 | 6.69 | 5.69 |
| **Transport** | 3.82 | 4.14 | 7.11 | < 6.04 |
| **Buildings** | N/A | 1.95 | 4.63 | < 4.63 |
| **Industry** | 3.88 | 3.12 | 5.99 | < 5.69 |
| **Agriculture** | 4.10 | 3.33 | 4.62 | < 4.53 |
| **Waste Management** | 1.11 | 1.39 | 1.85 | <1.85 |
| **Land Use, Land Use Change, and Forestry (LULUCF)** | -6.35 | -5.62 | -5.93 | -6.18 |

The implementation of climate change mitigation measures is primarily funded from the state budget, which is reviewed and designed annually by the Georgian Ministry of Finance. While the Energy Development Fund is responsible for seeking and developing potential renewable energy projects and contributes to the reduction of GHG emissions in the energy sector. While the Municipal Development Fund, in coordination with the Ministry of Regional Development and Infrastructure, procure projects related to municipal infrastructure. Although these funds are not directly targeted at mitigation measures, they may affect emission reductions in cities.

However, other funds are not yet operational. The Ministry of Economy and Sustainable Development has not formulated or submitted any recommendations for the Energy Efficiency Fund or the Renewable Energy Fund, which are expected to provide resources that support the various mitigation measures within the Climate Action Plan.

International donors and lenders have also been actively involved in financing climate change mitigation measures since 2009.[12]

Table 4.2 below includes each of the activities indicated in the Climate Action Plan.

### Table 4.2. Sectoral budget for different activities specified in the Climate Action Plan

| Sectors | Activities |
|---|---|
| **Energy Generation and Transmission** | Promoting renewable energy generation (wind, solar, hydropower) |
| | Improving the average efficiency of thermal power plants |
| | Reinforcing the national energy transmission system & reduction of losses |
| | Strengthening institutional and policy-making capacities |
| **Transport** | Increasing the share of technically sound private cars with low emissions |
| | Encouraging a reduction in the demand for fossil fuels and the use of biofuels |
| | Encouraging the use of public and non-motorized transport |
| | Strengthening institutional and policy-making capacities |

[12] Including the Asian Development Bank, Austrian Development Agency, Austrian state funding, Czech Development Agency, European Union, European Neighborhood Investment Fund (NIF), European Bank for Reconstruction and Development, European Investment Bank, Federal Ministry for Economic Cooperation and Development (Germany), Environment, nature protection and Federal Ministry of Nuclear Safety (Germany), Global Environment Facility, Government of Finland, Green Climate Fund, International Bank for Reconstruction and Development, International Development Association, International Finance Corporation, International Fund for Agricultural Development, German Development Bank KfW, Development Bank of Korea, Kingdom of Norway, Swiss Agency for Development and Cooperation (SDC), Swedish International Development Agency (SIDA), United Nations Development Program (UNDP), United States Agency for International Development (USAID), and World Bank.

| | |
|---|---|
| **Buildings** | Increasing energy efficiency by designing a methodology for the certification of energy efficient buildings |
| | Increasing energy efficiency by raising consumer awareness |
| | Increasing energy efficiency by promoting the installation of energy efficient and effective lighting |
| | Promoting the use of solar energy for heating water |
| | Strengthening institutional and policy-making capacities |
| **Industry** | Reducing emissions and energy consumption from production processes |
| | Strengthening institutional and policy-making capacities |
| **Agriculture** | Reducing emissions from cattle feed, soil, and pastures |
| | Strengthening institutional and policy-making capacities |
| **Waste Management** | Reducing greenhouse gas emissions from landfills |
| | Promoting waste recycling |
| | Reducing greenhouse gas emissions from wastewater |
| | Strengthening institutional and policy-making capacities |
| **Land Use, Land Use Change, and Forestry (LULUCF)** | Restoration of degraded forest |
| | Promoting sustainable forest management |
| | Strengthening institutional and policy-making capacities |

# 5. THE CGE MODEL FOR THE EVALUATION OF GEORGIAN CLIMATE POLICY

## 5.1 The ICPA model

The ICPA model of Georgia is a derivation of the small open economy flavor of the GTAP9inGAMS model provided by Lanz and Rutherford (2016), which has been updated to include GTAP 10 data.

**Production**
Economic sectors produce goods using primary factors, such as natural resources, labor, and capital, as well as composite inputs of energy and non-energy intermediates (material). Production technologies are described by *constant elasticity of substitution* (CES) cost functions, which reflect the substitution possibilities of inputs at different stages of the production process by constant elasticities of substitution. Trade-offs between different energy carriers or intermediate non-energy inputs with the composites of energy and material are likewise captured by CES cost functions. More specifically, the sector-specific energy aggregate consists of electricity on the one hand and fossil fuels on the other; where the fossil fuel aggregate, in turn, is a CES function of specific energy goods (coal, oil, gas). Production in economic sectors is characterized by constant returns to scale: if all inputs are doubled, output also doubles. The production of primary (fossil) energy requires the use of specific energy resources and has diminishing returns to scale with regard to non-resource inputs.

**Factor mobility**
The primary production factors are labor, capital, and natural resources. Labor and capital are assumed to be mobile across sectors, but not across borders. Natural resources are provided to economic sectors according to a *constant elasticity of transformation*

(CET) function: the supply of sector-specific varieties responds to prices, however certain natural resources, for example, in agriculture cannot perfectly substitute natural resources in coal mining.

**Consumption**
Consumption demand results from household utility maximization, subject to budget constraints. Households earn income from wages, capital interests, and resource rents adjusted for government transfers. Disposable income is then spent on investments and consumption goods, according to household preferences. In the setting of our static model, savings (viz., demand for investment goods) are fixed at the empirically observed initial level projected to 2030.

**State**
Public authorities levy taxes to finance transfers and the provision of public goods. Public goods are produced with goods or services that are purchased at market prices. The level of public goods provisions is kept constant (in real terms) across all policy simulations so that welfare changes from policy reforms for private households are not affected by changes in the supply of public goods (assuming separability between private and public consumption). Changes in revenues of the public sector caused by policy interventions are redistributed to households.

**International trade**
Georgia is assumed to be a price taker in international trade, i.e., changes in Georgian import and export volumes do not influence relative prices on the world market – export and import prices in foreign currency (the so-called terms of trade) thus remain constant. Domestically produced goods supply the domestic and the export market, where CET functions determine sales shares according to relative prices on the export and domestic market. Analogously to export, product heterogeneity is also assumed on the import side. Domestic producers and consumers have preferences regarding the origin of a product. For example, in their intermediate demands, producers view steel made in Georgia differently to the quality of imported steel; similarly, consumers differentiate, for instance, food products by their place of origin. The heterogeneity assumption (named after Armington 1969) allows for price differences between domestically produced goods and imports, without one type perfectly substituting the other. The trade behavior of the model therefore agrees with the empirically observable price responses of trade. The ICPA model furthermore works on the assumption that policy reforms do not change countries' balance of payments. The total value of exports thus equals the total value of imports in terms of foreign currency. It is this constant balance of payments that implicitly determines the real exchange rate between domestic and foreign currency.

**$CO_2$ emissions and reduction target policies**
The combustion of fossil fuels – coal, oil, and gas – during production and consumption leads to $CO_2$ emissions. These energy-related $CO_2$ emissions can be reduced, in principle, through three channels:

(i) fuel switching (substitution of fuels for each other), (ii) efficiency improvements (viz., substituting energy inputs with other inputs such as capital), or (iii) direct energy savings (via reduced production or consumption activities). The ICPA model includes two policy instruments for the reduction of emissions: a carbon tax and emissions standards. With carbon taxes, for energy conversion, each unit of fossil fuel demand is taxed in proportion to the $CO_2$ released by this use. Under a $CO_2$ tax, all three channels (i–iii) are used efficiently since: (a) the relative price changes of the different energy goods leads to fuel switching; (b) the increased energy cost offers incentives for efficiency improvements; and (c) overall increases in the cost of energy-intensive goods leads to a reduction in their demand. The tax revenue the government accrues will then mostly be transferred to households due to the requirement that real government spending be constant.

In the case of emissions standards,[13] sectors can reach the standards (which correspond to a limit on emissions per unit of output) by (i) using the fuel switching reduction channels and (ii) efficiency improvements. However, since sectors do not have to make carbon tax payments to the government, their output, at a given emissions intensity, is cheaper than it would be under a carbon tax. Thus, under a standard, a reduction in the traded quantities of emissions-intensive goods (direct energy savings); (iii) does not happen effectively even though firms are efficiently meeting standards within their sectors.

## 5.2 Forward calibration

For the ICPA model to represent the Georgian economy in 2030, it has to be forward calibrated from the year 2014, for which the base year calibration is established on GTAP data. The ICPA forward calibration is designed to reflect that (i) the overall size of the economy will grow according to GDP projections, and that (ii)

[13] In the ICPA model, efficiency standards are implemented as "sector internal" carbon prices, which give firms sector specific incentives for fuel switching and efficiency improvements, but the carbon price revenue is not going to the government, rather it is recycled within sectors via output-specific subsidies that compensate firms for exactly the amount of carbon price payments they have spent.

energy use is expected to decrease in line with the emissions trends from the baseline assumptions in the Georgian 2030 Climate Change Strategy. Table 5.2.1 summarizes the projections implemented in ICPA's forward calibration.

**Table 5.2.1. Projections of GDP and energy demand for forward calibrating the ICPA model, from the 2014 base year to 2030**

| Parameter | Projection (indexed to 2014=1) |
|---|---|
| GDP | 2.11 |
| Energy demand for transport | 1.72 |
| Energy demand for energy | 1.83 |
| Energy demand for buildings | 2.37 |
| Energy demand for industry | 1.92 |
| Energy demand for agriculture | 1.39 |

## 5.3 Data

Consistent data on transactions between production, consumption, and bilateral trade flows, as well as physical energy flows and emissions, are provided in version 10 of the Global Trade Analysis Project (GTAP) database (Aguiar et al., 2019). Version 10 of the database features 65 sectors over 141 regions (120 represent single countries). The GTAP database also contains all the information for constructing a global and balanced Social Accounting Matrix (SAM) of economy-wide value flows for given base years.

We have established the ICPA model on the base year data from 2014 and forward calibrated the model to represent the state of the Georgian economy in 2030 within a business as usual scenario. We have moreover aggregated the 65 sectors in the GTAP dataset. into 12 sectors/commodity groups (see Table 5.3.1). These consist of four primary energy goods (coal, crude oil, natural gas, and refined oil), electricity, and seven non-energy goods. The factors of production in our analysis are capital, labor, and natural resources.

**Table 5.3.1. Sectors in the ICPA model**

| Sectoral label | Description |
|---|---|
| Oil | Petroleum and cooking products |
| Gas | Natural gas |
| Ele | Electricity |
| Cns | Construction |
| Ros | Recreational and other services |
| Col | Coal |
| Cru | Crude oil |
| Eit | Energy-intensive goods |
| Trn | Transport |
| Agr | Agriculture |
| Mfr | Other manufactured goods |
| Ser | Services |

The GTAP data set additionally provides a range of elasticities of substitution and elasticities of transformation to be used in the calibration of production functions and Armington aggregates (describing the trade-off between imported and domestically provided varieties of a given good). Table 5.3.2 lists the elasticities used in the ICPA model and points to their respective data sources and values.

**Table 5.3.2. Elasticities of substitution and elasticities of transformation used in the ICPA model**

| Elasticity parameter | Trade-off | Value/Source |
|---|---|---|
| $\sigma_{(KLE,MAT)}$ | Capital-labor-energy aggregate vs. materials | 0.2 |
| $\sigma_{MAT}$ | Between intermediate materials inputs | 0.5(**)/GTAP 10(*) |
| $\sigma_{KLE}$ | Capital-labor aggregate vs. energy | 0.25 |
| $\sigma_{KL}$ | Capital vs. labor | GTAP 10(*) |
| $\sigma_{ENE}$ | Electricity vs. fossil fuel aggregate | 0.3 |
| $\sigma_{NEN}$ | Between fossil fuels | 0.8 |
| $\tau_{D,X}$ | Supply to domestic or export market | GTAP 10 (*,***) |
| $\sigma_{D,M}$ | Domestic vs. imported variety | GTAP 10 (*,***) |
| $\tau_{res}$ | Resource supply to sectors | GTAP 10 |

(*) ICPA elasticities are weighted averages of values by the GTAP 10 sector.
(**) For household consumption, GTAP 10 does not provide a value.
(***) GTAP 10 provides one parameter for the overall price sensitivity of trade flows; ICPA follows Lanz and Rutherford (2016) in calibrating $\sigma_{D,M}$ and $\tau_{D,X}$ from these values.

## 5.4 Policy Scenarios

As previously mentioned, the 2030 Georgian Climate Change Strategy attempts to prescribe how emissions in the demand categories of “transport”, “energy”, “buildings”, “industry”, and “agriculture” will change to reach the 11% reduction in GHG emissions, compared to the baseline scenario. According to the strategy document, the $CO_2$ emission reductions required are 15% for transport and energy, 5% for industry, and 2% for agriculture.[14] Nevertheless, the strategy remains vague as to which policy measures shall lead to these reductions in emissions.

In order to capture the different methods for attaining these overall targets, we have employed two policy scenarios for reaching category-specific targets, which are consistent with those set in the 2030 Georgian Climate Change Strategy document:

**Differentiated taxes:** Category-specific $CO_2$ taxes with different rates for emissions in each demand category, as set by policymakers. This assumes policymakers have sufficient experience with the effects of different $CO_2$ tax rates on emissions.

**Standards:** Category-specific $CO_2$ emission standards that prescribe various emission intensity standards for different demand categories. Standards are expressed as tons of $CO_2$ emitted per quantity of output produced. Policymakers are again assumed to be well informed regarding the effects on emissions (through efficiency gains and changes in output level) that such emission intensity standards may have.

We have also introduced an additional policy scenario to contrast these category-specific policy measures with a policy that allows emissions reductions to be implemented where they can be achieved at the least cost and where $CO_2$ emissions are taxed at the same rate throughout the economy:

**Uniform tax:** A uniform $CO_2$ tax is levied on all energy-related emissions throughout the economy. The policymaker is assumed to be able to set a $CO_2$ tax that can match the estimated reduction in emissions from the differentiated taxes and standards scenarios.

[14] Our model assumes that $CO_2$ emissions also have to be reduced by 11% (proportionality assumption).

It is worth noting that **our analysis is conducted by sector and by category, respectively.** Here, "sectors" reflect a partition of economic activities according to their output. GTAP uses a sectoral partition of the economy similar to the UN general CPC and ISIC classifications,[15] while we aggregate the GTAP sectors into ICPA model sectors (see Table 5.3.1). The "categories" are defined from Georgia's most recent Climate Strategy and Action Plan and reflect the type of fuel use rather than economic output.

The relevant *sectors* included in our analysis for Georgia (from the GTAP dataset) are:

- Agriculture;
- Construction;
- Electricity generation;
- Energy intensive industry;
- Household consumption;
- Manufacturing;
- Recreational services;
- Services;
- Transport.

We reaggregated the sectors into the following broader emissions *categories*:

- Agriculture - solely representing the agricultural sector;
- Building - including emissions from household consumption and service sectors, mostly associated with heating, cooling, and lightning;
- Energy generation - including emissions from the electricity generation sector;
- Industry - containing emissions from energy intensive industry, manufacturing, construction, recreation, parts of services (those not included in the building category), and parts of the transport sector (emissions from industrial vehicles);
- Transport - including commercial and household transport.

## 5.5 Results

Although all the instruments in our model lead the economy to achieving national emission targets, their distributional and efficiency impacts differ.

**Tax levels and $CO_2$ emissions**

While setting a uniform carbon tax would make all categories bear the same tax burden per unit of $CO_2$ abated, the burden would vary with differentiated taxes or standards for category-specific contributions. The table below (Table 5.5.1) shows that compliance with commitments is costliest for the energy and transport categories in the differentiated tax scenario, which is hardly surprising since they experience the strictest restrictions on total carbon emissions.

**Table 5.5.1. Prices of uniform and differentiated taxes per ton of $CO_2$, by category**

| | Differentiated tax | Uniform tax |
|---|---|---|
| Transport | 40.81 | 21.61 |
| Building | 0* | 21.61 |
| Energy generation | 60.56 | 21.61 |
| Industry | 0.98 | 21.61 |
| Agriculture | 19.10 | 21.61 |
| Average tax rate | 23.4 | 21.61 |

*Note: The Georgian 2030 Strategic Plan and the 2021-2023 Action Plan for Climate Change do not set specific targets for the building category.

In the case of a uniform carbon tax, it is important to note that the final categorical distribution of $CO_2$ emissions differs from differentiated taxes and standards, and those category-specific targets set in the 2030 strategy. A uniform tax cannot effectively ensure the enforcement of category-specific targets since the reduction in emissions within observed categories will be guided exclusively by the relative cost of emission abatement. However, it does lead to the least expensive achievement of national targets. In this instance,

[15] UN general CPC and ISIC classifications

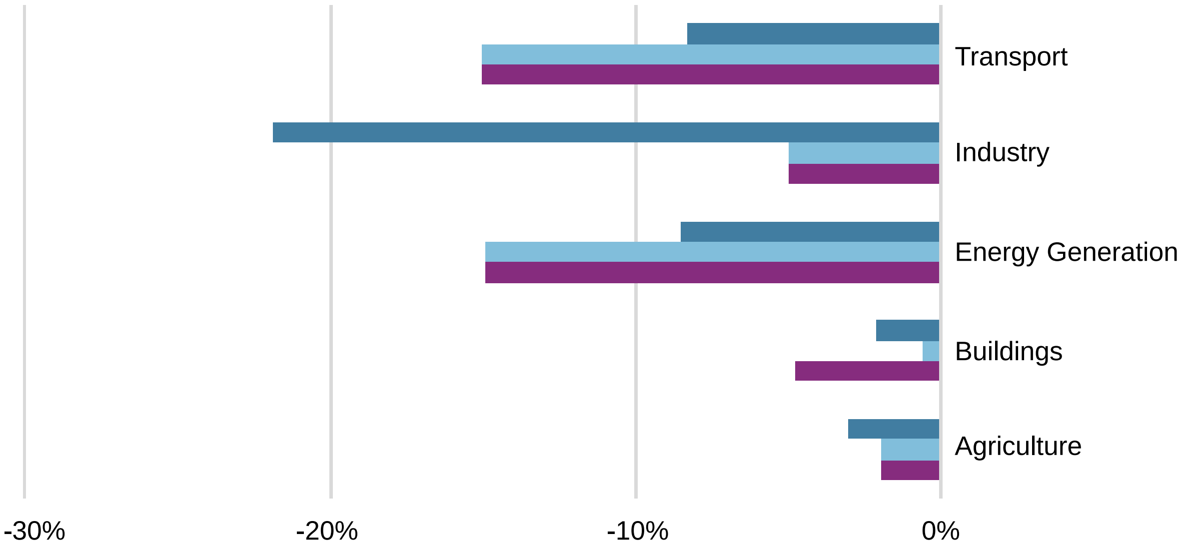
policymakers would only have to concentrate on setting the uniform carbon tax to a level that ensures the realization of national targets. Market forces could thereafter be expected to achieve these targets at the lowest cost. This approach is likely to lead to a more balanced redistribution of abatement costs across the targeted categories.

The intuition behind these results is that abatement costs tend to increase as one tries to reduce emissions within a given category (with the cheaper-to-abate emissions decreasing first). Rather than imposing more stringent targets to some categories, it is more efficient to leave economic agents the choice of abatement, and its extent. At the category level, those with the lowest cost of abatement would reduce emissions first, while those with the highest outlay would only reduce emissions later when the abatement costs in the other categories increases. This would lead to an optimal redistribution of abatement expense, given the cost of the existing abatement technologies and the value of the carbon tax. According to our model, this would lead to lower than planned abatement in the energy and transport categories, and higher than planned abatement in industry, agriculture, and buildings (Figure 5.5.1).

It is worth highlighting that the industry category reduces emissions the most under a uniform tax. These results are not surprising as the margin for emission reduction is greatest in industry, as implied by the implicit price per ton of $CO_2$ emitted in the differentiated tax scenario (containing emissions from construction, recreation, manufacturing, parts of the service and parts of the transport sector). It is the same case for agriculture, as the current targets for the sector are relatively modest compared to other sectors. Whereas the opposite is true in transport and energy generation, while there is a mixed picture for the building category.

Finally, the building category, which includes emissions from both household consumption and the service sector, appears to experience the lowest emissions reduction under the differentiated tax (given the non-binding nature of the target in the strategic document), and the highest under sectoral standards (setting standards that reduce emissions would lead to a reduction in household demand for services and, therefore, emissions below the target).[16] Under a uniform tax, building emission reductions remain in between these two options.

**Figure 5.5.1. Categorical relative percentage change in $CO_2$ compared to the baseline scenario in different policy scenarios**




| | Agriculture | Buildings | Energy Generation | Industry | Transport |
|---|---|---|---|---|---|
| Uniform tax | -3.07% | -2.14% | -8.51% | -21.89% | -8.31% |
| Differentiated tax | -1.95% | -0.57% | -14.95% | -5.01% | -15.05% |
| Standards | -1.95% | -4.79% | -14.95% | -5.01% | -15.05% |

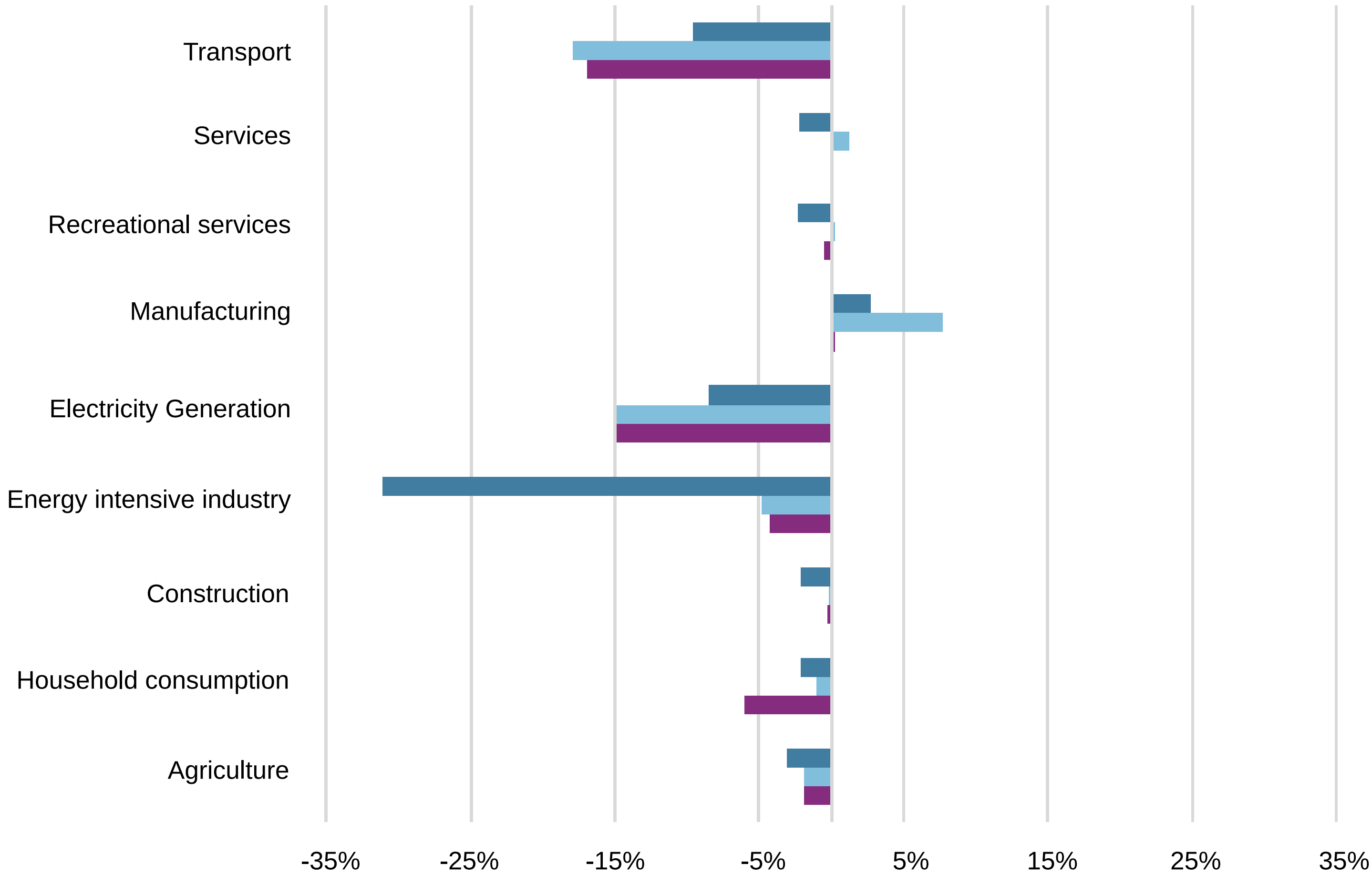
[16] Total household consumption decreases more under standards, and this leads to both a direct reduction in household emissions and an indirect reduction in emissions from such services as heating and lighting.

Considering the expected percentage change in $CO_2$ from a more disaggregated – sectoral – perspective (Figure 5.5.2), it is possible to see the effects of alternative emission reduction policies more clearly.

Under a **uniform tax**, the largest percentage reduction in $CO_2$ emissions is derived from energy intensive industry (more than a 30% reduction), followed by transport (-9.6%), and electricity generation (-8.5%). As highlighted in the category analysis, the uniform tax generally leads – with the notable exception of the energy intensive industry sector – to a smoother distribution of burdens in reducing overall $CO_2$ emissions.

Under **differentiated taxes**, the top three emission-reducing sectors are the same, though the ranking changes. The largest percentage reduction in $CO_2$ emissions is now derived from the transport sector (-18%), followed by electricity generation (-15%), and (distant third) energy intensive industry (-4.9%). Finally, under **standards**, the top three emission-reducing sectors are transport (-17%), electricity generation (-15%), and household consumption (-6%).

**Figure 5.5.2. Sectoral relative percentage change in $CO_2$ compared to the baseline scenario in different policy scenarios**




| | Agriculture | Household Consumption | Construction | Energy-intensive Industry | Electricity Generation | Manufacturing | Recreational services | Services | Transport |
|---|---|---|---|---|---|---|---|---|---|
| Uniform tax | -3.07% | -2.11% | -2.10% | -31.13% | -8.51% | 2.77% | -2.4% | -2.24% | -9.6% |
| Differentiated tax | -1.95% | -1.00% | -0.14% | -4.86% | -14.95% | 7.68% | 0.29% | 1.17% | -17.97% |
| Standards | -1.95% | -5.97% | -0.29% | -4.24% | -14.95% | 0.20% | -0.49% | 0.05% | -16.94% |

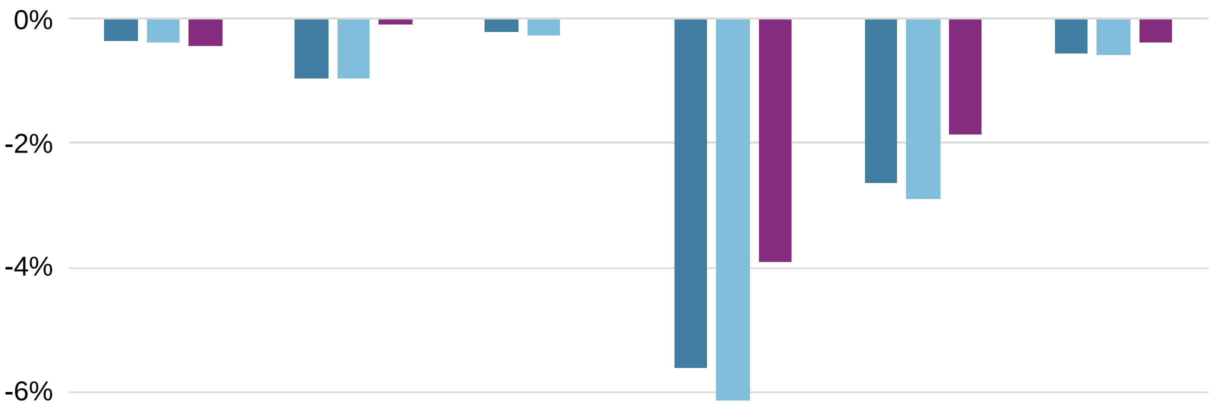
**Economic implications**

The main focus of this research is to assess the expected impact of alternative policy options on the welfare of Georgian society. We will start by presenting changes in GDP and its components, then focus on household consumption, since it is a central welfare measure in the given model.

**Demand-side**

One way to represent GDP is to sum up *household consumption, governmental expenditure, investments,* and *net exports* (which is the difference between the *exports* and *imports* of the country). The model allows us to identify the effects of the proposed measures on each of these components. As mentioned above, real governmental expenditure and investment are kept constant and changes in the corresponding values purely depict variations in price, while in other components this can be caused by alterations in both quantity and price. The results of the analysis are reported in Figure 5.5.3.

**Figure 5.5.3. Percentage change in different components of GDP – Demand-side**




| | Household Consumption | Governmental Expenditure | Investment | Export | Import | Total GDP Change |
|---|---|---|---|---|---|---|
| Uniform tax | -0.37% | -0.95% | -0.23% | -5.59% | -2.64% | -0.56% |
| Differentiated tax | -0.40% | -0.98% | -0.28% | -6.13% | -2.89% | -0.60% |
| Standards | -0.45% | -0.10% | 0.01% | -3.91% | -1.84% | -0.39% |

Our model shows that, due to the increased costs associated with $CO_2$ reduction, **all three policies result in a reduced nominal Gross Domestic Product (GDP)** compared to the baseline scenario, however the GDP reduction varies across policies. The reduction in GDP associated with the introduction of a uniform carbon tax amounts to 0.56% compared to the baseline scenario, while under the introduction of differentiated taxes and standards it stands at 0.60% and 0.39%, respectively.[17] It is important to highlight that such a reduction in GDP does not necessarily imply a reduction in social welfare, as it does not incorporate the improvements to environmental conditions in which individuals and companies live and operate, alongside their associated benefits.

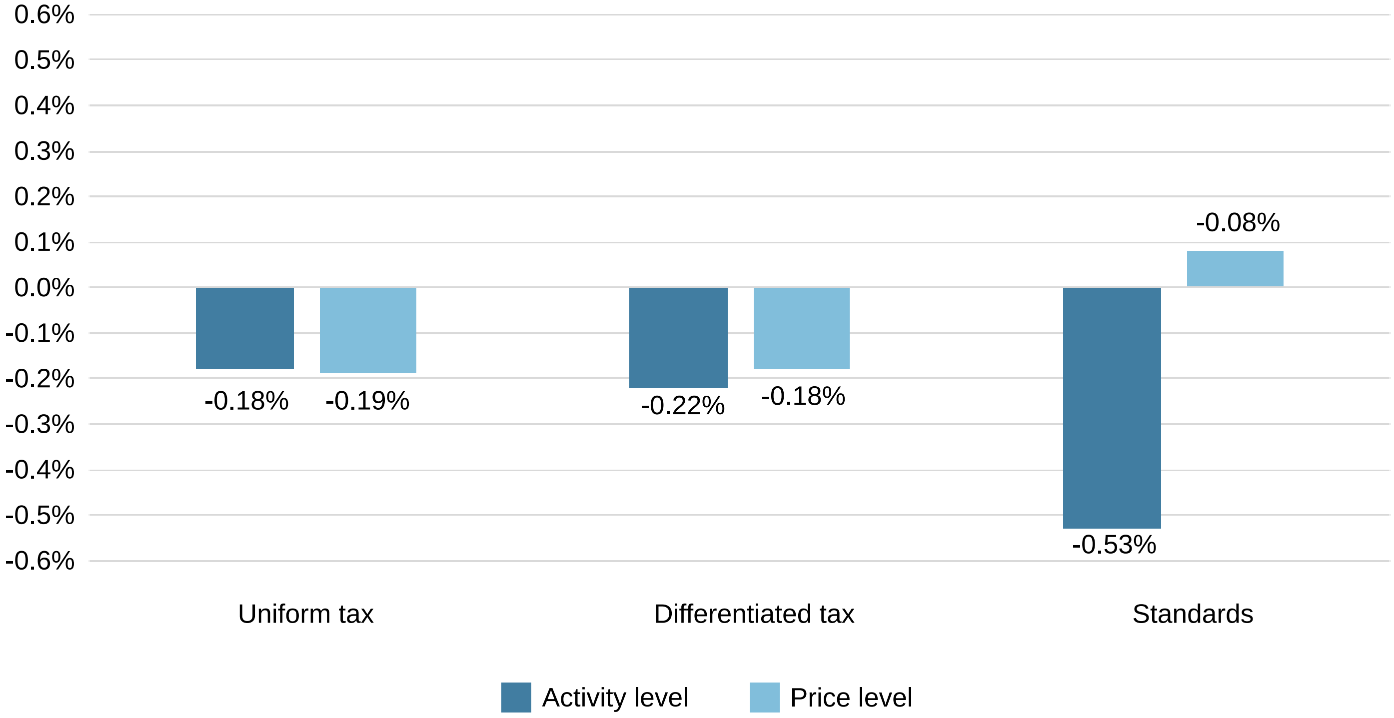
From a qualitative point of view, **we can observe a reduction in all GDP components**, for every option, **with *exports* experiencing the largest contraction.** Nevertheless, the impact of the options is still quantitatively different among different policy options (Figure 5.5.3). For instance, a reduction in *public spending*[18] and *investment goods* would be the direct effect of price level reductions; unsurprising, since the demand for machines, buildings, and infrastructure is likely to decline due to the restrictions imposed on production. **Real changes in household consumption can offer the most representative picture of how a policy option effects social welfare**. Compared to the baseline, we note a decrease in household consumption in each scenario, though **the least significant social**

[17] Changes in GDP (expressed in USD) are to some extent driven by exchange rate effects. These may be driven by assumptions about trade (trade closure) in the model.

[18] The same as governmental expenditure.

**welfare decline, in nominal as well in real values, is associated with the introduction of uniform taxes.** The introduction of both a uniform tax and differentiated taxes are reflected in decreased consumption (-0.18% and -0.22%, respectively) and price levels (-0.19% and -0.18%, respectively), whereas in case of standards, the reduction in consumption (-0.53%) offsets the increase in the price level (+0.08%) (Figure 5.5.4).

**Figure 5.5.4. Percentage change in real household consumption and the corresponding average prices of consumption goods**




The superior performance of uniform tax was expected, as this policy option allows for the least costly alternatives and leaves more income for households to spend on consumption goods and services. The introduction of a tax forces consumers to face the costs associated with their choices.[19] Standards, however, do not imply a full internalization of the costs associated with higher emissions from consumers. Cheaper energy services and cheaper energy intensive goods equate to more demand for those products. Therefore, to achieve the desired targets, standards must be set excessively high compared to the optimal level. This in turn leads to disproportionate production costs, which increases prices on the goods market and reduces the quantity of goods and services households can acquire. As such, ***household consumption* suffers from the highest decline under standards**. Not only is the amount spent on goods and services lower, given the price increase, the quantity of goods and services consumed by households undergoes an even more notable reduction.

It is also important to note that **the estimated welfare loss likely overestimates the true loss to households, which benefit from living in an improved environment. Such unmeasured gains are likely similar across the scenarios** as the total emission targets achieved are identical.

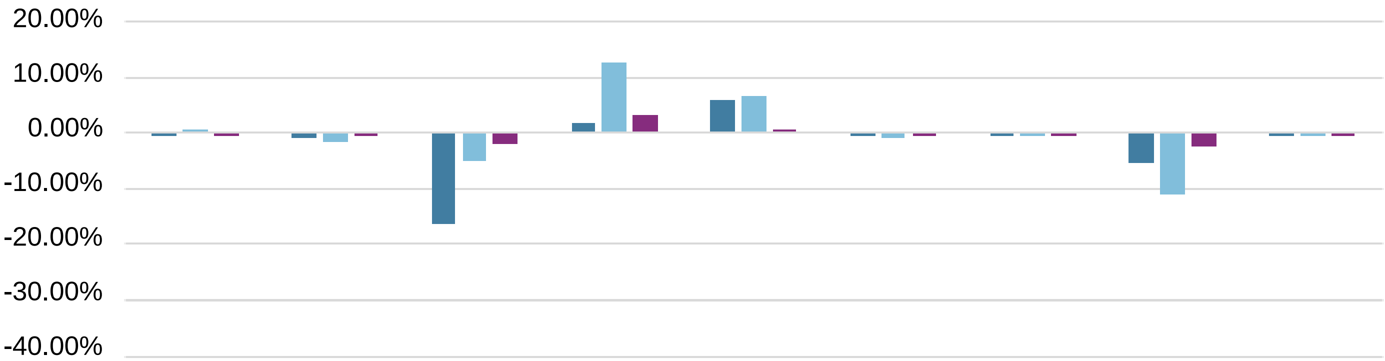
Finally, **the negative effect on *net exports* is purely quantitative, since the model regards Georgia as a small economy which cannot affect world prices.** Thus, looking at the trade balance, **there is a negligible real increase in *net exports* in the case of standards, while there is a marginal decline with uniform tax, and a greater reduction under differentiated taxes.**

**Sectoral analysis**

GDP can also be expressed as the sum of value-added (VA) generated in different sectors. Figure 5.5.5 below reveals what happens at the sectoral VA level for each of the different policy options.

[19] Note that even though they are costs for individual agents, taxes are not regarded as a real cost to society as - according to the model - tax revenues (including revenues from carbon taxes) are transferred back into society.

## Figure 5.5.5. Percentage change in different components of GDP – Sectoral Value-Added Analysis




| | Agriculture | Construction | Energy-intensive Industry | Electricity Generation | Manufacturing | Recreational & Other Services | Services | Transport | Total GDP Change |
|---|---|---|---|---|---|---|---|---|---|
| Uniform tax | -0.02% | -0.84% | -16.28% | 1.76% | 5.74% | -0.58% | -0.63% | -5.53% | -0.56% |
| Differentiated tax | 0.70% | -1.44% | -4.88% | 12.62% | 6.58% | -1.00% | -0.42% | -10.94% | -0.60% |
| Standards | -0.19% | -0.20% | -1.83% | 3.17% | 0.60% | -0.33% | -0.23% | -2.47% | -0.39% |

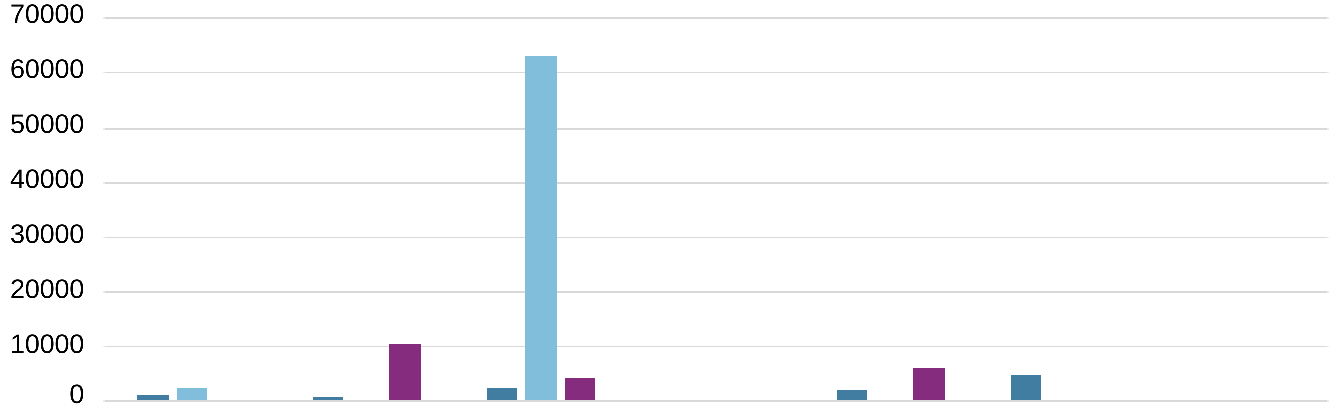
Under each policy option, VA generated in the ***construction, energy-intensive industries, recreation, services,*** **and the *transport* sectors suffer contractions** and more than offsets the **VA increases from the *electricity generation* and *manufacturing* sectors.** The only sector for which results vary, depending on the option considered, is agriculture. **The VA in the *agricultural* sector increases under a differentiated tax policy**, although it **decreases when uniform taxes or standards are introduced.**

It is important to remember that the difference in VA can be due to changes in both quantity (in activity levels/output of the respective sector) and price (where the market price of labor and capital reflect their marginal productivity and the value of the respective sector's output). By separating quantity from price effects, we discover that *transport and energy-intensive industries* are the two most adversely affected sectors, especially in real terms where the negative implications are compensated by increased product prices. *Electricity generation* and *manufacturing*, the most positively affected sectors, appear to gain for different reasons. While growth in the VA of the electricity generation sector is primarily triggered by price increases, the expansion in the manufacturing sector's VA would be higher without the price decreases that hit the sector. There are other logical outcomes, for example, transport and energy-intensive industries are the largest emitters in the economy, hence they experience the largest contraction. Their increased production costs would reflect in higher prices. However, since the manufacturing sector is not a key contributor to total $CO_2$ emissions, its value-added would expand as its output could increase without any restrictions, thereby more than compensating the decrease in prices. Finally, a reduction in electricity generation is likely due to the shrinking share of thermal power production, the main input of which, natural gas, would experience price increases due to policy restrictions.

Even though the effects are similar in each scenario, the magnitude of each differs substantially. The direction follows a logical sequence in every scenario, **the more carbon dioxide a sector is expected to reduce, the higher the decline in its value-added**. For example, under differentiated taxes and standards, the transport sector is more negatively affected than energy-intensive industries, and its VA declines less when a uniform tax is introduced. This is because under a uniform tax the transport sector does not require a 15% cut in emissions. When it is introduced, part of the burden is shifted towards energy-intensive industries, those which can reduce emissions at a lower cost. As uniform tax results in the fewest cost outcome among all policy options, it results in a better outcome for society as a whole.

It is also interesting to consider the average cost of abating one ton of $CO_2$ in each policy scenario. From Figure 5.5.6 one can see that cost distribution differs among economic agents and policy options. In the case of uniform tax, the service sector experiences the highest cost per ton of abated $CO_2$ compared to the baseline scenario, whereas, for differentiated tax, the construction sector incurs the highest margin cuts. As for the standards, the agricultural sector needs a substantial sacrifice to reduce one ton of $CO_2$. It is therefore helpful to discern which sectors may require additional time and preparation if policymakers decide to introduce any of these policy options (Figure 5.5.6).

**Figure 5.5.6. Loss of value-added per ton of abated $CO_2$ in different sectors (USD)**

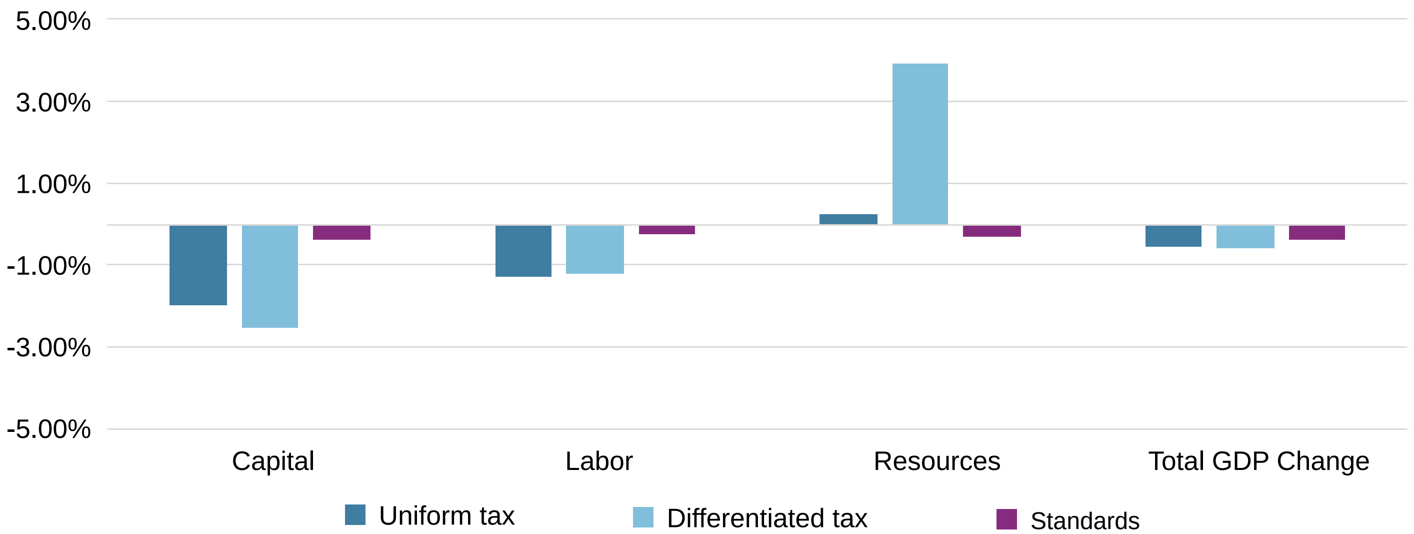



| | Household Consumption | Agriculture | Construction | Energy-intensive Industry | Recreational & Other Services | Services | Transport |
|---|---|---|---|---|---|---|---|
| Uniform tax | 1284 | 843 | 2377 | 179 | 2251 | 4904 | 335 |
| Differentiated tax | 2415 | | 62981 | 344 | | | 354 |
| Standards | 372 | 10568 | 4209 | 148 | 6348 | | 85 |

**Income-side**

Finally, another interesting way to look at GDP is in terms of remuneration to different factors of production, such as income to *capital, labor, and resources*. The economic impacts of the alternative policy options can consequently be analyzed via changes in the remuneration of factors utilized in generating GDP. Please note, the analysis does not include taxes or subsidies. Moreover, final conclusions about total welfare cannot be drawn from the given decomposition, as it simply represents the distributional effects among different factors of production. The results are presented below in Figure 5.5.7.

**Figure 5.5.7. Percentage change in different components of GDP – Factors of production**



In all policy scenarios, the remuneration received by capital and labor declines due to a reduced production level,[20] which translates into a decreased demand for capital and labor. The scale of this decrease is highest for capital under the differentiated tax and for labor under the uniform tax scenario. This occurs as sectors that contribute highly to $CO_2$ emissions are more capital intensive, and to meet emission targets they therefore have to decrease their production level more so than non-capital-intensive sectors, which leads to a reduced demand for capital. Both factors of production lose the least with the introduction of standards because, in this case, less reduction in output is needed to meet the predefined target levels.

Income from resources increases in both the uniform and differentiated tax scenarios, yet it declines under standards. In the model, resources are derived from gas, coal, crude oil, agriculture, and the manufacturing sector. Since gas, coal, and crude oil have a negligible share in total resources (14%), it is most informative to observe the effects on resources from the agricultural and manufacturing sectors. The real output of agriculture and manufacturing increase more under the uniform and differentiated tax scenarios rather than with standards. Thus, in the case of the former, demand for inputs of sectoral production increase correspondingly, while supply remains the same. Resultingly, the price of resources from these sectors keeps rising. Considering standards, growth in real agriculture, manufacturing, and crude oil products is minimal, while there is a decrease in the other sectors. Each of these alterations in combination translate into reduced prices, and a respectively diminished income from resources in these sectors.

# 6. CONCLUSION

Complying with the emission targets defined in Georgia's Climate Strategy and Action Plan, we have investigated the economy-wide implications of alternative policy options to discern the most effective measures and their effects on welfare. Specifically, three scenarios were analyzed: the introduction of differentiated carbon taxes (by category), emission standards, and a uniform carbon tax. The model shows a reduction in GDP in each scenario. This, however, does not reflect the true change in social welfare, as it fails to correctly capture the impact on the consumption utility of the Georgian population, nor does it factor in improved environment quality or the associated benefits. A better measure of changes in social welfare – although it still fails to wholly capture the benefits an enhanced environment – is represented by changes in household consumption. The assessment has shown that **under a uniform tax the market would achieve the overall emission target with the lowest loss of welfare**; due to a more efficient distribution of emissions reductions across sectors, leading to the least decline in household consumption. Significantly, category specific targets under this option would not be achieved, but the overall national emissions would be the same as under such category specific targets. Given that unmeasured benefits (a better quality environment and the corresponding advantages) can be expected to be identical across the three alternatives (all alternatives lead to the same reduction in $CO_2$ emissions), it indicates **that the uniform tax option would be the most efficient for the country.**

Having analyzed the impacts on different GDP components, it is clear that – under each scenario – exports experience the highest decline, resulting in reduced net exports. Nevertheless, the change in net exports is not substantial. Changes in GDP (expressed in USD) are to some extent driven by exchange rate effects. These may be driven by assumptions about trade (trade closure) in the model. Further research may reveal how results behave under different trade closures and highlight the sensitivity of results with respect to such modelling assumptions.

The sector-specific analysis shows that – under all policy options – ***transport* and *energy-intensive industries* are the hardest hit sectors, while *electricity generation* and *manufacturing* see a positive effect.** However, the magnitude of the effect differs. For example, both transport and energy intensive industries shrink the least under standards. When taxation is used, energy intensive industries shrink the most under a uniform tax and less with differentiated taxes, while the opposite is true for the transport sector. This seems to indicate the greater potential for an efficient reduction in greenhouse gas emissions within energy intensive industries. In all policy scenarios, capital and labor income decrease, due to reduced production levels in complying with the emission targets. While resource income increases under both the uniform and differentiated tax scenarios, and declines under standards, which may be due to the effects of supply and demand forces on resource intensive sectors, mostly agriculture and manufacturing.

[20] Factor endowments are fixed in the economy, consequently supply is the same while demand is decreasing, reflected in reduced wages.

# 7. RECOMMENDATIONS

The simulation exercise conducted highlights the importance of equating marginal abatement costs across sectors, rather than attempting to set arbitrarily differentiated taxes or emission standards. Setting a uniform carbon tax and letting market players freely explore their optimal response leads to a higher level of social welfare, and thus to a greater extent preserves households' ability to acquire and consume necessary goods and services. The introduction of standards emerged – instead – as a significant welfare-reducing option; with companies and consumers paying only indirectly for reducing emissions, but not actually being taxed (and, therefore, bearing the cost) for the emissions generated.

To ensure the most effective implementation of the analyzed policy options, society should be informed beforehand about any planned changes. This would grant producers and consumers enough time to adjust. Concurrently, active campaigns should increase awareness and expose any expected costs and benefits for economic agents.

Moreover, in order to efficiently achieve the set targets on time, climate change mitigation policy actions should be properly coordinated among the responsible institutions, business associations, and civil society. As the country needs to comply with international commitments towards UNFCCC, institutional level policy options should, ideally, also be complemented by business initiatives in the green economy.

Each of the policies examined in our exercise require, for maximal effectiveness, strong knowledge of the relationships across sectors, of linkages between production in each sector, and of greenhouse gas emission generation. In the absence of perfect information, policymakers will likely be unable to set a policy to the optimal level, therefore it may be possible to take advantage of the lessons learnt in our exercise and iteratively converge fairly close to the optimum. One possible approach is to set a uniform carbon tax and adjust it progressively (up or down) depending on the amount of emissions generated by the economy, contingent on the final target. Market forces would ensure that the emission reductions take place at the lowest possible social cost. If policymakers find differentiated targets indispensable, monitoring the marginal abatement costs in different parts of the economy would help notify policymakers of inefficiencies and indicate when differentiated targets should be shifted from one category to another.

For this to be possible, setting up a well-functioning system for monitoring and evaluation is required to collect real-time, detailed data about greenhouse gas emissions and – if differentiated targets are implemented – marginal abatement costs. This will help improve the accuracy of policy actions towards the achievement of national goals and ensure timely adjustments in case of deviations.

In consideration of the potentially vast economic and social impacts of policies cutting greenhouse gas emissions, it is advisable to also gather a wide range of socio-economic data regularly. Such data should be utilized in assessing the economic and social impacts of the chosen options, and to highlight critical areas where supporting interventions might be necessary. Thus, further – and continued – analysis is needed to stimulate more efficient, effective, and equitable evidence-based policymaking towards climate change mitigation.

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