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REPORT

ASSESSMENT OF SOCIAL AND ECONOMIC IMPACTS OF INCREASED AMBITION NDC ON ENERGY, AGRICULTURE AND WATER MANAGEMENT SECTORS IN UZBEKISTAN

UZBEKISTAN, 2021

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This report provides the results of modeling and assessment of the three sectors – energy, agriculture and water management that are the key ones for low-carbon development in Uzbekistan. They have been considered in the twofold: in terms of formation of a national socially-oriented model of transition to a green economy and, at the same time, the implementation of the international obligations committed nationally to reduce greenhouse gases emissions. The associated overall importance of these sectors for the Central Asia region and the need for appropriate concerted action was considered as well.

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Abbreviations and symbols used

AEMCS	Automatic Electricity Metering and Control System
AV	Added Value
BGU	Biogas Unit
CC	Climate Change
CCSGT	Combined-Cycle Steam and Gas Turbine
CHPP	Combined Heat and Power Plant
CIS	Commonwealth of Independent States
DI	Drip Irrigation
EE	Energy Efficiency
GDP	Gross Domestic Product
GHG	Greenhouse gases
GO	Gross Output
GTU	Gas Turbine Unit
LULUCF	Land Use, Land-Use Change and Forestry
mult (X)	Multiplier of Output by Final Product
TPP	Thermal Power Plant
RES	Renewable Energy Sources
SDGs	Sustainable Development Goals
SNA	System of National Accounts
UNDP	United Nations Development Programme
UZS	Uzbek Soum (national currency)
WDI	World Development Indicators (World Bank Database)
WPP	Wind Power Plant
SCFi	Sectoral Carbon Footprint i.
ΔGIFPi	Growth in Industry Final Products i.
ΔCIOi	Changing Industry Output i.
SGGEi	Sectoral Greenhouse Gas Emissions i.

Introduction

The overall goal of this and previous stages of the study on this topic is to develop recommendations for the formation of new commitments of Uzbekistan to reduce greenhouse gas emissions (GHG) under the Paris Agreement.[1]

As part of the *first stage of the study* in 2020[2], it was found that developing countries have achieved the greatest success in switching to a low-carbon development trajectory, which managed to form a climate policy model based not only on international GHG emission reduction commitments, but also considering the national development priorities. As part of this approach, investments in the green technologies have contributed to **strengthening social progress, expanding employment and increasing the average income of citizens of these countries.**

In the process of searching for such a model for Uzbekistan, it was found that *large-scale investments in green technologies alone are not enough to transition to a low-carbon economy*. Investments in green projects will be ineffective without strengthening institutions, improving macroeconomic environment, changing the priorities of economic policy aimed at reducing pressure on natural resources and diversifying the economy. This hypothesis was confirmed through analysis of national statistics on GHG emitting sectors, and an econometric analysis of statistics from 76 developing countries.

Another result of the first study was the conclusion that the **traditional approach to the development of green economy can have some impact on employment and income of the population in Uzbekistan in the short and medium term.** Using the example of the project implemented in the Power Sector (PS) to replace equipment at the seven thermal power plants (TPP) with combined-cycle steam and gas turbines (CCSGTs), the effects related to gas consumption decrease and other intermediate products while maintaining the same electricity generation were modeled (based on the "Input-Output" method[3], i.e. I-O). Calculations have shown that CCSGT reduces the employment and income of the employees in the technologically interrelated sectors.

Approaches to the assessment of carbon footprint for all sectors of the economy, including those that are not direct emitters, were also worked out. Recommendations on approach to the formation of a carbon regulation policy in Uzbekistan were formulated.

Within development of the research, the **two key tasks** were set:

[1] Law of the Republic of Uzbekistan "On ratification of the Paris Agreement" No. 491 of 02.10.2018

[2] The report "Assessment of the impact of measures to reduce greenhouse gas emissions on the social and economic situation in Uzbekistan", Tashkent, 2020.

[3] The I-O method represents the intersectoral balance of the Republic of Uzbekistan. It gives a picture of the flows of goods and services, presenting indicators by: a) *aggregation levels* (macroeconomic and sectoral); b) *purpose* (goods/services for final consumption, including household consumption, government expenditures, exports, investments); c) *production goals* (final/intermediate consumption); d) *sources of origin* (import/local production). For each sector and for the economy as a whole, the balance identities are performed: a) production equals consumption; b) equality of GDP by any measurement method, i.e. production method (amount of value added for all sectors); method of calculation applied for final consumption; and method of calculation by factor value.

1) To deepen the previous study and strengthen recommendations for the *formation of a national socially-oriented model of transition to a green economy* with consideration of fulfillment of the *international commitments for GHG emissions reduction* to which the country would sighed-in;

2) To deepen the analysis of sectors that are the key subjects to low-carbon regulation. For Uzbekistan, *in addition to energy sector, such sectors are agriculture and water resources management ones*. These sectors: a) make a decisive contribution to GDP production; b) host a significant part of the employed population, including those who are employed in agriculture (sector with the lower level of income generation); c) are crucial in terms of the structure of GHG emissions (energy and agriculture); and d) are the most vulnerable to the climate change impacts. At the same time, the problem of efficient use of water resources is very common for the countries in Central Asia and requires coordinated actions of all countries of the region.

As a result, **an active climate policy is largely formed in these three sectors**. Moreover, the sectors are key to ensuring the well-being of the population and determining the success of **a number of long-term strategies adopted by Uzbekistan for the period up to 2030** (national SDG goals, Poverty Reduction Strategy, Employment Strategy, Social Protection Strategy, etc.).

The report consists of 6 sections and 11 annexes.

The first section presents the sectoral structure of GHG emissions based on the results of the GHG emission inventory conducted by the Center of the Hydrometeorological Service of the Republic of Uzbekistan (Uzhydromet) for the period 1990-2017.

The second section analyzes the impact of the reforms implemented in the three sectors that are under consideration of this study in 1993-2020 on the dynamics of their specific sectoral GHG emissions.

The third section analyzes the experience of developing countries that have reduced GHG emissions and, at the same time, achieved significant economic and social progress.

The fourth section analyzes the conditions at the macro level that ensure low-carbon development but are not limited only to the traditional investments' factor.

The fifth section includes estimates resulted from assessment the social and economic effects of utilization of alternative green technologies in the three sectors. The section is presented in 4 blocks:

- *Methodological issues related to carbon footprint assessment.* Implementation of an active climate policy requires an assessment of the carbon footprint for particular sectors as well as for the economy as a whole, and assessment of each sectors' contribution to changing this indicator. This block summarizes the existing approaches on the integral assessment of the level of economy carbonation, based on that the alternative estimates of amount of specific sectoral GHG emissions are made.
- *Assessment of the social and economic impacts of utilization of alternative green technologies in the energy sector.* Which green technologies used in the energy sector are more promising: projects on use of the combined-cycle steam and gas (CCSGT) units by the thermal poverty plants (energy saving), or projects focused on harnessing the technologies using the renewable energy sources (RES), in this case, the project on wind turbines? To answer this question, the results of the analysis examining utilization of CCGTs in the energy sector (2020) were supplemented with similar assessment of a specific project on piloting the first wind power plant (WPP) in Uzbekistan. The criteria for efficiency of green technologies used included financial stability of energy sector, reduction of carbon footprint of the economy as a whole, maximizing the projects' contribution

to expanding employment and income of the employed ones, and minimizing the investment costs.

- *Assessment of the social and economic impact of utilization of alternative green technologies in agriculture.* For agriculture, the utilization of *biogas units* (BGU) for the period up to 2040 have been worked out with consideration of the growth of livestock and degree of its waste (manure) use by BGU. The associated effects on employment were estimated based on the two options: a) traditional one, which envisages import of equipment and consumables, and b) establishment of domestic production of biogas units. The comparison of options was done based on the criteria included reducing carbon footprint, expanding employment and investment costs.
- *Assessment of water-saving technologies' contribution into adaptation of economy and population to water stress and deficiency.* The macroeconomic, sectoral and social effects with consideration of various degrees of water resources scarcity were assessed based on estimates of potential for increasing efficiency of the existing irrigation system and introduction of drip irrigation technology.

The sixth section contains recommendations on consideration of the national development priorities at formulation of next generation NDC commitments. The results and conclusions obtained from the modeling allowed to outline *a national model of transition to low-carbon economy,* which ensures not only reduced GHG emissions, but also increased employment, income growth and poverty reduction.

1 | Sectoral Dynamics of GHG Emissions

According to the data of the GHG inventory conducted by the Center of the Hydrometeorological Service of the Republic of Uzbekistan (Uzhydromet) for the period 1990-2017, the total GHG emissions in 2017 amounted to 177.8 million tons of CO_2-eq. (excluding CO_2 absorption by forests in the Land Use, Land Use Change and Forestry) and 173.1 million tons of CO_2-eq., with consideration the absorption of CO_2 by forests. In general, during 1990-2017, the GHG emissions *decreased* by 9.5%, while only by 9.2% for the period 2010-2017 (Table 1).

The structure of GHG emissions in Uzbekistan includes:

- *Emissions of 4 direct GHG:* carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and hydrofluorocarbons (HFCs). Estimates of CH_4, N_2O, and HFCs emissions are converted into CO_2 equivalent. The largest share is accounted for carbon dioxide, its contribution to the total GHG emissions was 58% in 2017. Methane was accounted for 36%, nitrous oxide for 6.7% and hydrofluorocarbons for 0.2%.
- *Assessment was conducted for the sectors with the highest GHG emissions:* Energy (sub-category of "Fugitive emissions from natural gas processing facilities" under the category of "Fugitive emissions from fuels"); Industrial Processes and Product Use, including F-gases (categories "Chemical Industry – Ammonia Production – CO_2 emissions", "Chemical Industry – Nitric Acid Production – N_2O emissions", "Mineral industry – Cement Production"); Agriculture, Forestry and Other Land Use (category "Forest Lands remaining as the Forest Land"); and Waste (category "Solid Waste Disposals").

TABLE 1 GHG EMISSIONS IN UZBEKISTAN, 1990-2017, MILLION TONS OF CO_2-EQ.

Year	Energy*	Industrial Processes & Product Use (IPPU)	Agriculture	Waste	Total GHG Emission	LULUCF**	Net-GHG Emission
1990	165.2	8.4	14.1	1.9	189.6	-12.1	177.5
2000	200.9	5.8	14.7	2.4	223.8	3.7	227.5
2010	162.8	8.3	23.3	2.5	196.9	8.4	205.3
2013	128.6	8.1	26.6	2.6	165.9	5.2	171.1
2014	130.9	8.6	27.4	2.6	169.5	-2.6	166.9
2015	124.3	8.3	28.5	2.6	163.8	-4.1	159.6
2016	129.0	8.6	29.9	2.6	170.1	-4.7	165.4
2017	136.1	8.3	30.6	2.7	177.8	-4.7	173.1
Trend							
Δ (1990 -2017)	-17.6%	-1.2%	117.0%	40.1%	-6.2%		-2.5%
Δ (2010 -2017)	-16.4%	-1.2%	31.3%	8.0%	-9.7%		-15.7%
Contribution							
1990%	87.1%	4.4%	7.4%	1.0%	100.0%		
2013%	77.5%	4.9%	16.0%	1.6%	100.0%		
2017%	76.6%	4.7%	17.2%	1.5%	100.0%		

Source: Hydrometeorological Service Center (Uzhydromet)

Notes: *According to the IPCC classification, the energy sector covers GHG emissions from the combustion of fuel in stationary and mobile sources (generation of electric and thermal energy, transmission of electric and thermal energy, transport), as well as GHG emissions from the extraction, processing, transportation of natural gas, oil and coal.

**Land Use, Land Use Change and Forestry

This table is based on preliminary GHG calculations performed as part of the preparation of the first biennial update report of the Republic of Uzbekistan (which was scheduled for completion at the end of July 2021.

In 1990-2017, the sectoral structure of GHG emissions changed: the share of the energy sector decreased (from 87.1% to 76.6%) and the share of the agriculture sector increased (from 7.4% to 17.2%) due to an increase in the number of livestock and the use of nitrogen fertilizers. The contribution of the IPPU and Waste sectors remained almost unchanged. In the Land Use, Land Use Change and Forestry (LULUCF) sector, there were significant changes in CO_2 emissions and removals, but contribution of this sector to total GHG emissions is insignificant (about 2.5%).

In 2017, **93.8% of the total GHG emissions were accounted for by energy and agriculture.** These sectors should be considered as the **key ones for climate policy.**

2 | Impact of Reforms on Dynamics of GHG Emissions

The Annex 1 summarizes the main reforms implemented in the energy sector in 1993-2020. When analyzing their impact as related to GHG emissions reduction, the following points were taken into account:

- *Scale of energy system:* Uzbekistan is the largest producer of electricity in Central Asia. In 2020, the capacity of power system was 14,131 MW. In 2000, this figure was 7,750 MW, and 10,830 MW in 2016.[4] That is, over 16 years, 3,000 MW were introduced, and the same amount was only in 2017-2020. Transportation and distribution of electricity is implemented through the power transmission lines of which length is over 241,000 km and their voltage vary from 0.4 to 500 kV. Uzbekistan also has cross-border transmission lines with Afghanistan, Kazakhstan, Kyrgyzstan, Tajikistan and Turkmenistan, i.e. there is potential for accelerating the process of decarbonization of the region.
- *Management System.* The centralized management system that existed before 2001 did not allow improving the efficiency of electricity production/sales. To solve this problem, the Presidential Decree # 2812 on “Deepen the reforms in the electricity sector of the Republic of Uzbekistan” was adopted on 22 February 2001. However, until 2019, the management system remained relatively centralized that did not allow changing the monopolistic nature of the energy market and energy pricing.
- *Growth of energy demand by 2030.* The power system generates annually 66.4 billion kWh[5] (2019), of which more than 85% is produced at the thermal power plants (TPP) and combined-cycle heat and power plants (CHPP) running on the natural gas. About 11% is accounted for by hydro power plants (HPPs). According to the projections, the demand for electricity will increase to 120.1 billion kWh by 2030.[6] It is expected to meet this demand through: a) stopping natural gas exports by 2025 due to increasing the degree of its internal processing; b) increasing generating capacities; and c) introducing energy-saving technologies. The total energy saving potential is estimated at 22.7 million tons annually that would result in million tons of GHG emissions reduced.[7]

In general, the 5 key reforms were initiated and being implemented in the energy sector:

- **Institutional reforms to ensure the country’s energy security in the context of the Soviet Union collapse since 1991-1992:** a) creation of a single management body in the electric power sector and in the coal sub-sector (SJSC “Uzbekenergo”); b) introduction of new generation capacities and reconstruction of the existing facilities; c) ensuring stability of electricity production and power transmission in the Central Asian by maintaining the country’s presence in the unified energy system of Central Asia until 2009. The reforms led to a number of effects that were accompanied by increase of GHG emissions: a) volume of hydrocarbon production increased; b) country stopped importing energy re-

[4] Ministry of Energy of the Republic of Uzbekistan

[5] Ministry of Energy of the Republic of Uzbekistan

[6] The Concept of providing the Republic of Uzbekistan with electricity for 2020-2030, Ministry of Energy of the Republic of Uzbekistan, 2020.

[7] “Towards sustainable energy: Low-carbon Development Strategy of the Republic of Uzbekistan”, UNDP 2015.

sources since 1996; c) energy exports increased by more than 10% annually, and energy resources consumption domestically increased by 8-8.5% annually since 2009; d) over 400,000 toe of fuel saved through energy facilities' modernization and repairs.

- **Expansion, retrofitting and modernization of generating capacities:** a) replacement of outdated equipment with new energy generation technologies such as combined-cycle steam and gas turbines (CCSGT) and cogeneration gas turbine units (CGTU); b) modernization of low-voltage power grids (10-6-0.4 kV). The introduction of CCSGT and CGTU will reduce the specific fuel consumption for electricity production[8]. In this case, the total fuel burned at the 7 pilot TPPs will decrease to 36% compared to the current fuel consumption[9]. Fuel savings would amount to 4.2 million toe or 5.16 billion m^3 of natural gas. The modernization will be completed through: a) replacement of outdated steam power generation equipment for CCSGT and CGTU at all TPPs/CHPPs is implemented; b) introduction of new environment-friendly and clean coal technologies at the coal-fired TPPs.
- **Development of alternative (renewable) energy sources.** For 2020-2030, the goal is to increase the share of RES in the total electricity production from 10% to 25%[10]. This will be achieved through using solar water heaters in all new buildings/structures, as well as construction of: a) medium and small sized hydropower plants (HPPs); b) solar power plants; d) wind power plants; and e) nuclear power plant.[11]
- **Reduction of energy losses.** Losses (methane leakage in oil and gas sector, losses in power transmission and distribution grid, etc.) do not allow reducing the cost of electricity production and are a source of GHG emissions growth. This problem is being solved by: a) expanding smart remote metering of electricity consumption at the demand side (population); and b) rehabilitation of the existing and construction of new power transmission lines, and c) energy audit of enterprises with high energy consumption, which will be carried out on the basis of analytical data from the Unified Information System of the Ministry of Energy, starting from 2022[12].
- **Creating a competitive energy market.** In 2019, a new stage of reforms aimed at transition to a competitive energy market by 2025 was started[13]. This will be implemented through restructuring oil and gas system, modernizing gas transportation system, increasing hydrocarbon production, improving metering and monitoring of the primary energy resource production (Concept of Energy Sector Development up to 2030). In the power sector, it is planned: a) introduce a corporate governance at newly established energy companies (JSC "Thermal Power Plants", JSC "Regional Electric Networks", JSC "Main Electric Networks of Uzbekistan"); c) commercialize energy companied in energy sector; d) implement energy tariff reform; e) increase participation of private sector; and e) liberalize electricity prices.

The Annex 2 summarizes the **main reforms implemented in agriculture** in 1993-2020. When analyzing their impact as related to GHG emissions reduction, the following points were considered:

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[8] "Towards sustainable energy: Low-carbon Development Strategy of the Republic of Uzbekistan", UNDP 2015.

[9] Thermal power plants: Syrdarya, Novo-Angren, Tashkent, Navoi, Takhiatash, Angren, Talimarjan.

[10] Presidential Decree No. UP-3012 "On the Program of measures for the further development of renewable energy, improving energy efficiency in industries and the social sphere for 2017-2021," May 26, 2017

[11] It is expected that the first nuclear power plant will consist of two reactors with a capacity of 1,200 MW each.

[12] Resolution of the President of the Republic of Uzbekistan "On additional measures to improve the energy efficiency of the economy and reduce the dependence of the economy on fuel and energy products by attracting available resources" No. 4779 dated July 10, 2020 https://lex.uz/pdfs/4890081

[13] Presidential Decree No. UP-5646 "On measures to radically improve the management system of the fuel and energy industry of the Republic of Uzbekistan," February 1, 2019

The structure of GHG emissions. In the structure of GHG emissions, the fermentation in the digestive system of ruminants (cattle and sheep) is accounted for 51.2%; storage of manure, its use as fertilizer for soil, and manure residues on pastures amount to 30.2%; and mineral fertilizers is accounted for 13.8%[14]. In addition, a small amount of methane is emitted with use of organic fertilizers, growing rice, and burning agricultural waste.

The technology factor. According to the "Soviet" agrotechnological map, each hectare during one growing season must undergo 18 types of processing using tracked and wheeled vehicles. To process one hectare, up to 300 liters of fuel are burned annually. Considering that 4,300,000 hectares are used for row crops in Uzbekistan, the total fuel consumption is 1,290,000 tons per year.

In general, the 5 key reforms were initiated in agriculture:

- **Institutional transformations** of unprofitable state farms into collective farms (agricultural shirkats), the subsequent reorganization of agricultural shirkats into private farms and dekhkan farms, as well as the creation of diversified farms (since 2015). The impact of these reforms on the dynamics of GHG emissions was weak, since the financial capabilities of agricultural producers remained low (inability to buy technologies and drugs to adapt to climate change).
- **Reducing lands for cotton growing and increasing lands for growing winter wheat, fruit and berry, vegetables, vineyards, etc.** Reduction of agricultural lands for growing cotton resulted in irrigation water savings (cost of irrigation water used for wheat is 2 times lower than for cotton) and less use of machinery and fuel (use of machinery in cotton fields during the growing season is 10 times or 3 times higher than for wheat). The associated GHG emissions reduction was achieved.
- **Expansion of intensive gardens and greenhouses with using resource-saving technologies.** Technologies used in gardens and greenhouses (solar water heating panels, drip irrigation, and hydroponics) are instrumental for: a) adaptation to extreme weather events and climate risks, and b) reduction of GHG emissions (use of fuel-based equipment was reduced/excluded).
- **Abolishing the state orders for grain and cotton growing (since 2020)**. It is expected that this will result in reduction in GHG emissions by up to 30% through the purchase of resource-saving technologies. In addition, market prices (instead of government orders) will enable water savings due to the cultivation of highly profitable crops and the introduction of water-saving technologies;
- **a sharp increase in the number of cattle**. During 1992-2020, the number of cattle increased from 5,275 heads to 12,611.8 thousand heads.[15] In the absence of proper processing of animal waste (for each unit of cattle there is 1.37 tons of fermentation per year), this has resulted in a sharp increase in GHG emissions in agriculture over the past 30 years.

The Strategy of Agriculture Development for 2020-2030[16] stipulates ambitious goals aimed at: a) reduction of water consumption per 1 ha of irrigated lands by 20% by 2030; b) reduction of associated GHG emissions in agriculture by 50%.

[14] Report of the national expert on agriculture Mukhamedzhanov Sh. "Study of the main factors affecting agricultural production and the associated reduction of greenhouse gas emissions", 2021.

[15] As of July 1, 2020. Source: State Statistics Committee

[16] Presidential Decree No. UP-5853 "On approval of the Strategy for the Development of agriculture of the Republic of Uzbekistan for 2020-2030," October 23, 2019

Annex 3 summarizes the **main reforms implemented in the water resources management and hydropower sectors** in 1993-2020. The following points related to GHG emissions reduction were taken into account in the analysis:

- *A factor of growing water scarcity.* The water withdrawal limit for Uzbekistan is set at 64 billion m^3 annually. Due to global climate change and problems of transboundary water use, the actually used annual volume of water is now 51-53 billion m3, i.e. 20% lower in relation to the established water intake limit set.
- *A factor of hydro power plants scaling-up.* The gross hydropower potential of Uzbekistan (based on 656 rivers) is estimated at 88.5 billion kWh, and technical one is 21.09 billion kWh. Currently, only 6.27 billion kWh are generated using HPP, i.e. less than 30%[17].

In general, the following key 4 reforms have been initiated in 1993-2020:

- **Transition to water rationing since 1993.** Water withdrawal limits were introduces for agricultural water users as 2 times a year and 1 time a year for non-irrigation water user. On the one hand, this resulted in decrease of water resources consumption the formal consumers. On the other hand, the following problems were observed: a) increased unauthorized water withdrawal; b) increased water transportation costs (procurement of pumps and transport for water delivery); and c) increased fuel consumption by additional equipment required for water delivery. In general, the limiting water withdrawal was rather contributed to increases GHG emissions in water management sector.
- **Rehabilitation of irrigated lands and promotion of efficient use of water resources.** As a rule, these tasks were implemented under the national programs aimed at reduction of water losses and decrease of soil salinity through: a) upgrading the amelioration and reclamation equipment and machinery available in the water users' associations and water resources management organizations; and b) repair/restoration of irrigation canals, collector and drainage networks, water pumps and other equipment.
- **Additional support measures during periods of low water availability.** The basis for planning agricultural and water-energy activities is the Uzhydromet forecast on the expected water availability in the Amudarya and Syrdarya river basins during the vegetation season. The Cabinet of Ministers developed government resolutions on measures aimed at prevention of negative impact of low water availability during the periods of water stress and drought (2000, 2008, 2011, 2014 and 2018) that included: a) sowing seeds with follow-up coverage by polyethylene film and irrigation with use of plastic pipes; b) additional purchase of portable diesel pumps for irrigation water supply from collector and drainage networks to fields; c) cleaning of irrigation networks and repair of hydrotechnical facilities. As a result, increased GHG emissions were observed due to: a) increased production of polyethylene (energy-intensive and health harmful technology); and b) increased demand for energy resources, fuels and lubricants, and construction materials.
- **Support for hydropower.** Hydropower is an ideal source of power generation in terms of reduction of GHG emissions. HPP is well suited for quick regulation of power generation production (TPP can regulate power generation within a few hours, while and for nuclear power stations (NPP) this requires several days). The HPP also allows to accumulate water in winter and dump it for irrigation needs in summer. There are 36 HPPs operating in the country with a total installed capacity of 1.83 GW and electricity generation of about 6.8 billion kWh per year[18]. The Strategy of Water Resources Management Sector Development for 2020-2030 sets the key priority goal as significant increase of hydropower generation share in the country's energy mix. However, there are many barriers such as

[17] Conceptual provisions and directions for the development of the use of renewable energy to produce electric and thermal energy in Uzbekistan in the long-run, Uzbekenergo, 2011.

[18] "Towards sustainable energy: Low-carbon Development Strategy of the Republic of Uzbekistan", UNDP, 2015.

expensive design work, complicated licensing procedure, standardization of equipment, etc. particularly related to micro HPPs to achieve this goal. Moreover, water resources deficiency affects power generation by HPPs (2-3 months a year HPP has low power generation output and/or is not operational due to deficiency or lack of water in the rivers)[19]. This situation results in use of coal firing TPP and reduces share of HPP share in the country's energy mix, and this therefore increases amount of CO_2 emissions.

Reforms in the water resources management sector neither promoted greater efficiency of water resources use, nor resulted in GHG emissions reduction due to the following reasons: a) 66% of the irrigation system channels have an earthen bed, and therefore 35-40% of water is lost during transportation in the irrigation networks; b) 94% of pumping stations using outdated equipment, which expired its service life, and they are not energy efficient; and c) water-saving technologies are have been introduced and are operational on only 6% of the irrigated lands.[20]

Overall, the reforms implemented in the three sectors did not have a systemic focus on reducing emissions. In 1990-2017, the specific GHG emissions in energy sector decreased from 1.027 t/ths kWh to 0.51 t/ths kWh (Fig. 1). However, this was achieved due to: 1) reduction of methane leaks in oil and gas sector; 2) deindustrialization of national economy (reduction of energy consumption resulted from mass closure of industrial enterprises) because of transition period shocks/structural reforms implemented in Uzbekistan but due to investments and harnessing advanced efficient green technologies. Obviously, the potential for such measures is very limited. In addition, in recent years, a course has been taken to create large industrial clusters, i.e. the process of deindustrialization of the economy of the economy will increasingly change to the opposite trend of reindustrialization of the economy. If this is not accompanied by the introduction of low-carbon technologies, the volume of GHG emissions can increase significantly.

The reforms in agriculture had more institutional reforming nature and did not contribute to GHG emissions reduction. The positive impact has been observed with promoting use greenhouses and establishment of intensive gardens (2019) as well as thanks to abolishment of the state orders for grain and cotton growing (since 2020). However, the scale of such impact is still insignificant. As a result, the dynamics of GHG emissions (in terms of tons of milk/meat production) is volatile.

Reforming the water resources management sector have not resulted in GHG emissions reduction and greater efficiency of water resources usage.

Ambitious plans to reform the sectors up to 2030 will require huge investments that at the same time could be directed to solving the social and economic problems. To identify an optimal ambition of national commitments for **GHG emission reduction, with consideration of potential social and economic effects**, it makes sense to consider the international experience and best practices.

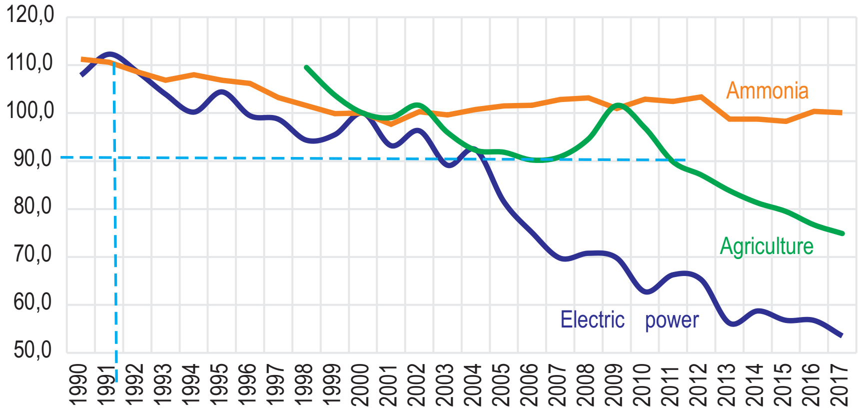
The following sections are formulated based on the following logic. Section 3 analyzes the experience of other developing countries, which have reduced GHG emissions but at the same time managed achieving significant economic and social benefits. Section 4 analyzes the macro level conditions that enabling low-carbon development without limiting focus on the traditional investment factor. Section 5 analyzes the social and economic effects achieved within the particular green projects implemented in the three sectors under consideration of this study. Section 6 contains conclusions and recommendations on considering

[19] Interview of the Director of the Andijan HPP https://anhor.uz/ekologiya/vnedrenie-maloy-gidroenergetiki-v-uzbekistane.-sovremennosty-i-perspektivi

[20] Presidential Decree No. UP-6024 "On approval of the Concept of Water Management Development of the Republic of Uzbekistan for 2020-2030," July 10th, 2020 https://lex.uz/docs/4892946

the national development priorities on the way of transition to implementation of climate action policy.

FIGURE 1 SPECIFIC GHG EMISSIONS IN "ENERGY" AND "AGRICULTURE" (LIVESTOCK) SECTORS, (2000=100%)



Source: authors

Sources of information: Emission statistics, Uzhydromet

Sectoral output in physical terms (million kWh, thousand tons of ammonia, meat, milk, State Committee for Statistics

Source: Report "Assessment of the impact of measures to reduce greenhouse gas emissions on the social and economic situation in Uzbekistan", UNDP, 2020.

3 | Trends in Low-Carbon Development: Uzbekistan and Developing Countries

The analysis was carried out for **76 developing countries** that are similar to Uzbekistan in terms of their development characteristics. Country selection criteria include: a) GDP per capita in the range of 3-25 thousand USD (PPP); b) population of at least of 5 million people; c) share of industry in the GDP structure is at least 20%. This approach ensured comparability with other countries, uniformity of data and applicability of the results of correlation and econometric analysis.[21]

Two samples were formed among 76 countries: 1) the CIS countries and 2) 5 benchmark countries, where the best trend of GHG emissions reduction and trend of strengthened social progress were observed.

These 5 countries were selected based on the following approach. Out of 76 countries, the 35 countries that had their **specific GHG emissions below the average level of 76**

[21] The information base of the analysis includes 12 Excel matrices with a dimension (76x20), each of which corresponds to a specific indicator. The rows of the matrix correspond to 76 countries, and the columns correspond to the year of the reporting period (from 2000 to 2019). The analysis used both the matrices in their original form and different estimates obtained on their basis: average median estimates, average median changes in indicators in initial units and as a percentage.

BOX 1. METHODOLOGY ON FORMATION OF INFORMATION DATA BASE BASED ON WORLD EXPERIENCE

The identification of factors and justification of their importance for the specific GHG emissions reduction was done through analysis of 76 developing countries for the period of 2000-2018 (2019) with use of the following indicators:

EM	Specific GHG emissions in kg of CO2 per USD(2015) of GDP (indicator of climate change mitigation)
EI	Energy intensity of the economy in kgoe per 2015 PPP 1,000 USD of GDP (indicator of resource saving and adaptation to climate change)
GFCF	Gross fixed capital formation (as % of GDP, an indicator of investment activity)
ManVe	Manufacturing, value added (as % of GDP, an indicator of economic diversification)
LabInd	Employment in industry (as % of the total number of people employed, a structural indicator)
Res	Resource rent (as % of GDP, an indicator of pressure on natural resources capital)
RQ	Regulatory quality indicator (ranging from -2.5 to 2.5, level of development of institutions)
CoCor	Control of corruption indicator (ranging from -2.5 to 2.5, level of development of institutions)
RoL	Rule of law indicator (ranging from -2.5 to 2.5, development of institutions)
GE	Government effectiveness indicator (ranging from -2.5 to 2.5, development of institutions)
KOF	Economic globalization index (a scale from 0 to 100)
SPI	Social progress index (a scale from 0 to 100)

The indicators were chosen based on: a) results of a review of publications on this subject[1]; b) availability of statistics in the world databases: The World Bank (https://databank.worldbank.org/source/world-development-indicators); International Energy Agency (http://renewnews.ru/iea/); Social Progress Imperative Agency (https://www.socialprogress.org/mission); and c) need to consider the social effects when implementing measures on climate change mitigation

[1] Report "Assessment of the impact of measures to reduce greenhouse gas emissions on the social and economic situation in Uzbekistan", UNDP, Tashkent, 2020

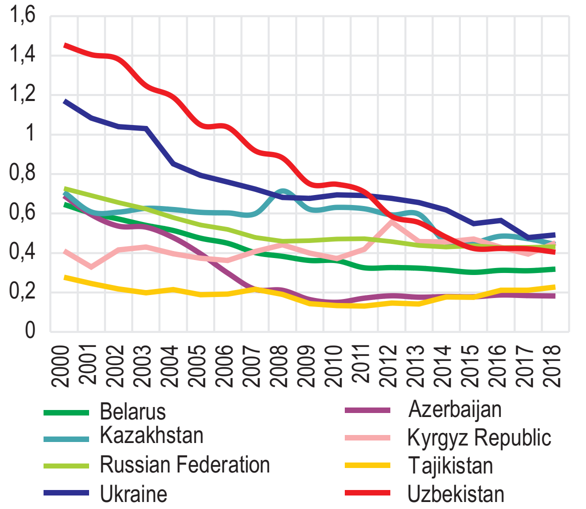
countries (0.24 kg of $CO_{2\text{-eq.}}$ per USD (2015) of GDP) in 2018 have been selected. From these 35 countries, the countries that are not comparable with Uzbekistan in terms of number of populations, level of development, and economic structure (share of industry in GDP) were excluded. From the remaining 8 countries, the 5 countries with the best GHG emissions reduction trends in 2010-2018 were selected: *Malaysia* (reduction of GHG emissions from 0.3 kg to 0.24 kg or 1.25 times), *Israel* (1.52 times), *Mexico* (1.22 times), *Slovakia* (1.36 times) and *Romania* (1.41 times).

The decrease in carbon intensity in the 5 countries was accompanied by an **increase in social progress** (the **SPI** index included 54 indicators), which reflects progress in improving the environment, healthcare, security, and reducing income inequality, etc. In 2011-2020, the SPI index for Mexico increased from 69.5 to 73.5; for Malaysia from 71.6 to 77; for Slovakia from 81 to 83.2; for Romania from 76.4 to 78.4. The example of these 5 countries suggests the **possibility of combining climate policy with solving social problems**, which makes this experience valuable for Uzbekistan.

In 2000-2018, Uzbekistan has made significant progress on the indicator of CO_2 emissions per 1 USD of GDP (specific GHG emissions in kg of CO_2-eq. per 1 USD of GDP (2015 prices), **EM** indicator, Fig. 2). In 2000, in Uzbekistan the level of specific GHG emissions (1.454 kg of CO_2-eq./USD) was 2.5 times higher than the average estimate for the group of the leading CIS countries (0.661 kg of CO_2-eq./USD), but since 2011 Uzbekistan reached the level of Ukraine, since 2012 the level of Kazakhstan, and by 2018 the levels of Kyrgyzstan and Russia. Such significant progress was made possible because of the implemented sectoral modernization programs and restructuring technologically backward and unprofitable industries. However, starting from 2015-2016, the rate of decarbonization in Uzbekistan started to decline (Fig. 2 and 3).

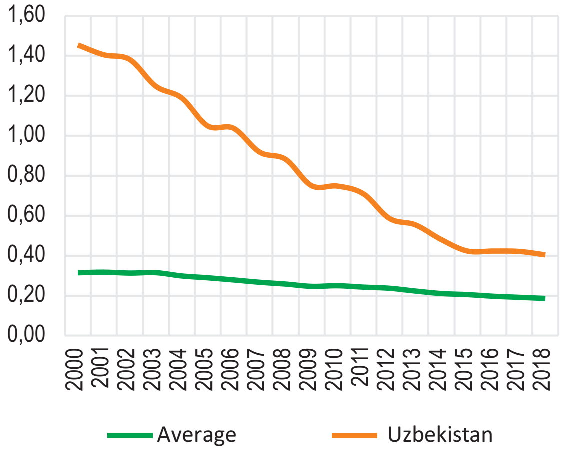
The trend is even more evident when it is compared with the average estimate for the 5 benchmark countries (Fig. 3). In 2000, the gap in the level of the specific GHG emissions was over 1 kg of CO_2-eq./USD but by 2010 it was reduced to 0.5 kg of CO_2-eq., and by 2015 to 0.22 kg of CO_2-eq. However, this process slowed down later, and the gap was remained almost unchanged until 2019. This indicates that the *potential for GHG emis-*

FIGURE 2 CARBON INTENSITY OF GDP OF UZBEKISTAN AND CIS COUNTRIES, 2000-2018, (KG OF CO2-EQ./2015 USD OF GDP)



Source: Data from the International Energy Agency

FIGURE 3 CARBON INTENSITY OF UZBEKISTAN'S GDP AND AVERAGE ESTIMATE FOR 5 BENCHMARK COUNTRIES, 2000-2018, (KG OF CO2-EQ./2015 USD OF GDP)



sions reduction in Uzbekistan have been exploited and more systemic measures are required to accelerate the process of economy decarbonization.

A similar trend has been identified through use of indicator of *energy intensity* (**EI**) *of economy* in Uzbekistan. In 2000, the energy intensity was 774 kgoe per 1,000 USD of GDP (2015 prices), while it had decreased by 2 times (to 335 kgoe per 1,000 USD of GDP) by 2010, and up to 205 kgoe per 1,000 USD of GDP that was followed by sharp slowed down of the energy intensity indicator decline.

4 | Conditions Forming an Active Climate Policy: World Experience and Uzbekistan

To identify conditions that can form the basis of a national model of low-carbon development, an analysis was carried out at the macro (Section 4) and micro level (Section 5).

This section aims to present a set of conditions required for low-carbon development path at the macro level that forms the framework of climate policy for all sectors of national economy (not just for the three sectors under consideration in this study). Such conditions can be formulated based on analysis of the world experience, for which the three methodologies were used: method of grouping countries, correlation analysis and econometric analysis.

The method of grouping countries. The average median estimates of carbon intensity indicators for 4 groups of countries selected from 76 developing countries according to the criterion of CO_2-eq. emissions per 1 USD of GDP (**EM** indicator) were compared. Group 1 includes the countries with the lowest specific GHG emissions, and Group 2 joins the countries with moderate GHG emissions, etc. (Table 2).

TABLE 2 AVERAGE ESTIMATES OF ENERGY INTENSITY OF GDP, INDICATORS OF ECONOMY STRUCTURE, INVESTMENTS AND QUALITY OF PUBLIC INSTITUTIONS FOR 4 GROUPS OF DEVELOPING COUNTRIES RANKED BY THE LEVEL OF SPECIFIC GHG EMISSIONS, (CO_2-EQ. PER UNIT OF GDP, EM INDICATOR)

Indicators/Factors	Group 1 (low level)	Group 2 (moderate level)	Group 3 (intermediate level)	Group 4 (high level)
Specific emission range (2018, kg CO2-eq./USD)	0.07-0.17	0.18-0.26	0.28-0.37	0.39-0.62
Number of countries in the group	28	22	13	11
Average values for 2000-2018 (2019)				
Specific emissions (kg CO2-eq./USD of GDP)	0.13	0.22	0.31	0.50
Energy intensity (kgoe/1,000 USD of GDP, 2015 prices)	75.2	102.9	129.3	200.0
Gross fixed capital formation (% of GDP)	22.3	22.8	24.7	24.8
Manufacturing, value added (as % of GDP)	13.9	15.5	13.9	13.8
Employment in industry (as % of employed)	20.4	23.2	25.4	25.5
Resource rent (as % of GDP)	2.5	5.1	15.7	12.1
Regulatory quality (from -2.5 to +2.5)	0.22	0.16	-0.03	-0.62
Control of corruption (from -2.5 to +2.5)	-0.20	-0.11	-0.17	-0.84
Rule of law (from -2.5 to +2.5)	-0.11	-0.04	-0.14	-0.77
Government effectiveness (from -2.5 to +2.5)	0.0	0.2	0.05	-0.46
Economic globalization Index (0-100)	55.8	61.8	67.1	52.7

Source: Calculations based on data from the World Bank and other international organizations

Note: The list of countries included in groups 1-4 is given in Annex 4.

The analysis allowed to draw the following conclusions:

- The transition from group 1 to group 2 and from group 2 to group 3 means a rapid increase in the average estimate of specific GHG emissions by about 10 (0.1) kg CO_2-eq./USD, and from group 3 to group 4 by 20 (0.2) kg CO_2-eq./USD;
- A direct relationship of the specific GHG emissions was found with the *energy intensity of GDP,* i.e. an increase of 27 kgoe/USD (26, 70, respectively, during the transition from group 1 to groups 2, 3 and 4), and inverse relationship with the regulatory quality indicator (indicator fell from 0.22 for group 1 to 0.16 in group 2, (-0.03) in group 3 and (-0.62) in group 4). **Countries with a high level of specific GHG emissions have a high level of energy intensity and low quality of government regulation;**
- In other areas, the relationship with GHG emissions was also revealed, although it is not so obvious. If groups 1 and 4 are combined, it could be concluded that GHG emissions are related to the *pressure on natural resources capital* (direct). When combining the groups 1 and 2, an inverse relationship with GHG emissions has been identified with the level of rule of law, control of corruption and government institutional effectiveness, i.e. **with the level of institutional development;**
- The first three groups of the countries (85% of the sample) with the lowest and average levels of specific GHG emissions are also directly related to the globalization index. Increased globalization is associated with increase of specific GHG emissions (during transition from group 1 to group 2, and from 2 to 3). The most likely it is **an impact of the current model of globalization**, when developed countries moved industries with high carbon footprint production to developing countries;
- The analysis showed that there is no direct relationship between specific GHG emissions and *investments and the structure of the economy* (the share of manufacturing in GDP and the share of people employed in industry). This may indicate that the investment-structural factor is not dominant among other factors and conditions necessary for the transition to a low-carbon economy.

The correlation analysis makes it possible to clarify the conclusions formulated through the methodology on grouping the countries, since it uses accurate statistical criteria for the closeness of the relationship between the indicators of carbon and energy intensity. The correlation coefficients are calculated for 2010-2018 in the form of: a) average-median estimates of indicator levels[22] (Annex 5); b) average-median estimates of indicator changes (current year minus the previous year, Annex 6).[23]

First of all, the analysis confirmed a **strong relationship between GHG emissions (EM) and energy intensity (EI)**[24]. The analysis also showed the **importance of institutional factor for reducing GHG emissions**. Thus, three of the four indicators of the quality of state institutions showed a significant negative relationship with specific emissions:

- **CoCor,** control of corruption indicator (the relation with the emission (**EM**) $\mathbf{R^2}$ = – 0.35, with energy intensity (**EI**) $\mathbf{R^2}$ = – 0.45);
- **RoL**, rule of law indicator (the relation with the emission **(EM)** $\mathbf{R^2}$ = -0.42;

[22] For each indicator, a vector of 76 elements (countries) is formed, each of which is the average median estimate of this indicator for 2010-2018 for each country. For example, for the emission (**EM**) for Albania, this element is equal to 0.115 kg / USD = **median**{ 0,128 (2010), 0,131(2011),... }, etc.

[23] For example, for Albania, the average median **EM** estimate was +0.001 kg / USD = **median**{ 0.001(2010), 0.003 (2011), -0.022 (2012), ... -0.005 (2018)}, and for China -0.004 kg / USD = **median**{ -0.004 (2010) to -0.013 (2018)}.

[24] The corresponding correlation coefficients are high (0.94 in Annex 4 and 0.91; 0.78 in Annex 5 available un the full report) and statistically significant (P-val < 0.1).

- Regulatory quality indicator (the relationship with the emission (**EM**) R^2 = -0.36, with the energy intensity (**EI**) R^2 = -0.46.

Two more conclusions have been formulated: **Development of the manufacturing industry constrains GHG emissions and the growth of energy intensity** (**ManVE** indicator, correlation coefficients -0.55 and -0.42, respectively), and **growth of the pressure on natural capital stimulates carbon and energy intensity** (resource rent indicator **Res**, correlation coefficients +0.57 and + 0.69, respectively).

The analysis did not reveal a link between GHG emissions (energy intensity) and investments (GFCF), confirming the conclusion formulated using the country grouping methodology. This shows the fallacy of the stereotype that green investments are the main condition for success in the transition to low-carbon development pathway. For example, in the UNEP report "Towards a Green Economy: Pathways to Sustainable Development and Poverty Eradication" (2011)[25], annual investments of USD1.3 trillion (about 2% of world GDP in 2010) into 10 key sectors of economy in 2012-2050 are proposed as the key mechanism for transforming the world economy into a low-carbon economy by 2050.

The EaP Green Report "Assessment of the Green Transformation of the Economy: A Guide for the EU Eastern Partnership Countries"(2016)[26] points to technologies and innovations as the key measures of climate action policy. The report notes the importance of international financial flows in support of the introduction, adaptation and dissemination of green technologies and knowledge, as well as the use of pricing, taxation and transfers of technologies that form more "green" behaviors. However, the report does not mention the importance of creating appropriate institutions, without which the use of all these tools will be impossible or ineffective.

The results of the analysis allowed to position Uzbekistan according to the factors of low-carbon development. Figure 4 shows how the average estimates of GHG emissions, resource rent and energy intensity of Uzbekistan for 2010-2018 exceeded the average estimates for the CIS countries and benchmark countries. The largest gap by 5.61 times (by 3.28 times with the CIS countries) was formed by the resource rent indicator. Given that, according to the GDP per capita indicator, Uzbekistan is included in the category of countries with a per capita income level below the average estimates, this result indicates *a low efficiency of using natural resources and a wasteful raw material nature of the development model.*

In the conditions of inefficient use of natural resources, *it is problematic to expect on closing the gap with the global average benchmarks on the carbon and energy intensity of economy, which reached 2.3 and 2.7 times, respectively (1.8 and 2.4 times compared to the average CIS).*

The correlation analysis revealed the directions of strengthening institutional capacity that ensure transition to low-carbon development pathway: improving the government regulatory quality (**RQ**), rule of low (**RoL**), and control of corruption (**CoCor**). Uzbekistan's positions on these indicators (from -2.5 to +2.5) are shown in Figure 5.

The biggest gap is in quality of government regulation. The benchmark countries' average rating of this indicator for the period of over the past 10 years was +0.74 (on a scale from -2.5 to +2.5), while for Uzbekistan it is (-1.57), which is lower than in the other CIS countries (-0.54). Therefore, the initial step in the transition to a green economy in Uzbekistan should be implementation of an **administrative reform.**

There are also serious gaps in the indicator of control of corruption: for Uzbekistan it is -1.22, for CIS it is -0.92; and benchmark countries is +0.09, and rule of law is -1.13; -0.84; +0.33,

[25] https://sustainabledevelopment.un.org/content/documents/126GER_synthesis_en.pdf

[26] http://www.green-economies-eap.org/ru/resources/EaP%20GREEN_GGI%20Guide_clean_RUS_Final.pdf

FIGURE 4 POSITIONS OF UZBEKISTAN AND AVERAGE ESTIMATES OF THE CIS COUNTRIES ACCORDING TO THE CRITERIA OF CARBON– AND ENERGY– INTENSITY AND LOAD ON NATURAL CAPITAL (BENCHMARK COUNTRIES =1)

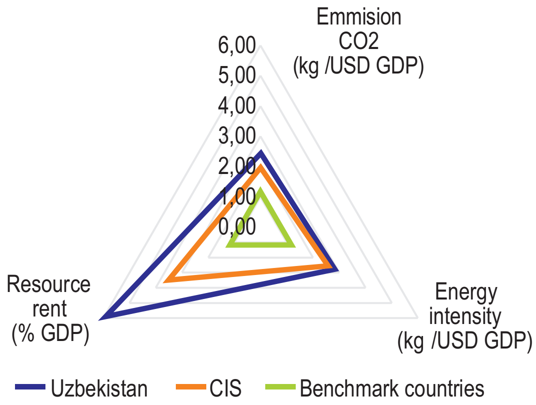
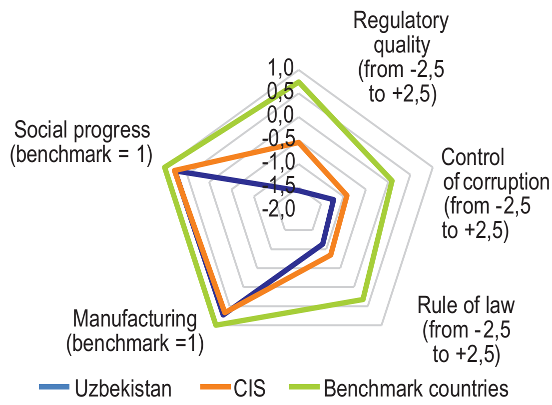


FIGURE 5 POSITIONS OF UZBEKISTAN AND AVERAGE RATINGS OF THE CIS COUNTRIES ACCORDING TO THE CRITERIA OF QUALITY OF INSTITUTIONS, SOCIAL PROGRESS AND STRUCTURAL PARAMETERS



Source: calculations based on data from international organizations for 2010-2018

respectively. This indicates the **insufficiency of measures taken in recent years in Uzbekistan in the field of combating corruption.**

In addition to the indicators of the quality of institutions, the Figure 6 shows the position of Uzbekistan related to two more indicators such as social progress and economic diversification. For comparison, these indicators are expressed in times to their values for the benchmark countries. The high value of social progress **SPI** for the benchmark countries (77.8 on a scale from 0 to 100) shows that it is possible to create favorable conditions under which **the transition to low-carbon development pathway can be combined with increase in employment, income of the population, and poverty reduction**. For Uzbekistan, the **SPI** value is only 59.8, and for the CIS countries – 68.4, emphasizing the importance of *improving the quality (inclusiveness) of economic growth.*

In terms of diversification, Uzbekistan lags behind the benchmark countries (18.4%), although it corresponds to the average level of the CIS countries (12-13%). This pointы out **the need for a transition to a new industrial policy**, as a condition for progress in the low-carbon development.

Econometric analysis. The purpose of this analysis is to quantify the relationship between the indicators of carbon and energy intensity, on the one hand, and factors that form their dynamics, on the other hand. Since the main tool of climate policy is **green resource-saving technologies**, the emphasis is placed on finding conditions that strengthen contribution of the investment factor for accelerating the decarbonization of the economy. The analysis was performed for 2000-2018:

a) for 76 developing countries (all indicators – **EM**, **EI**, etc. are used in the form of levels)[27];

b) based on the statistics of international organizations for Uzbekistan (all indicators-EM, EI, etc. are used as a difference (for example, EM-EM(-1)), which ensured their stationarity for analysis.[28]

The econometric analysis showed that:

- An increase in the quality of institutions (according to the **RQ,** government regulatory quality criterion) **reduces specific GHG emissions** (coefficient before **RQ** is -0.32), and pressure on natural resources capital (**Res**) and share of people employed in industry

[27] Average median estimates for 2010-2018 cross-section analysis

[28] The generated regression equations are presented in Annex 7.

(**LabInd) contribute to increase of specific GHG emissions**, although the influence of these two factors is insignificant (+ 0.003 and +0.008).

- **The investment factor contributes to reducing energy and carbon intensity, if the quality of institutions in terms of government regulatory quality (RQ) is not lower than a certain threshold value.** The impact of the investment factor on reducing GHG emissions will be stronger while the difference between the actual value of **RQ** indicator and the threshold value is higher. When the quality of institutions is below the threshold, climate policy becomes ineffective.

Poor quality of institutions is the *key barrier to reduction of energy intensity (GHG emissions) of economy for the most developing countries.* The benchmark countries the average **RQ** score over the past 10 years was 0.74, which means decrease of energy intensity (carbon intensity) of the economy with increase of investments, while the situation is different in the

BOX 2 TESTING HYPOTHESIS ABOUT THRESHOLD VALUE OF QUALITY OF PUBLIC INSTITUTIONS

To test this hypothesis, the following econometric equation has been used:

$$\mathbf{EI} = c1 + c2^{*}\ \mathbf{GFCF}\ ^{*}(\mathbf{thr} + \mathbf{gov}) + c3^{*}\mathbf{F3} + c4^{*}\mathbf{F4} + \ldots$$

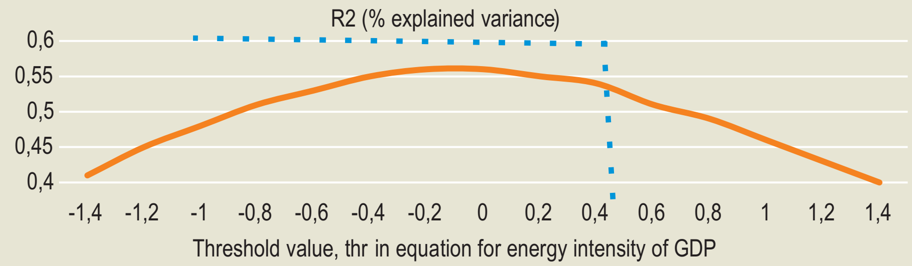
Where:

thr is the threshold value for the quality indicators of institutions **thr, F3, F4,**.... (factors other than investments and institutional development). With this design, e.g. if the threshold value of thr = +1 and the value of the quality of government institutions indicator **gov** > -1[1]**,** the expression in parentheses will be positive. In this case, if **thr** = -1 according to the results of evaluation of the parameters of this equation, the coefficient *c2* turned out to be negative and statistically significant, then the growth of investments **GFCF** will reduce the value of **EI**. At the same time, the impact of investments on energy intensity will be stronger the higher the value of the actual **gov** indicator in relation to the received threshold value **thr.**[2]

During the testing process, many combinations of indicators of institutions and factors affecting **EM** (**EI**) were sorted out. The threshold value for institutions **thr** was selected based on the range of changes (from -2.5 to +2.5), quality criteria and the statistical significance of the equation.

In relation to the indicator of the regulatory quality **RQ** and energy intensity **EI**, equation # 4 (Annex 7) was obtained with a threshold value of **thr** close to zero. Fig. 6 shows the effect of the threshold value of **thr** on the value of the explanatory power of the equation **R²**. At the point **thr = 0**, the value of the explanatory power reaches a maximum (over 55%) with good estimates of other statistical criteria of significance,[3] which allows determining it as sufficiently reliable.

FIGURE 6 INFLUENCE OF THRESHOLD VALUE (THR) ON EXPLANATORY ABILITIES OF ENERGY INTENSITY EQUATION (EI = a + b*gfcf*(thr + rq) + c*kof)



Source: econometric analysis results

[1] For the CIS countries, the dynamics of the quality indicators of institutions (**RQ, RoL, CoCor, GE**) lay in the region of negative values (on a scale from -2.5 to +2.5), i.e., below the global average (equal to approximately zero).

[2] Similar regressions with threshold values are widely used in the practice of econometric analysis (C. Hurlin (University of OrlÈans) (2018). Advanced Econometrics II. Chapter 3. Panel Threshold Regression Models; V. Popov. V. Polterovich (2006). Stages of Development, Economic Policies and a New World Economic Order. MPRA Paper No. 20055, posted 18 Jan 2010 https://mpra.ub.uni-muenchen.de/20055/

[3] P-val for the coefficients c2 and c3 were 0.0000 and 0.0005. The distribution of the equation errors corresponds to the Jarque-Bera test for the normality of the distribution (P-val=0.495>>0.1). There is no autocorrelation of errors with the investment factor.

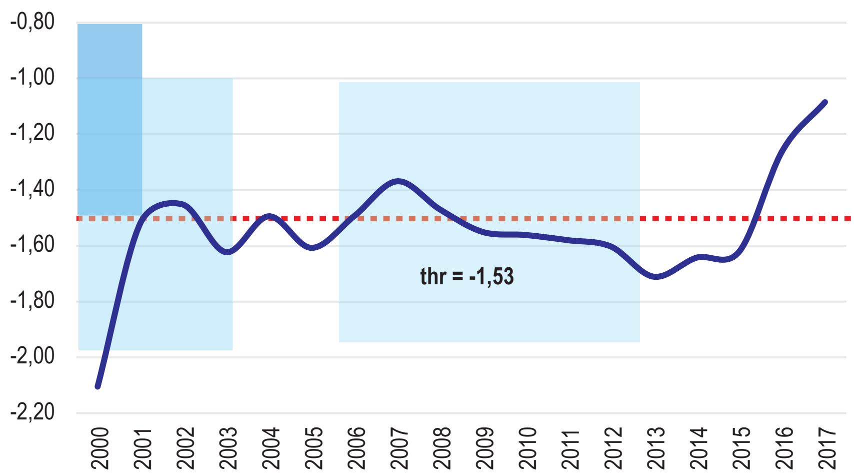
CIS countries and in Uzbekistan. The **RQ** values are negative (-0.54 for CIS countries and -1.57 for Uzbekistan) that means positive relationship between the investments and energy intensity (GHG emissions), and that achieving goal of low-carbon development would not be possible exclusively focusing on green technologies and investments.

- **Similar conclusions are drawn on relationship of the emission indicator (EM) with other factors.** The threshold values of **RQ** were +0.2 for the pressure on natural resources capital (**Res**) and factor of economic globalization (**KOF**) (equation # 5) and -0.5 for the factors **Res and LabInd** (equation # 6) indicating the importance of institutions not only for natural resources conservation, but also for GHG emissions reduction.

The effect of measures aimed at improving the regulatory quality (**RQ)** and combating corruption (***CoCor)* is delayed by 1-2 years (equation # 8)**;

Uzbekistan also has a threshold for the quality of institutions, achievement of which activates the factor of investments in GHG emissions reduction. A search of combinations of factors, lags, and threshold values allowed finding (equation # 9) that such a threshold for **RQ** was -1.53 (on a scale from -2.5 to +2.5). In 2000-2018, the trend in the regulatory quality in Uzbekistan was positive (the dotted line in Fig. 7). However, the average estimates for the period (-1.51 (arithmetic mean) and -1.53 (median average) were close to the threshold (-1.53), which significantly reduced the effect of growth of investment activity in terms GHG emissions reduction.

FIGURE 7 PHASES OF NEGATIVE (OR NEUTRAL) INFLUENCE OF INVESTMENT FACTOR ON REDUCTION OF SPECIFIC GHG EMISSIONS IN UZBEKISTAN, 2000-2018



Source: Parameters of equation # 9 (Annex 7) and World Bank statistics.

Note: The darkened areas are the intervals of 2000-2018, when the investment factor did not have an impact (or a weak impact) to reduce specific emissions. Light areas are intervals with a moderately positive influence.

For the control of corruption indicator (**CoCor**) the threshold value for Uzbekistan was -1.03 (equation # 10) with an average assessment (-1.16) and an average median assessment (-1.22) for 2000-2018. **The trajectory of the indicator was below the threshold value** for almost the entire period of 2000-2018, which led to exclusion of the investment factor from the number of factors contributing to GHG emissions reduction.

The analysis revealed significant potential for improving effectiveness of climate action policy in Uzbekistan, associated with improving the quality of institutions. In the last 10 years, the regulatory quality **RQ** corresponded to the global average assessment (about 0, and not -1.57 on a scale from -2.5 to +2.5), the elasticity of reducing GHG emissions by investments would improve from +0.006 (weak direct relationship) to -0.159. This means that increase in investments by 1 percentage point (e.g. increase in gross investments from 24% of GDP to 25% of GDP) would result in reduction of GHG emissions by 0.159 kg CO_2-eq./USD of GDP[29] compared with their actual increase by 0.006 kg CO_2-eq./USD with the current regulatory quality **RQ** = -1.57**.**

TABLE 3 ASSESSMENT OF STRENGTHENING INFLUENCE OF INVESTMENTS FACTOR ON REDUCTION OF SPECIFIC GHG EMISSIONS WITH INCREASE IN QUALITY OF INSTITUTIONAL ENVIRONMENT IN UZBEKISTAN

Increasing quality of government institutions	Directions for strengthening capacity of government institutions			
	Increasing regulatory quality		Control of corruption	
	Growth rate of RQ	Elasticity of EM according to GFCF	Growth rate of CoCor	Elasticity of EM according to GFCF
a. From the current level to the average for CIS countries	+1,03 (from -1,57 to -0,54)	from +0,006 to-0,16	+0,30 (from -1,22 to -0,92)	from +0,013 to -0,009
b. From the current level to the average for developing countries	+1,57 (from -1,57 to 0)	from +0,006 to -0,159	+1,22 (from -1,22 to 0)	from +0,013 to -0,073
c. From the current level to the average for benchmark countries	+2,27 (from -1,57 to +0,70)	from +0,006 to -0,243	+1,123 (from -1,22 to -0,09)	from +0,013 to -0,08

Source: calculations based on the parameters of regression equations # 3 and # 10, as well as the World Bank statistics.

29 The arithmetic mean estimate of specific CO2-eq. emissions for 2010-2018 in Uzbekistan was 0.528 kg CO2-eq./USD.

5 | Social and Economic Consequences of New Technology Introduction: Sectoral Assessments

This section aims to define a set of conditions for low-carbon development at the micro level. This problem is considered based on: a) analysis of approaches applied to estimate the size of specific sectoral GHG emissions; and b) evaluation of effects of the typical projects implemented in the three sectors under consideration.

5.1 METHODOLOGICAL APPROACHES ON ASSESSING CARBON FOOTPRINT BY SECTORS AND ECONOMY AS A WHOLE

The specific sectoral GHG emissions are a key indicator in climate change. The higher the specific sectoral carbon intensity, the higher carbon intensity of the economy and the stronger negative impact of the economy on climate change challenge during economic growth, and vice versa. There are many publications on this topic, especially on the analysis of carbon intensity of energy sector (key GHG emitter),[30] in which carbon intensity is determined by the value of specific CO_2 emissions per unit of electricity generated. Similarly, the carbon intensity of the products of other sectors that are the direct emitters is determined by e.g. GHG emissions (kg of CO_2 or CO_2 equivalent) per ton of mineral fertilizers (chemicals), cement (building materials industry), etc.

This traditional approach to assessing carbon intensity of the sector's products has the following limitations:

- it focuses on production, while the modern economy is being transformed largely considering the changes in consumer demand and preferences;
- it does not allow considering the growth of GHG emissions induced by development of sectors that are not direct GHG emitters;
- it does not allow considering the resource efficiency factor (ratio between final and intermediate consumption).

According to the classical definition, the carbon footprint of a product is GHG emissions generated at all stages of its life cycle, i.e. from ore extraction to its disposal after loss of its useful properties.[31] The indicator is considered in the twofold: assessment of direct GHG emissions (possibility of control) and assessment of indirect GHG emissions that occur during the product life cycle (which are not easily controlled).

While the traditional methodology on calculating the specific GHG emissions can be used for direct assessment, an indirect assessment requires considering the closeness of interrelations of sectors that arise within the process of production, distribution and consumption of products. The methodology that takes these relationships into account to the greatest extent

[30] The carbon intensity of electricity in the world and in Russia. Energy Bulletin of the Analytical Center under the Government of the Russian Federation, No. 73, May 2019. URL: https://ac.gov.ru/archive/files/publication/a/22245.pdf

[31] For example, A.Umnov et al. The carbon footprint as an indicator of the impact of the economy on the climate system. Bulletin of RSUH: Series " Economics. Management. Law". 2020. No. 2.

is the Input-Output method (I-O) or the Leontiev model.[32] The method uses the multiplier technique (see the UNDP study developed in 2020) and a special Algorithm for calculating the carbon footprint of the sector (Annex 8), which focuses on incremental indicators, but not on the volume. From this point of view, the Algorithm allows getting *more objective picture of green transformation of the economy.*

In general, the evolution of approaches on calculating the "sectoral carbon footprint" indicator (specific GHG emissions) can be presented as follows: 1) gross GHG emissions (thousand tons); 2) specific sectoral GHG emissions (kg CO_2-eq./t (m^3)); 3) specific GHG emissions in kg CO_2-eq. per 1 USD of GDP; 4) carbon footprint calculated in accordance with the SDGs 2030 requirements (kg/increase of 1 mln UZS of the final product). Below are the estimates of carbon footprint using **various calculation approaches**:

- traditional approach using gross GHG emissions and gross output by the economy as a whole: **336** kg CO_2-eq./mln UZS;
- amount of added values of economic sectors according to the I-O methodology: **635.1** kg CO_2-eq./mln UZS;
- using GHG emissions and GDP (sum of the added values of economic sectors according to the system of national accounts, SNA): **562.1** kg CO_2-eq./mln UZS (lower than the value indicated in the bullet above due to the fact that GDP is higher than the amount of value added by the value of the net indirect taxes, which do not directly affect GHG emissions);
- based on the I-O methodology of multipliers of outputs, mult (x / y): **593** kg CO_2-eq./mln UZS.

The comparison of estimates of carbon footprint showed that in 2017 the specific GHG emissions significantly decreased in most sectors that are direct GHG emitters (t CO_2-eq./mln UZS of output), compared to 2016:

- Agriculture: from 0.245 up to 0.196;
- Chemistry: from 0.644 to 0.436;
- Production of construction materials: from 0.459 to 0.413;
- Metallurgy: from 0.137 to 0.056;
- Generation of electric and thermal energy: from 10.611 to 9.953;
- Waste utilization: from 7.125 to 3.882;
- Exclusively for Transport **increased:** from 0.375 to 0.473.

In the economy as a whole, the specific GHG emissions decreased from 0.400 t CO_2-eq./mln UZS up to 0.336 t CO_2-eq./mln UZS. As a result, despite increase in the materials intensity of economy, in 2017 the value of carbon footprint (multiplier of GHG emissions by the final product) decreased to **596** kg CO_2-eq. per 1 mln UZS of the final product compared to **706** kg CO_2-eq./mln UZS in **2016**, or by 110 kg CO_2-eq./mln UZS. The largest decrease was noted in such sectors as **electricity generation and delivery (by 811 kg** CO_2-eq./mln UZS**)**, **oil and gas (211 kg** CO_2-eq./mln UZS**)**, basic metals (197 kg CO_2-eq./mln UZS), metal ores (187 kg CO_2-eq./mln UZS), **agriculture (87 kg** CO_2-eq./mln UZS**)**, food products (82 kg CO_2-eq./mln UZS), etc.

The I-O methodology allowed making the *sectoral decomposition of this result*. The share of 7 sectors-direct GHG emitters in the carbon footprint was almost 3/4 (Table 4), and the remaining part is with the sectors that are not direct GHG emitters (71 industries). The highest contribution to the carbon footprint of the economy is made by energy sector (about

[32] UN Handbook on Supply, Use, and Input-Output Tables with Extensions and Applications. New York, 2018.

32%) and agriculture (about 23%), and among the remaining 71 sectors that are not the direct GHG emitters are trade, public administration and defense authorities (4.7% for each). Thus, the full estimate of GHG emissions with consideration of final product growth of the economy by 1 mln UZS exceeds the estimate of GHG emissions by the sectors, which are the direct GHG emitters by almost 1.36 times. **This requires considering the indirect effects in all sectors at development of low-carbon development programs.**

TABLE 4 CONTRIBUTIONS OF VARIOUS ECONOMIC SECTORS TO CARBON FOOTPRINT OF ECONOMY AS A WHOLE, 2017

593 kg CO2-eq. per UZS1 mln of final product as related to carbon footprint of economy as a whole (100%)				
437 kg CO2-eq.by 7 sectors that are direct GHG emitters (**73.7%**)			156 kg CO2-eq. by other sectors (71) that are not direct GHG emitters (**26.3%**)	
188 kg CO2-eq. by Energy (**31.7%**)	134 kg CO2-eq. by Agriculture (**22.6%**)	148 kg CO2-eq. by other sectors (5) that are direct GHG emitters (**19.4%**)	55 kg CO2-eq. by trade, public administrations and defense authorities (**9,3%**)	101 kg CO2-eq. by other sectors that are not direct GHG emitters (**17,0%**)

Source: calculation of emission multipliers based on the **I-O** *methodology for 2017 and Uzhydromet statistics on the magnitude of sectoral emissions*

5.2. POWER SECTOR: SCENARIOS OF RESOURCE SAVING AND USE OF RENEWABLE ENERGY SOURCES FOCUSED ON ENVIRONMENT, EMPLOYMENT, AND INCOME OF POPULATION

The energy sector is the source of the largest specific emissions. This study examined on which green technologies in the energy sector are more promising for Uzbekistan: projects that increase energy efficiency (combined-cycle steam and gas units), or projects on harnessing technologies using renewable energy sources (wind turbines). At the same time, the results obtained based on the analysis of operation of the combined steam and gas units (CCSGT) in the power sector in 2020 were used.[33]

The effects of harnessing energy saving and renewable energy sources (RES) using technologies. There are two possible channels for impact of green projects on carbon footprint and financial sustainability of the sector:

a. Direct channel: new technologies that reduce the specific GHG emissions of the sector -> reduce the multiplier of emissions for this sector and interlinked sectors -> reduce carbon footprint of the economy as a whole.

b. Indirect channel: new technologies that reduce the specific consumption of natural gas, electricity, transport -> reduce the multiplier of GHG emissions for this sector and interlinked sectors -> reduce carbon footprint for the economy as a whole.

An example of the *direct impact* of green technologies is RES based units that do not require use of fossil fuel. The higher share of RES in the structure of the country's energy mix, the lower specific GHG emissions in the economy as a whole. An example of *indirect effects* is modernization of irrigation system that ensures delivery of the same amount of water with less electricity consumption by pumping stations. There are also *mixed options*, when the green technologies both reduce GHG emissions (through increasing energy efficiency) and save natural resources (e.g. use of biogas units (BGU) to generate electricity and heat).

[33] The report "Assessment of the impact of measures to reduce greenhouse gas emissions on the social and economic situation in Uzbekistan", UNDP, 2020.

Direct effects of RES based technologies in power sector. The purpose of calculations is to demonstrate on how during the transition from traditional power generation to using CCSGT (project cost is USD4 billion, option 1, energy saving scenario) and wind turbine farm (WPP with a capacity of 1.5 GW, project cost is USD1.8 billion[34], options 2 and 3, renewable energy use scenario), the *structure of the sector's costs* is changing (unit cost of natural gas per unit of electricity output) and *financial sustainability of the sector* (share of depreciation and profit). The results of estimates are summarized in Table 5.

TABLE 5 EFFECTS OF USE OF ALTERNATIVE TECHNOLOGIES IN POWER GENERATION SECTOR IN UZBEKISTAN

Indicators	Traditional generation		Replacement with CCSGT (energy saving) Option 1		WPP with 20% installed capacity load Option 2		WPP with 30% installed capacity load Option 3	
	billion UZS	%	billion UZS	%	billion UZS	%	billion UZS	%
Electricity output	10,696.4	100.0	10,696.4	100.0	11,172.4	100.0	11,409.8	100.0
Added value	4,292.3	40.1	4,741.2	44.3	4,547.1	40.7	4,678.0	41.0
including depreciation	343.5	3.2	1,119.3	10.5	696.8	6.2	707.2	6.2
Profit (added value – depreciation – remuneration)	1,870.8	17.5	1,543.9	14.4	1,678.7	15.0	1,754.2	15.4
Intermediate consumption	6,404.1	59.5	5,954.9	55.7	6,625.3	59.3	6,731.8	59.0
including natural gas	1,548.9	14.5	1,101.7	10.3	1,553	13.9	1,551.7	13.6
Output growth, %	-	-	-	-	4.45%		6.67%	

Source: Author's calculations. The calculations are based on the balance ratios of the System of National Accounts (SNA) and the data in table I-O. For more information, see Annex 9.

The implementation of the energy saving scenario (modernization of TPP using CCSGT) will result in natural gas savings, which will increase the share of value added in the sector's output structure from 40.1% to 44.3%. However, the high cost of the project (USD4 billion) will increase depreciation costs by almost 3 times (from 343 to 1,119 billion UZS with a service life of the equipment of 20 years). This will significantly reduce the amount of conditional profit (from 17.5% to 14.4% of the output). If the increased amount of depreciation charges is imposed on the consumer, this will lead to increase in electricity prices by 10696.4 + (1119.3 – 343.5)/10696.4 = 1.072 or by 7.2%.

The implementation of WPP scenario will result in increased energy production by 4.45% (option # 2) and by 6.97% (option # 3) without increase in natural gas consumption. As a result, in the whole energy sector, the specific gas consumption per unit of energy generation will decrease from 0.145 in the initial state to 0.139 (option # 2) or to 0.136 (option # 3, Annex 9). This will result in decrease in the intermediate consumption and increase in added value, as in the energy saving scenario with use of CCSGT. However, these changes will be noticeably less, because the reduction of specific natural gas costs in the WPP scenario is lower than in the CCSGT scenario (0.145-0.103=0.042, option # 1 and 0.145-0.139 = 0.006, option # 2 and 0.009 in option # 3).

Being capital-intensive, the WPP project radically increases depreciation costs (by more than 2 times) with the same service life of the equipment. Therefore, the amount of conditional profit is reduced from 17.5% in the initial state to 15% in option # 2 and to 15.4% in

[34] The construction of the first wind power plant in Uzbekistan has begun. https://www.spot.uz/ru/2021/04/02/wind/

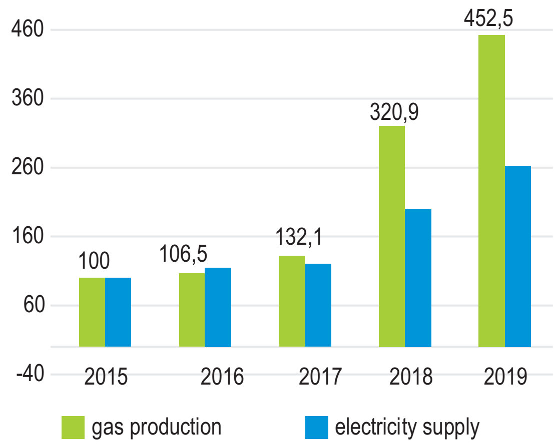
option # 3, with subsequent negative consequences for the financial situation of the sector or for consumers.

Comparison of energy saving scenario (option # 1) with WPP scenario (options # 2 and # 3). Despite the best indicators of natural gas saving and reduction of the specific GHG emissions (up to 8,444 t CO_2-eq./billion UZS in option # 1 against 10,138 and 9,903 t CO_2-eq./billion UZS in options #2 and # 3, respectively,)[35] the energy saving project is inferior to the WPP project in terms of the share of conditional profit in the output structure. This conclusion contradicts the point of view that in countries with a significant reserve of generating capacities and lagging behind the global average level of energy efficiency, investments in energy conservation would allow achieving more significant results on reducing carbon intensity of the economy comparing to the investments in renewable energy.[36] This is partly due to the higher cost of the CCSGT project (USD4 billion) compared to the WPP project (USD1.8 billion), which is also reflected in the higher depreciation costs in option # 1 (UZS1,119.3 billion) compared to options # 2 and # 3 (UZS 698.8 billion and UZS 707.2 billion, respectively).

However, the main reason for the lower relative values of conditional profit in the energy saving scenario is the price of natural gas in Uzbekistan, which is artificially underestimated compared to the global average estimates.[37] This is reflected in the low estimate of the share of natural gas consumption in the sector's output structure (0.145, or 14.5%). It is known that in the countries where natural gas dominates in the structure of primary energy sources and its price is close to the global average price, this share is much higher.[38] **Only in this case, the resource-saving projects become more promising and efficient compared to renewable energy projects.**

Calculations have shown that for Uzbekistan, *the critical value of the share of natural gas consumption in the structure of the sector's output, the excess of which makes the resource saving project more preferable compared to the wind farm project*, is **0.163,** or **16.3%** (0.145, or 14.5% in the structure of industry output in the base period). It is determined by the relative rate of increase in gas prices compared to increase in electricity prices, as well as by the narrowing gap between the global average and domestic gas prices.

FIGURE 9 PRICES FOR GAS PRODUCTION AND ELECTRICITY SUPPLY, % (2015 = 100%)



Since 2017, a gap in favor of an accelerated increase in natural gas prices has emerged and rapidly increased in Uzbekistan (Fig. 9). This leads to an increase in the share of gas costs in the structure of electricity prices, improving performance of resource-saving project compared to the WPP (renewable energy focused) project.

Full effects (direct and indirect) of alternative technologies in the electric power industry. The purpose of the calculations is to compare the sce-

[35] The advantage of reducing the specific emissions of the first scenario over the second (2217 t CO_2-eq./ billion UZS vs. 473 and 708 t CO_2-eq./billion UZS, respectively) becomes less obvious if we recalculate these emission reductions by the cost of projects, i.e. dividing them by $ 4 billion for the first scenario and by $ 1.8 billion for the second (554.2 t CO_2-eq./ billion UZS vs. 262.8 and 393.3 t CO_2-eq./billion UZS), respectively).

[36] For example, B. Porfiriev, A. Shirov, A. Kolpakov. How to complete the tour. Expert, No. 4, January 18-24, 2021

[37] About $ 50-60 per 1000 m^3 against $ 140-160 in Germany and other European countries in 2016.

[38] In Russia, gas generates about 50% of electricity, and in the cost structure of the largest generating companies operating mainly on gas (MosEnergo, OGK-2, Interrao, T Plus), fuel costs account for 60-85% of the electricity price.

narios of energy saving and a wind farm (using RES) in terms of reducing carbon footprint, project cost and social impact.

The methodology on calculating the carbon footprint has been discussed above. It considers not only direct, but all indirect interrelations between the sectors of economy within the process of production and consumption of products based on the I-O methodology.

The reduction of specific natural gas consumption for electricity generation due to utilization of WPPs (Annex 9) and associated specific emissions reduces the estimates of carbon footprint by all sectors of the economy. However, the magnitude of such decrease is noticeably less than the one achieved through utilization of CCSGT. If the value of carbon footprint of the economy as a whole was **821** kg CO_2-eq./mln UZS of final consumption, the use of CCSGT resulted in reduced emissions to **694** kg CO_2-eq. (i.e. by **126** kg CO_2-eq.), and with harnessing WPPs, such decrease will be **28** kg CO_2-eq. (at 20% of installed capacity), or **41** kg CO_2-eq. at (30% installed capacity). At the same time, it should be considered that replacement the existing equipment with CCSGT is more expensive. The corresponding project is estimated at USD4 billion, while the project aimed at using RES with operation of WPP is estimated at USD1.8 billion.

The ratio remains unchanged even the estimates are recalculated as per USD1 billion. The introduction of CCSGT reduces the carbon footprint of economy by 31.6 kg, and WPP reduces it by 14.5 kg CO_2-eq. (option # 2) or by 21.7 kg CO_2-eq. (option # 3). This result confirms the conclusion on the *priority of energy saving in the formation of Uzbekistan's climate action policy for the upcoming years.*

Within the Top 10 sectors with the greatest reductions in carbon footprint as related to power sector through utilization of CCSGTs and WPPs, the power sector is the leader (Table 6). At the same time, the average estimate of reducing the carbon footprint for the Top 10 sectors

TABLE 6 ASSESSMENT OF TOP-10 SECTORS OF ECONOMY WITH THE GREATEST REDUCTIONS IN CARBON FOOTPRINT UNDER VARIOUS SCENARIOS ON INTRODUCTION OF ALTERNATIVE TECHNOLOGIES IN POWER SECTOR (KG OF CO_2-EQ./MLN UZS FINAL CONSUMPTION)

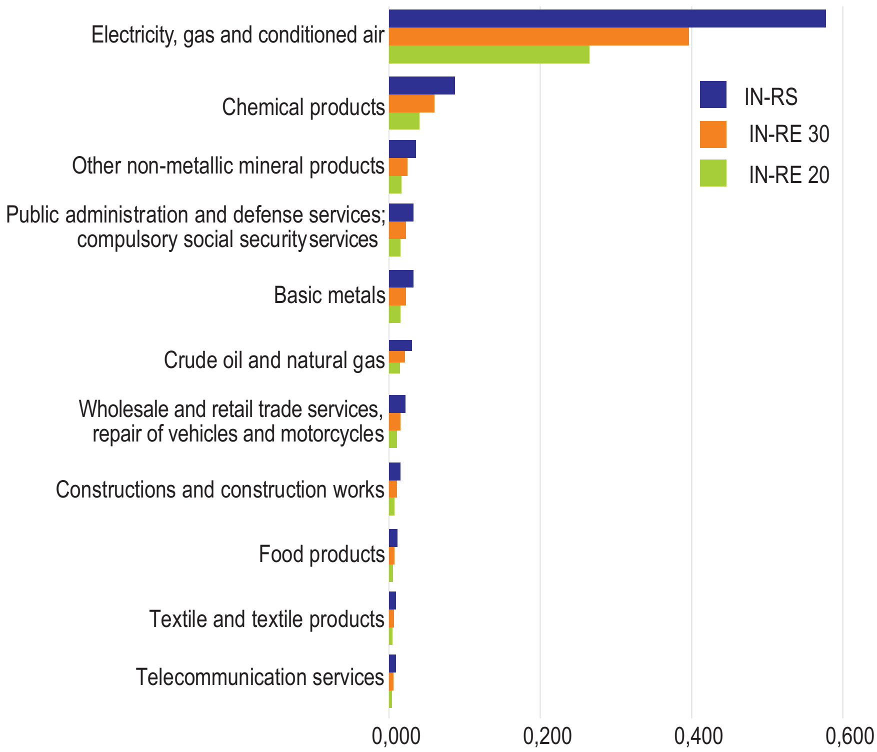
Sector	Absolute decline according to scenarios			A decrease in terms of USD1 billion investments		
	WPP		CCSGT	WPP		CCSGT
	20% of installed capacity	30% of installed capacity		20% of installed capacity	30% of installed capacity	
1. Electricity, natural gas and air conditioning	503	753	2310	265	396	577
2. Sewage system services; sewage sludge	112	168	515	59	88	129
3. Natural water and water supply services	111	166	511	58	88	128
4. Services provided by member organizations	76	114	349	40	60	87
5. Chemical products	75	113	346	40	59	86
6. Paper production and paper products	74	111	340	39	58	85
7. Metal ores	50	76	232	27	40	58
8. Sports, entertainment, and recreation services	45	67	205	23	35	51
9. Coal and brown coal (lignite)	37	56	171	020	29	43
10. Other individual services	37	55	170	20	29	42
Sector's average rating (for 10 sectors)	112	168	515	59	88	129

Source: calculations based on the I-O methodology

FIGURE 10 TOP-10 SECTORS WITH GREATEST REDUCTIONS IN CARBON FOOTPRINT WITH VALUE ADDED IN STRUCTURE OF THE ECONOMY >1% IN TERMS OF USD1 BILLION INVESTMENTS (T CO_2-EQ./ MLN UZS OF OUTPUT) WHEN IMPLEMENTING ENERGY-SAVING (IN-RS) AND WIND ENERGY (IN-RE) TECHNOLOGIES

Source: calculations based on the I-O model

Note: IN-RS reduction of carbon footprint for resource-saving scenario (CCSGT); IN-RE20 (30) in scenario of wind turbines with 20% and 30% installed capacity, respectively



through harnessing WPP (20% of installed capacity) is 112 kg CO_2-eq./mln UZS of final consumption, while *in the economy as a whole* this estimate is only **28** kg CO_2-eq. Almost the same ratios are typical for WPP related option (30% of installed capacity) and CCSGT. However, all these sectors (with the exception of chemistry and electric power) do not make significant impact on the economy. Their share of value added in the structure of economy is about 4%. Consequently, **the modernization of only one energy sector is clearly insufficient to transfer the economy to a low-carbon development trajectory.**

The composition of sectors will be different if the sectors with the greatest reductions in carbon footprint are selected from those ones, which share in the economy structure in terms of their value added is higher than 1% (Fig.10). While in the first case, the 6 out of 10 sectors are related to the service sector, in the latter approach the only two are belonging to the service sectors (public administration and telecommunications services). They account for 1/3 of the economy structure. However, the average sector's estimate of reducing carbon footprint (36-54 kg CO_2-eq. for WPP scenario in terms of USD1 billion investments) is almost 2 times lower than for the approach to selection of the first top ten sectors (59-88 kg CO_2-eq. for WPP scenario in terms of USD1 billion investments) without consideration of their weight in the economy. The conclusion is that it is advisable expanding search for new green technologies that ensure the **maximum reductions of carbon footprint in terms of USD1 billion investments for the sectors, which form the basis of economy and export.**

The social effect of modernization of power sector is insignificant. As it was shown in the previous study report (2020), utilization of CCSGT reduces demand for natural gas, volume of its production, output, employment, including in the interrelated sectors. To eliminate these effects, the compensatory measures are required to maintain natural gas demand (expansion of gas exports, gasification of rural areas, etc.). The same effects, though on a smaller scale, is relevant WPP scenario, which, in general, **is neutral in relation to employment and income of the population.**

On the other hand, there are socially-oriented projects that, at the same cost, create new jobs without worsening the environmental situation. An example is the *textile and apparel* *sectors*, where investments in 2017-2020 alone led to increase in the number of jobs from 100.5 thousand in 2016 to 315 thousand in 2020.[39]

Another example is the implementation of 5 projects focused on cotton yarn production, which total cost amounts to USD100 million and creates 4,500 new jobs and provides output of USD112 million.[40] The I-O methodology allowed to evaluate the *full effects* in case of the entire additional volume of yarn is recycled and sent to tailoring. Thus, the total employment growth in the economy as a whole will amount to 15.8 thousand people (9.7 thousand of them are employed in the apparel industry, and 3.5 thousand are in the cotton yarn production), i.e. more than 3 times higher than the direct estimate (4.5 thousand jobs). The growth of revenues for the economy as a whole will increase by 0.24%, and the growth of the public budget revenues will increase by 0.5%. The consumption of clothing and sewing products will increase by 30%, the production of clothing by 17.5%, cotton yarn by 3.4%, and additional GDP growth will be 0.3%.

Thus, the textile project being almost 20 times lower in cost than WPP project provides a significant contribution to increased employment and reduced poverty without serious negative impacts on environment. In terms of 1 billion UZS of investments, a socially-oriented project can provide additional employment for **150-160** thousand people vs slight reduction in carbon footprint (2.0-2.5% for the economy as a whole) and lack of significant social effects when implementing the RES projects.

5.3. AGRICULTURE: ASSESSMENT OF IMPACTS OF BIOGAS PLANT UTILIZATION ON ENVIRONMENT, RESOURCE CONSERVATION AND EMPLOYMENT

Agriculture is the leading sector of economy. According to the data in table I-O for 2017, agriculture was accounted for 30.7% of the total output of economy (29.5% for industry and 33% for services sector; 33.7% of the total value added (21.3% for industry and 39.5% for services sector) and 25.2% of the total number of employees (14.7% for industry and 55.9% for services sector). Agriculture is the leading sector in terms of the gross profit amounted to 41.9% (21% for industry and 31.1% for services sector) and share of products in household consumption 40.6% (27.5% for industry and 13.1% for services sector). Unlike other sectors, agriculture is least dependent on the import of intermediate raw materials: the share of agriculture was only 4.9% (88.2% for industry and 6.6% for services sector). At the same time, agriculture is one of the sectors, which is most vulnerable to climate change impacts.

Direct effects from Utilization of biogas units (BGU) up to 2040. The purpose of modelling was to estimate the reduction of specific GHG emissions for various options of utilization of new technology (biogas units) for cattle manure disposal (BGU), as well as estimate the required investments and social effect (new jobs). The initial conditions (Section a, Table 7) determined the approach of model calculations (see Annex 10).

The analysis of the obtained results allows us to draw the following conclusions:

Conclusion 1. *The introduction of BGU is a promising direction for agriculture's transfer to the of low-carbon development trajectory*. Even 10% coverage of cattle (by 2030 in option # 1 and 2025 in option # 2, indicator 11 in Table 7 and Figure 11) can **break the trend of increasing GHG emissions in agriculture.** A wider coverage of cattle by 70% (by 2040,

[39] Overview of the development of the textile industry in Uzbekistan in 2017-2020. https://yuz.uz/ru/news/obzor-razvitiya-tekstilnoy-otrasli-uzbekistana-v-2017-2020-godax

[40] Estimated data of the company "Boyovut Techno Cluster". See also "The investment program of the Light Industry of Uzbekistan has been replenished with 10 more projects worth $80.7 million" Uzreport. https://uzreport.news/economy/investprogramma-legproma-uzbekistana-popolnilas-eshhe-10-proektami-otsenochnoy-stoimostyu-80-7-mln

TABLE 7 FORECAST ESTIMATES OF THE EFFECTS OF BIOGAS UNIT UTILIZATION IN AGRICULTURE UP TO 2040

Indicators	Unit	2020 (report)	Option No.	2025 (forecast)	2030 (forecast)	2035 (forecast)	2040 (forecast)
a. Initial conditions							
1. Cattle	ths heads	12,612	-	13,412	13,812	14,012	14,012
2. Meat production	ths tons	2,522.4		2,682.4	2,762.4	2,802.4	2,802.4
3. Milk production	ths tons	10,972.4		11,668.4	12,016.4	12,190.4	12,190.4
4. Milk and meat, total	ths tons	13,494.8		14,350.8	14,778.8	14,992.8	14,9928
5. Percentage of cattle coverage by BGUs for manure disposal	%	0.0001	1	5	10	15	20
			2	10	20	40	50
			3	20	40	55	70
6. Number of required BGU (at the end of the period)	ths units	0.1	1	26.8	55.2	84.1	112.1
			2	53.6	110.5	224.2	280.2
			3	107.3	221.0	308.3	392.3
7. Cost of imported BGU in absence of domestic production	mln USD	0	1	174.4	377.1	573.8	765.1
			2	348.7	754.1	1,530.1	1,912.6
			3	697.4	1508.3	2,103.9	2,677.7
8. Cost of imported BGU with development of local manufacturing	mln USD		1	156.9	263.9	286.9	306
			2	313.8	527.9	765.1	765.1
			3	627.7	1,055.8	1,052.0	1,071.1
9. Investments over the past five years into development of local manufacturing	mln. USD	0	1	92.4	97.9	191.6	194.4
			2	184.7	195.8	576.3	388.8
			3	369.5	391.5	670.0	681.0
b. Effects of BGU utilization on emissions, resource conservation and employment							
10. Gas saving, total	ths m^3	0	1	21,442	44,162	67,203	89,604
			2	42,884	88,325	179,208	224,010
			3	85,767	176,650	246,411	313,614
11. Emissions from agriculture, total	ths tons	30842	1	31,158	28,879	24,903	19,922
			2	29,519	24,319	14,803	7,401
			3	26,239	16,213	7,401	2,220
12. Specific emissions from agriculture	kg. CO2-eq./kg of livestock products	2.29	1	2.17	1.95	1.66	1.33
			2	2.06	1.65	0.99	0.49
			3	1.83	1.10	0.49	0.15
13. Fertilizers saving	ths tons	0	1	49	101	153	204
			2	98	201	409	511
			3	196	403	562	715
14. Number of new jobs without domestic production of BGU	ths jobs	0	1	0.67	1.38	2.10	2.80
			2	1.34	2.76	5.60	7.01
			3	2.68	5.52	7.71	9.81
15. Number of new jobs in case of domestic manufacturing of BGU	ths jobs	0	1	1.13	4.25	9.36	14.42
			2	2.27	8.49	24.97	36.06
			3	4.54	16.98	34.34	50.48

Source: calculations based on the conditions and algorithms given in Annex 10

option # 3) will reduce GHG emissions in the sector in more than 10 times (from 30,842 thousand tons CO_2-eq. to 2,200 thousand tons CO_2-eq.), thereby making a significant contribution to reducing GHG emissions in the economy as a whole.

Conclusion 2. *The reduction of GHG emissions will occur despite the increase in the number of cattle from 12.6 mln heads* in 2020 to 14.0 mln heads by 2035, due to dynamic reduction in the *specific GHG emissions* from 2.29 kg CO_2-eq. per 1 kg of livestock products in 2020 to 1.33 kg CO_2-eq. by 2040 in option # 1 and to 0.15 kg CO_2-eq. through wider

FIGURE 11 FORECAST OF GHG EMISSIONS IN AGRICULTURE AT DIFFERENT SCALES OF BGU UTILIZATION (THS TONS CO_2-EQ.)

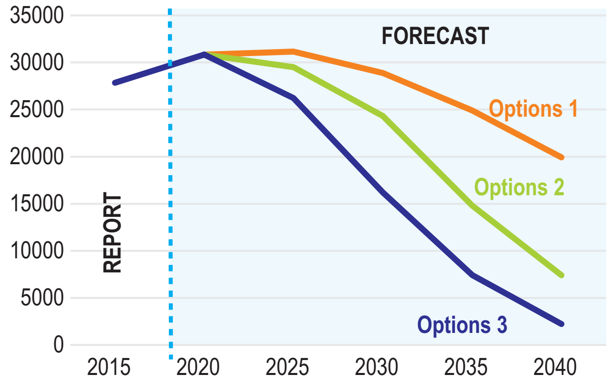
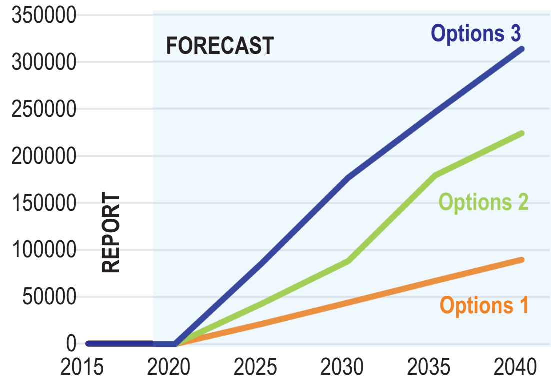


FIGURE 12 FORECAST OF NATURAL GAS SAVINGS IN AGRICULTURE AT DIFFERENT SCALES OF BGU UTILIZATION (THS M^3)



Source: Authors' estimates

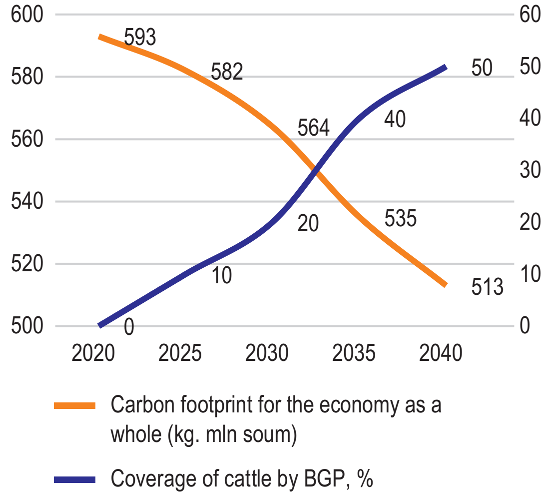
utilization of BGU (option # 3) even with considering the current production capacities of the BGU with a bio-reactor of 6 m^3 manufactured in China. In the coming years, the technical parameters of BGU would be increased that will allow achieving even greater outputs with the same number of operational BGU.

Conclusion 3. *Another effect is the saving of natural gas through its substitution by the produced biogas*, which thermal calorific value does not much differ from the natural gas one (coefficient 0.73). By 2040, the natural gas savings could amount to 89.6 mln m^3 at the moderate pace of harnessing BGU and up to 131.6 mln m^3 at the accelerated transition to low-carbon development pathway. Within the specified enabling environment, the sector can be self-sustainable with its biogas production by 2029 in option # 3 (Figure 12) and by 2033-2034 in option # 2. Biogas can be used for generation of the electrical and thermal energy to cover both heat and hot water supply domestic needs and at the production scale (electricity generation and heating of greenhouses), indicating the **high potential of BGU utilization**.

Conclusion 4. *Fertilizer savings by 2040 can reach 17% of the total volume of their output in 2017* (1.2 mln tons) with 20% coverage of cattle by BGU utilization (option #1) and up to 60% (with 70% coverage of cattle by BGU utilization, option # 1). This will increase crop yields, eliminate the shortage of fertilizers, and strengthen the financial situation of farmers. In addition, by using biofertilizers, **it is possible to grow environmentally friendly agricultural products that have higher market value comparing with those products that were grown with using mineral fertilizers**. At the same time, as the practice shows, use of biofertilizers ensure the yield increases by 20-30%, and one ton of bio-fertilizer applied into 1ha of soil substitutes 50-60 tons of unprocessed cattle manure. Moreover, the use of biofertilizers will result in **environmental benefits and increased soil fertility**, undermined by many years of excessive use of mineral fertilizers.

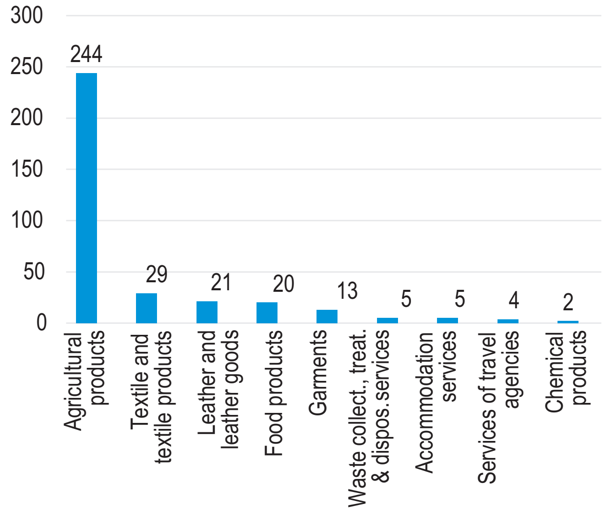
Conclusion 5. To achieve the above indicated benefits in case of the option 1 without initiation of local manufacturing of BGU), the investments amounted to USD0.8-2.7 billion would be required by 2040 (indicator 7). Under the option 2, the required investments would amount to USD1.9 billion, which is comparable to the cost of WPP project (USD1.8 billion). At the same time, the case of WPP considering the unchanged amount of electricity generation, the reduction of GHG emissions is estimated in the range of 1,368-2,056 thousand tons CO_2-eq., while utilization of BGU technologies would result in GHG emission reduction in the amount of 23,441 thousand tons CO_2-eq., i.e. it is meaningfully higher even in the case of growth of agriculture production output (at the constant amount of output, the GHG emission reductions will be even higher). This shows a **significantly higher efficiency of BGU utilization for the economy as a whole, compared to WPP technologies.**

FIGURE 13 FORECAST OF NATURAL GAS SAVINGS IN AGRICULTURE AT DIFFERENT SCALES OF BGU UTILIZATION, (1000 M³)



Source: Calculations of GHG emission multipliers based on data from table I-O for 2017, and statistics on agriculture related emissions of Uzhydromet

FIGURE 14 INDUSTRIES WITH MAXIMAL REDUCTIONS OF CARBON FOOTPRINT THROUGH BGU UTILIZATION IN AGRICULTURE, (KG CO_2-EQ.)



Source: Results of calculating GHG emission multiplier using I-O methodology

Conclusion 6. Comparison of the technological scenario of utilization of animal waste without local manufacturing BGU (indicator 7) with the scenario of without local manufacturing BGU (indicator 8 + indicator 9) shows that investments in the scenario of a phased transition to without local manufacturing BGU are higher (option 1 in terms of coverage of cattle livestock by BGUs by 2025 year is USD249.3 million in relation to without local manufacturing BGUs (156.9 + 92.4) versus USD174.4 million under the technological scenario focused exclusively on BGU imports). However, the excess of investment costs is not so great. In 2025, in all options, it was 43%. At the same time, as the development of local manufacturing BGU,[41] this excess in investment costs is reduced (by 2030 to 10.3% in option # 2 in terms of the livestock coverage).

Conclusion 7. *The transition to local manufacturing BGU creates more new jobs compared to the traditional scenario of importing BGU with the same indicators of reducing GHG emissions.* In option # 1 without the local manufacturing BGU (indicators 14 and 15), the number of employees increases from 0.67 to 2.8 thousand specialists (mainly for after sale service of procured BGU). In the same option in the case of local manufacturing BGU, the employment will increase from 1.13 thousand specialists to 14.4 thousand, i.e. the gap will increase from 1.7 times in 2025 to 5.1 times in 2040. Accordingly, **the incomes of the employed will grow, which increases contributions from green development to reducing poverty and achieving other social benefits.** Employment growth will be even higher, given the multiplicative effect of interaction of the new branch of mechanical engineering (BGU manufacturing) with other sectors of the economy.

Total effects (direct and indirect) from harnessing BGU technologies up to 2040. The purpose of the calculations is to estimate the carbon footprint of agriculture, other sectors and the economy as a whole withing the various options for BGU utilization.[42] At the same time, the average option of BGU utilization rate was considered (option # 2 with cattle cov-

[41] The share of biogas plants produced domestically in the local market, in accordance with the conditions laid down in the calculation, will grow from 10% of own production of the needs for installations in 2025 to 60% in 2040 – see Appendix 3, explanations for indicator 8.

[42] The calculations done with used the Input-Output table for 2017, and Uzhydromet statistics on industry GHG emissions for 2017, as well as the particular conditions and results obtained as part of direct calculations (Table 8).

erage by BGU up to 50% by 2040). The key factors that reduce the carbon footprint are reduction of specific GHG emissions in agriculture, natural gas and mineral fertilizers savings at scaling-up BGU utilization (indicators 10, 11, 13 in Table 7).

BGU utilization in agriculture can significantly reduce the carbon footprint of the economy as a whole. This is evidenced by the results of recalculation of the emission multiplier with consideration of the lower specific GHG emissions in agriculture, as well as the coefficients of direct costs of natural gas, fertilizers, electricity per unit of output of the sector (Annex 11), which reflect the process of harnessing BGU technologies with the coverage of cattle up to 50% by 2040 (option # 2, Table 7). Under this option, the carbon footprint can be reduced from 593 kg CO_2-eq. per 1 mln UZS of the final product up to 513 kg CO_2-eq., or by 13.5% (Fig. 13), which will make a *significant contribution to the fulfillment of Uzbekistan's international commitments to reduce GHG emissions.*

The BGU utilization results in decreasing contributions of sectors with the emissions to carbon footprint of the economy as a whole. Thus, in the absence of BGU (2020), the contributions of sectors with direct emissions to carbon footprint of the economy was 73.7% (see Table 4). In the case of BGU availability (option # 2), this indicator will decrease to 66.4%.

Among the sectors which a significant part of whose products are intended for export, the largest reduction in the carbon footprint through use of BGU is expected in such industries as textile production (29 kg CO_2-eq., Fig. 14), sewing, food production and other sectors that have close technological ties with agriculture. T*his reduces the risks of losses for national exports when the cross-border carbon regulation will be introduced by the developed countries.*

A comparison of the effects of harnessing green technologies in energy and in agriculture sectors allows confirming the *conclusion of efficiency BGU technologies*. While carbon footprint reduction of the economy as a whole a per USD1 billion of investments into construction and operation of WPP was 14.5-21.6 kg CO_2-eq.(depending on the efficiency of WPP), the modernization of the existing TPPs results in reduction by 31.5 kg CO_2-eq., but BGU utilization in agriculture is about 42 kg CO_2-eq. (Table 8).

TABLE 8 COMPARATIVE EFFICIENCY OF VARIOUS ALTERNATIVE TECHNOLOGIES BASED ON CARBON FOOTPRINT REDUCTION CRITERION FOR ECONOMY AS A WHOLE (AS PER USD1 BILLION OF INVESTMENTS)

Technologies	General assessment of carbon footprint reduction for a typical project (kg CO_2-eq./mln. UZS of final consumption)	Required investments (USD, billion)	Reduction of carbon footprint of economy as a whole per USD1 billion of investments
Introduction of WPPs with an efficiency of 20% (energy)	28	1.9	14.7
Introduction of WPPs with an efficiency of 30% (energy)	41	1.9	21.6
Modernization of TPP with the introduction of CCGT (energy)	126	4.0	31.5
Introduction of BGU in agriculture	80	1.9	42.1

Source: Results of calculations in sections 5.1 and 5.2

The I-O methodology allows assessing the impact of BGU utilization on employment and other social factors, since the direct calculation does not consider the reduction of employment at enterprises producing mineral fertilizers and in natural gas production companies, the demand for which products will decrease because of natural gas and mineral fertilizer savings through BGU utilization. Calculations have shown (Table 9) that the reduction in employment because of resource savings within the terms of the option # 2 without initiation of local manufacturing of BGU by 2040 can reach 8.4 thousand jobs that will exceed the additional demand for BGU service specialists, which is estimated at 7 thousand jobs. The largest decrease in jobs should be expected in chemical industry (by 5.4 thousand people), in which the decreased demand for mineral fertilizers would result in decline in production by 12.2%. In other words, **the introduction of green technologies in agriculture can reduce carbon footprint of the economy as a whole. However, without establishing local manufacturing BGU[43] the effects on employment and income of population will be negative.**

The situation is changing if gradual development of local manufacturing of BGU and achieving the share of local production of BGU to 60% of BGU demand by 2040 (see explanations on calculation of indicator 15, Table 7). Under these conditions, the output of the sub-sector C28 (Manufacture of machinery and equipment except electronics, electrical engineering, automotive) will increase by 3.6 times by 2040, creating additional demand for products producing by the interrelated sectors. Thus, the production of products in the following sectors such as basic metals (by 2.1%), metal products (2.0%), computers (2.5%), electrical equipment (2.6%) will increase. As a result, **the total employment in economy as a whole will increase by 20.5 thousand jobs and with service personnel by 27.5 thousand jobs**, which will increase incomes of the population and public budget revenues.

TABLE 9 FULL EFFECTS OF THE INTRODUCTION OF BGU TECHNOLOGIES FOR EMPLOYMENT (BY 2040 IN COMPARISON WITH 2020, NUMBER OF EMPLOYEES)

Indicators	Without domestic production of BGU	With creating domestic production of BGU
Reduction of employment due to savings in gas and fertilizers, including:	-8,395	+20,511
Chemistry	-5,445	-5,334
Trade	-365	+960
Agriculture	-267	+84
Gas	-146	-96
Machinery and equipment (no cars)	-3	+20,994
Metal Ores	-151	+1,032
Basic Metals	-7	+812
Metal Products	-32	+377
Service personnel	+7,010	+7,010
Total change in employment	-1,385	+27,521

Source: results of calculations based on the I-O model.

5.4. WATER MANAGEMENT: ASSESSMENT OF CONTRIBUTION OF WATER-SAVING TECHNOLOGIES TO ADAPTATION OF ECONOMY AND POPULATION TO WATER DEFICIENCY

The purpose of the calculations is to assess the economic, sectoral and social impacts of various degrees of water scarcity (reduction of available water resources by 10%, 20% and 30%). The calculations are based on the I-O methodology. The input parameters were expert estimates of the forecasted decline in agricultural production capacities at various degrees of water scar-

[43] Currently, this is a traditional model of technological development, focused on the purchase of imported equipment/technologies funded from foreign loans under government guarantees, as well as attracting international consultants for operation and maintenance of equipment, without attempts to establish domestic technological base and production facilities with completed technological cycles.

TABLE 10 FORECAST ESTIMATES OF THE IMPACT OF THE EXPECTED LOW WATER ON AGRICULTURAL PRODUCTION (PRODUCTION DECLINE IN % TO THE BASELINE LEVEL OF 2020)

Types of agricultural products	Level of low water (reduction of water flow in % to the average)		
	10%	20%	30%
1) maintaining the current trends in agricultural adaptation to drought and other impacts of climate change			
including Cotton	2	8	20
Crops	5	11	45
Vegetables and Fruits	15	30	63
Agriculture as a whole (% decline)	6.1	12.4	28.0
2) taking additional measures to adapt agriculture to drought and other impacts of climate change			
Agriculture as a whole			
including Cotton	0	5	12
Crops	0	8	30
Vegetables and Fruits	0	5	10
Agriculture as a whole (% decline)	0	2,7	6,7

Source: Report of Shukhrat Mukhamedzhanov "Study of the main factors affecting agricultural production and the associated reduction of greenhouse gas emissions", UNDP, 2020. The decline in agriculture is calculated based on the assumption that the shares of the key products in the total volume of production formed in 2020 will remain (cotton is 3.6%, cereals are 8.3%, vegetables, fruits are 37.3%, etc.).

city within the two scenarios: 1) with maintaining the current trends in agriculture adaptation to droughts, and 2) with the mass use of drip irrigation technology (DI).

The calculations show that *low availability of water resources poses serious threats not only for agriculture, but also for interrelated sectors, national economy, and population.* With a decrease in water flow from 10% to 30%, the decline in agricultural production could amount to 6.1%-28% that may result in decline of the households'[44] consumption of goods and services by 3.6%-9.3%, but their consumption of agricultural products would reduce by 9.3%-42.6%. This can lead to a *noticeable decrease of living standards of population.*

At the 30% water shortage, the decline in electric power industry, *ceteris paribus*, can be 2.6-2.7%, in the chemical industry – 6%, in the textile industry – 2.6%, in many types of services – 1.5-1.6%. In general, 30% shortage of water resources may result in **decrease GDP growth rate by 9-10%** (Table 11).

The scale of the negative impacts of drought periods can be significantly limited if measures are taken to adapt agriculture and population to negative climate change impacts. *The use of drip irrigation, strict water consumption metering and accounting, and improved water resources management can significantly reduce the forecasted decline in agricultural production.* If the scale of their implementation is significant,[45] then the option with an increased water deficiency by 10% shows that it is possible to maintain the basic level of agricultural production. In the most unfavorable scenario (i.e. 30% of water deficiency), a sharp decline in the water management sector output (by 28%) can be limited to 6-7% (Table 10, right side) by implementation of water saving and efficient management measures and activities. Accordingly, *the scale of negative impact on the economy and particular interrelated sectors will significantly decrease*. Calculations show that in this case the economy's decline will be 2-2.5% but 9-10% (Table 11, right side), or, in the value terms, 6,297 billion UZS but 26,297 billion UZS.

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[44] In accordance with the terminology of the system of national accounts, the most important element of which is the input-output methodology, the term "household" (along with the concepts of "government", "real sector", etc.) is key in macroanalysis. In this case, the concepts of "households" and "population" are identical to each other.

[45] The construction of water-saving technologies on an area of 2 million hectares, including drip irrigation systems on an area of 600 thousand hectares, will require investments in the range USD1,500-3,000 million.

TABLE 11 ASSESSMENT OF THE IMPACT OF THE EXPECTED LOW WATER ON INDUSTRIAL OUTPUT AND THE ECONOMY AS A WHOLE (PRODUCTION DECLINE IN % TO THE BASELINE LEVEL)

Sectors of the economy		Baseline Values 10%	Without Adaptation Measures (Option 1)			With the introduction of drip irrigation (Option 2)		
			20%	30%	10%	20%	30%	
1	Agriculture, forestry, and fisheries	100	-5.86	-11.90	-26.83	0	-2.58	-6.42
2	Gas and oil production	100	-0.02	-0.04	-0.09	0	-0.01	-0.02
3	Other extractive industries	100	-0.15	-0.30	-0.67	0	-0.06	-0.16
4	Manufacturing industry	100	-0.30	-0.61	-1.37	0	-0.13	-0.33
5	Energy sector	100	-0.58	-1.18	-2.66	0	-0.26	-0.64
6	Water and irrigation	100	-0.16	-0.33	-0.75	0	-0.07	-0.18
7	Transportation	100	-0.21	-0.43	-0.97	0	-0.09	-0.23
8	Construction	100	-0.02	-0.04	-0.09	0	-0.01	-0.02
9	Education	100	0.00	-0.01	-0.01	0	0.00	0.00
10	Healthcare	100	0.00	0.00	-0.01	0	0.00	0.00
11	Other services	100	-0.32	-0.66	-1.48	0	-0.14	-0.35
	TOTAL (GDP)	100	-2.11	-4.30	-9.68	0	-0.93	-2.32

Source: Calculations with use of I-O methodology for input parameters from Table 10

The effects of drip irrigation introduction are also very significant for employment. Under 30% of deficiency, the decrease of employment can amount to 250.3 thousand employees, which is almost 2% of the total employed population, if adaptation measures are not timely implemented. In the most negative scenario (i.e. 30% water deficiency), the preservation of jobs (190.4 thousand people) would be possible through application of drip irrigation technology (Table 12, the far right column), i.e. through to mitigation of water deficiency impact

TABLE 12 ASSESSMENT OF WATER DEFICIENCY IMPACT ON UNEMPLOYMENT (NEW UNEMPLOYED PERSONS)

Sectors of the economy		Without Adaptation Measure (Option 1)			With use of Drip Irrigation (Option 2)			Employment retention for 30% of water deficiency
		10%	20%	30%	10%	20%	30%	
1	Agriculture, forestry and fisheries	-49,762	-101,129	-227,943	0	-21,938	-54,578	173,365
2	Gas and Oil Production	-37	-75	-168	0	-16	-40	128
3	Other extractive industries	-75	-152	-344	0	-33	-82	261
4	Food products	-111	-225	-506	0	-49	-121	385
5	Textiles and text goods	-542	-1,101	-2,481	0	-239	-594	1,887
6	Chemical products	-587	-1,192	-2,688	0	-259	-643	2,044
7	Other manufacturing industry	-691	-1,403	-3,163	0	-304	-757	2,406
8	Energy Sector	-482	-980	-2,209	0	-213	-529	1,680
9	Water and Irrigation	-31	-62	-140	0	-14	-34	107
10	Transportation	-215	-438	-986	0	-95	-236	750
11	Construction	-39	-79	-179	0	-17	-43	136
12	Trade	-1,180	-2,397	-5,403	0	-520	-1,294	4,110
13	Education	-29	-59	-133	0	-13	-32	101
14	Healthcare	-9	-18	-40	0	-4	-10	31
15	Other Services	-864	-1,756	-3,958	0	-381	-948	3,011
TOTAL new unemployed:		**-54,652**	**-111,067**	**-250,341**	**0**	**-24,094**	**-59,941**	**190,400**

Source: Calculations done with use of I-O methodology for input parameters from Table 11.

on employment by 76%. Moreover, 91% of the total number of saved jobs fall on the jobs in agriculture, in which the largest part of low-income population is concentrated.

The calculations also allowed to estimate the effect of measures aimed at mitigation of climate change impact on the employed incomes. It amounted to UZS 1,700 billion, which is comparable to the annual income of all those employed in the following sectors (2017): metallurgy (UZS 1,879 billion), transport services (UZS 1,826 billion), and financial services (UZS 2,051 billion).

Another positive effect of harnessing drip irrigation technology is **reduction of carbon footprint** due to water savings as well as associated energy savings related to irrigation water delivery by pumping stations. The piloting use of drip irrigation technology in the farms of Namangan region demonstrated that the total water saving is 11.7 thousand m^3 per 1 hectare of cotton growing field, 6.6 thousand m^3 of water per 1 hectare of wheat and 11.4 thousand m^3 of water per 1 hectare of orchards.[46] The energy savings amount to UZS5 mln (in2018 prices) for 10 hectares of cotton fields, UZS3.1 mln for 10 hectares of grain and UZS3.2 mln for 10 hectares of orchards (apples). The yield growth is on average 40% for all crops, which indicates a **significant potential for use of drip irrigation and improvement of water management system with implementation of adaptation measures to mitigate climate change impacts.**

[46] Drip irrigation is a necessary reality for Uzbekistan. Publication in an electronic publication nuz.uz 05.09.2018 https://nuz.uz/ekonomika-i-finansy/35318-kapelnoe-oroshenie-neobhodimaya-realnost-dlya-uzbekistana.html

6 | Consideration of National Interests in Transition to Active Climate Policy: Conclusions and Recommendations

The analysis of world experience and sectoral calculations suggest that an active climate policy in Uzbekistan should be formed at **two levels: macroeconomic and sectoral**.

MACROECONOMIC LEVEL

Development of more systemic measures to accelerate the process of economy's decarbonization at the level of sectoral development programs. In 2000-2018, Uzbekistan has made significant progress in terms of the indicator of specific CO_2 emissions per 1 USD of GDP (in 2015 prices). However, since 2015-2016, the rate of GHG emissions reduction and rate of energy intensity of GDP reduction had started to decline, indicating the emergence of **new barriers** that hinder the process of economy's decarbonization. This indicates that the current potential of reducing GHG emissions in Uzbekistan have been fully exploited and more **drastic measures** shall be undertaken at the level of macroeconomic policy.

There is a need in combining climate policy with solving social problems. The size of new national commitments on GHG emissions reduction should be at the scale, which cost of achieving does not exceed the cost of eliminating the associated negative social and economic impacts. More ambitious commitments envisage introduction of new advanced technologies (less manual but more automated) that almost always is accompanied by reduction of jobs and need to re-channel the released labor force into other sectors along with the upgrading professional skills and re-training. For Uzbekistan, which for a long time has had a labor force-surplus economy, this is a serious development challenge. Climate policy should facilitate transition to low-carbon and **at the same time socially-oriented development pathway. This combination is key for Uzbekistan.**

The solution is to search for **double-dividend technologies ("win-win" technologies)** that combine the achievement of traditional effects (economic and social benefits) and climate change related effects (environmental benefits). The search for these technologies that contribute to reducing GHG emissions and at the same time are aimed at solving social and economic problems should become the **key priority of Uzbekistan's technological development policy**.

Development of tools for prioritizing "green" projects. Not always and not all "green" technologies are *socially oriented and climate/environmentally friendly*. Calculations done for the energy sector have shown that the effects of "green" development related to preservation of the existing jobs *can be negative*. Another challenge is that creating new jobs in the "green" sectors may require significant investments in the *retraining of the workforce*. In addition, the "green" technologies may have *negative side effects* for the environment/health, which may not be immediately identified, or are underestimated. As a result, the significant investments in these technologies may be unjustified.

The correct selection of projects should be **regulated by the technology development policy and "green" financing. There is neither one nor the other in the country yet.** The technology development policy has never been officially announced, and the "green" financing is available in the majority of cases with the donor grant funding. The selection of projects is not transparent. The single coordinator of the grant-based projects is the Ministry of Investment and Foreign Trade, which has not published criteria for the selection of "green" projects.

To create a national system of green financing, it would be required to:

1) Identify the criteria for selection of projects. For example, if the goal is to reduce GHG emissions, the nuclear energy should be considered as "green", because its carbon footprint is less than that of the most of other types of energy generation option. However, other criteria look not only at the climate change challenge, but also assess the risk of leaks and accidents may occur at the nuclear power plant. Therefore, nuclear energy in excluded from the "green" project list.

2) Develop tools for prioritizing "green" and socially-oriented projects. This would enable distinguishing between "climate change" and "other" focused investments under the national investment programs in order to correctly estimate the social and economic effects of "green" investments. Currently, the issue is debatable for many countries, including Uzbekistan. The experience of Ghana can be used as an example of prioritizing the green projects. The assessments of international experts have shown that Ghana's "green" projects are very effective, and the experience of this country in the process of selecting projects for green investments[47] can be used by other countries.

4. **Improvement of quality of institutional environment.** Large-scale investments in modernization of the sectors of economy with the highest GHG emissions alone **are not sufficient** for reduction of carbon intensity of the economy as a whole and of the particular sectors. A paramount condition is the development of institutions that are able to **effectively deliver** these investments, especially in the countries, including Uzbekistan, which rating of quality of their government institutions is low. Calculations have shown that investments become a **significant factor** in reducing GHG emissions, if the quality of institutions is above a certain threshold value. In the countries with the quality of institutions, which is below the certain threshold, the climate action policy becomes ineffective, even if it is implemented with an emphasis on green investments and green technologies.

The threshold value of the quality of institutions for Uzbekistan was (-1.53) based on the scale from -2.5 to +2.5. Although the trend of regulatory quality in Uzbekistan was assessed as positive one in 2000-2018, the average estimates for this period (-1.51 (arithmetic mean) and -1.57 (median average)) were close to the threshold (-1.53), which significantly devalued the effect of the growth of investment activity in terms of GHG emissions reduction. This indicates that the efforts undertaken in the recent years to improve the quality of institutions and combat corruption **are still insufficient** to activate the process of the economy's decarbonization. Therefore, to ensure a real and efficient transition to green economy development in Uzbekistan, the **further administrative reform should be implemented and strengthened**.

Of course, in a short term it would be impossible achieving the optimal values of macroeconomic and institutional factors. To start, it would be advisable including separate macroeconomic and institutional indicators into the set of indicators *that will be used for annual monitoring of changes in the macroeconomic and institutional environment in comparison with the global trends*. Combined monitoring of technological modernization (at least for the key GHG emitting sectors) indicator and environmental indicators will allow constant monitoring and analysis of climate investment efficiency and effectiveness.

SECTORAL LEVEL

Changing the methodology for calculating the sectoral carbon footprint. At the sectoral level, the main task is better assessing the scale of GHG emissions. Firstly, for estimation of emissions' amount the switching from calculation of gross GHG emissions to calculation

[47] Report "Climate Change Project Prioritization Tool and Guideline" prepared under the auspices of the Government of the Republic of Ghana, 2017.

of carbon footprint is required. Secondly, all 78 sectors and sub-sectors on which the economy of Uzbekistan is built on but the 5 key GHG emitting sectors shall be considered and counted. Such calculations were done in the previous study (2020). The results showed that *all 78 sectors and sub-sectors of the economy contribute to GHG emissions*. Moreover, the largest amount of GHG emissions is marked not only by the sectors that directly use carbon fuel in their production activities (5 sectors under consideration in this study), but several of services sectors. Thus, the Top 15 sectors with the highest values of the emission multiplier included 7 services sectors. In general, the calculations showed that the full estimate of GHG emissions with the growth of final product of the economy by UZS1 mln exceeds the estimate of GHG emissions by sectors, which are the direct emitters, in almost 1.36 times, which requires that **indirect effects are considered across all sectors and sub-sectors of the economy** for formulation of low-carbon development programs and sector-based investments projects.

Priority of the climate policy in the coming years should be energy conservation, not only in energy infrastructure, but also in all energy-intensive industries (metallurgical, chemical, irrigation, construction materials sectors). In 2016, the energy saving (CCSGT) and renewable energy (WPP) projects developed in the power sector were competed in terms of GHG emission reduction and financial stability. Since 2017, the situation had been changed rapidly in favor of energy saving (due to the outstripping growth in gas prices). Therefore, the **RES-focused projects should be considered selectively** avoiding with competition with the existing operational TPPs. Projects focused on promotion of renewable energy should be implemented in those regions and sectors that are in need of either the improved or more stable energy supply.

Time for the large-scale investments into renewable energy focused projects will come when the price for natural gas in Uzbekistan reaches the global average level. Currently, in Uzbekistan the price of natural gas is set as artificially low compared to the global average price. This is reflected in the low share of gas consumption in the sector's output structure (14.5%). **This is the only reason, why the resource-saving projects (CCSGT) are more promising (effective) compared to renewable energy projects.** For Uzbekistan, the critical value of share of natural gas consumption in the structure of electricity output, the excess of which makes the resource saving project (CCSGT) as more efficient and preferable than the wind farm project (WPP), is **16.3%**. This critical value is determined by the relative rate of growth of natural gas prices compared to the growth of electricity prices, as well as the closing the gap between the natural gas prices at the global average and domestic level.

Currently, in Uzbekistan the traditional recommendations on the need in large-scale investments in renewable energy are ineffective. Calculations have shown that utilization of CCSGT reduces the social indicators (employment and income of the employed), and the option of WPP is neutral in relation to them. Unlike the developed European countries with low or negative population growth rates, Uzbekistan cannot undertake new more ambitious commitments on development and implementation of RES-focused projects and reduction of the associated GHG emissions without consideration of potential losses for employment and financing of the poverty reduction programs. More promising for Uzbekistan is a socially-oriented strategy for transition to low-carbon economy, which envisages utilization of renewable energy technologies for electric and thermal energy generation in the energy deficient regions, along with development of **labor-intensive industries.** The justification of establishing the specific labor-intensive industries with consideration of features of the regions and the efficiency criteria requires additional research.

Use of biogas units is the most promising direction of agriculture sector transition to low-carbon development trajectory. As related to GHG emissions reduction, the utilization of BGU technology is effective even with 10% coverage of cattle by operational BGUs, but with 70% coverage of cattle by 2040, it can result in GHG emissions reduction in more than 10 times compared to 2020. In addition, the use of BGU leads to a number of co-beneficial effects: a) saving of natural gas; b) saving of mineral fertilizers; c) production of environment-friendly agricultural products, etc. Calculations show that **harnessing BGU technology is much more promising compared to the WPP technology.**

Uzbekistan needs to develop mechanical engineering sector (but only automotive industry) that creates new green technologies for agriculture. This implies **revisiting and changing the current model of technological development** and establishing national technological base for production of green technologies. Calculations have shown that the gradual development of domestic technological base for BGU manufacturing will create a greater number of new jobs compared to traditional imports of BGU **with the same GHG emission reduction indicators.** Unlike the automotive industry, which uncontrolled growth has increased GHG emissions, sharply worsened the environmental situation and increased inequalities in the national society, local manufacturing BGU and other green technologies will contribute to GHG emissions reduction, improvement of agricultural land fertility, and unlock new opportunities for growing environment-friendly agricultural products, increase the well-being of rural population and will thereby **contribute to the poverty reduction efforts.**

Harnessing drip irrigation technologies will significantly reduce the scale of negative impact of water resources deficiency on the national economy (GDP) and particular sectors. Agriculture, being one of the three key sectors of the economy, is experiencing an **acute shortage of water resources for irrigation needs**, caused both by climate change, unresolved issues of sharing available water resources by the countries of the Central Asia region, and by the outdated and low efficient irrigation systems. Therefore**, the introduction of water-saving technologies for agriculture is one of the priorities of the green climate action policy of Uzbekistan.** The effects of use of drip irrigation for employment, and therefore for the well-being of population, are also very significant. Without climate adaptation measures considering the 30% water resources shortage, the 250.3 thousand people, which is almost 2% of the total employed population, could lose their jobs. In the most negative scenario of 30% water resources deficiency, the use of drip irrigation will potentially save jobs for 190.4 thousand people, i.e. it neutralizes the negative impact of water stress on employment by 76%. Moreover, 91% of the total number of saved jobs fall on the jobs in agriculture sector, in which the largest part of low-income population is concentrated. Thus, drip irrigation will become an additional tool for reduction of poverty in rural regions.

The methodological approach to assessing the carbon footprint of industries and sectors of the economy makes it possible to perform such calculations on an ongoing basis when the original statistics change, and new reporting data appear.[48] The introduction of the developed model toolkit will ensure a deeper consideration of national interests in the formation of the country's green development agenda, the formation of new commitments to reduce greenhouse gas emissions within the framework of the implementation of the Paris Climate Agreement.

[48] For example, when adjusting the estimates of sectoral emissions or the appearance of new reporting tables 3B, more approximate to the current situation in the economy.

ANNEXES

ANNEX 1. KEY REFORMS IN ENERGY SECTOR AND THEIR IMPACT ON GHG EMISSIONS (CO2-EQ.), 1993-2020

Key reforms implemented in 1993-2020	Measures/channels of influence	Impact on emissions/ resource savings (qualitative assessment)
Ensuring the country's energy security (sustainable provision of the economy and the population with energy and coal), 1993-2009 Program to Develop and Reconstruct Power Generating Capacity in Uzbekistan's Energy Sector, 2001-2010 Presidential Resolution No. PP-2812 on Adding Impetus to the Reforms in the Electricity Sector of Uzbekistan, 22 February 2001. Cabinet of Ministers Resolution No. PKM-93 on Measures to Organize the Activity of SJSC "Uzbekenergo", 24 February 2001.	a single managerial body in the electric power and coal industries, SJSC "Uzbekenergo", was created on the basis of the Ministry of Energy and Electrification. This allowed to: a) implement a unified technical policy; b) carry out design, construction, installation, commissioning and repair works on its own; within SJSC Uzbekenergo were established a) Uzelektroset – daughter companies of electrical trunk grids specializing in electricity transmission; and b) regional stock companies for the distribution and sale of electricity. Uzgosenergonadzor, a state agency for oversight of the power sector, was established as a regulatory body for the electricity, thermal power, and coal sectors, which in turn was subsequently reorganized into the State Inspectorate Uzgosenergonadzor under the Cabinet of Ministers of the Republic of Uzbekistan since 2004, building upon the trunk electrical grids of unitary enterprise Uzelektroset, five regional electricity transmission affiliates were created, while distribution networks with up to 110 kV voltage were transferred to regional power distribution and sales enterprises (monopolistic and competitive activities are being made separate from each another); in 2004, the first unit at Talimarjan TPP with 800 MW design capacity was put into operation. reconstruction of two 300 MW power units at Syrdarya TPP financed by an EBRD loan; reconstruction of electricity network facilities and modernization of cable networks in the city of Tashkent; until 2009, the Uzbek energy system continued to remain in the Central Asian Unified Energy System (production and transmission of electricity in the region).49	By 1996 Uzbekistan was no longer an importer of fuel resources Emission pathways have not been positively affected but have resulted in resource savings: More than 400,000 toe of fuel was saved due to modernization and repairs. Since 2009, the volume of export of energy resources has increased by more than 10%, while its domestic consumption by 8-8.5% annually.

[49] When the Soviet Union collapsed, the Central Asian Power System (CAPS) continued to exist but collapsed in the 2000s: Turkmenistan left the CAPS in 2003, and Uzbekistan followed suit in 2009. In 2018, at the initiative of Shavkat Mirziyoyev, the President of Uzbekistan, the Unified Energy System of Central Asia was restored.

Key reforms implemented in 1993-2020	Measures/channels of influence	Impact on emissions/ resource savings (qualitative assessment)
Capacity building, technical re-equipment, reconstruction and modernization of existing facilities, 2010-2015 Presidential Resolution No. PP-1176 on Measures for the Implementation of the Investment Project "Construction of CCGT at Navoi TPP", 19 August 2009. Presidential Resolution No. PP-1277 on Measures for the Implementation of the Project "Introduction of Gas Turbine Cogeneration Technology at Tashkent CHPP JSC", 4 February 2010. Presidential Resolution No. PP-1366 on Priority Measures for the Implementation of the Investment Project "Expansion of the Talimarjan TPP with the Construction of 2 CCGT Units (450 MW each)", 14 July 2010. Presidential Resolution No. PP-1624 on Measures to Accelerate the Implementation of the Model Project "Improving Energy Efficiency at the Tashkent CHPP with the Introduction of High-Performance Cogeneration Gas Turbine Technology", 5 October 2011. Presidential Resolution No. PP-1692 on Measures for the Implementation of the Investment Project "Modernization of Hydrogenerators in Charvak HPP with Replacement of Impellers", 25 January 2012.	maintaining the installed capacity of power plants, prevention of emergency start-ups, improvement of technical and economic performance; introduction of modern technologies and equipment that conserve fuel and energy resources and reduce the environmental impact of energy production. increase productivity by reducing fuel consumption. construction of the first combined cycle gas turbine (CCGT) unit with a capacity of 478 MW at Navoi TPP in 2012. In addition to electricity generating, a district heating system was installed with an annual heat output of 330,000 Gcal. introduction of a cogeneration GTU (27 MW) and a waste-heat boiler (47 t/h) at Tashkent CHPP JSC, allowing to replace generating equipment that reached the end of its useful life	Strong positive impact on reducing emissions and saving resources: The commissioning of the CCGT unit allowed the Navoi TPP to increase electricity generation by almost 1.5 times with a lower cost price (compared to conventional gas and steam turbines). Savings of natural gas amounted to 330 mln m3/ year, and CO2 emissions reduced by 744 thousand tons at Navoi TPP. Fuel savings of the grid from the introduction of GTU will reach 35 mln m3 of natural gas per year by substituting power generation from other high specific fuel consumption TPPs. The introduction of a GTU at the Tashkent CHPP provided a reduction in CO2 emissions by 65 thousand tons per year.
Introduction of the Automatic electricity metering and control system (AEMCS), 2012. Presidential Resolution No. PP-1795 on Additional Measures for the implementation of the Project "Implementation of an Automatic Electricity Metering and Control System. The Electricity Metering System (0.4 kV Supply Lines) in Bukhara, Jizzakh and Samarkand Regions" with the Participation of ADB, 2 August 2012.	installation of the advanced electric meters for 7 mln consumers and their connection to AEMCS; reduction of losses, improving the accuracy and completeness of metering for electricity consumed by industries (main power lines) and the public.	Contributed to electricity saving. It is estimated that an average of 400 kWh of electricity can be saved in each house per year, which in the country as a whole will amount to 1.8 billion kWh (this will be enough to provide Jizzakh or Syrdarya regions with electricity throughout the year)

Key reforms implemented in 1993-2020	Measures/channels of influence	Impact on emissions/ resource savings (qualitative assessment)
State program for modernization and renovation of low-voltage electrical networks (10-6-0.4 kV) for the period of 2017-2021. Presidential Resolution No. PP-2661 on the Program for Further Modernization and Renovation of Low-Voltage Electrical Networks for the period of 2017-2021, 23 November 2016	modernization and renovation of low-voltage electrical networks with total length of more than 34.0 thousand km and more than 6.9 thousand transformer stations; stable supply of electricity to consumers and social facilities.	No impact on emissions, but led to reduced losses and increased service coverage: improved power supply to more than 2.5 mln consumers living in 2,721 makhallas (self-government); improved quality of electricity.

Key reforms implemented in 1993-2020	Measures/channels of influence	Impact on emissions/ resource savings (qualitative assessment)
Development of alternative (renewable) sources of energy. Presidential Resolution No. PP-3012 on the Program of Measures for the Further Development of Renewable Energy, Improving Energy Efficiency in the Sectors of the Economy and the Social Sphere for 2017-2021, 26 May 2017. Presidential Resolution No. PP-3379 on Measures to Ensure the Rational Use of Energy Resources, 8 November 2017. Presidential Resolution No. PP-3687 on Additional Measures for the Implementation of Investment Projects in the Field of Renewable Energy Sources, 28 April 2018. Presidential Resolution No. PP-4165 on Approval of the Concept for the Development of Nuclear Energy in the Republic of Uzbekistan for the Period 2019-2029, 7 February 2019. Presidential Resolution No. PP-4422 on Accelerated Measures to Improve the Energy Efficiency of Economic and Social Sectors, the Introduction of Energy-Saving Technologies and the Development of Renewable Energy Sources, 22 August 2019. Law No. ZRU-537 on Public-Private Partnership, 10 May 2019 Law No. ZRU-539 on the Use of Renewable Energy Sources, 21 May 2019	the country has a high potential in the field of renewable energy, which is practically not used; • The program includes 810 investment projects in the field of renewable energy for a total amount of USD 5.3 billion. From January 1, 2018, mandatory equipment of all new buildings and structures (except individual housing construction) with certified solar water heaters for hot water supply. In the future, all buildings/structures will be designed, constructed, and renovated using energy-efficient and energy-saving technologies. Opening of the Solar Energy Institute in 2013. Draft of the Roadmap for solar energy development in 2014. Construction of photovoltaic power plants (PVPPs) in Navoi, Samarkand, Jizzakh and Surkhandarya regions. Construction of the wind power plant (WPP) with a total capacity of 1.5 GW in Bukhara region. Construction of the reference Generation III+ NPP with two power units, each having installed capacity of 1.2 GW. Creation of a regulatory and legal framework to accelerate the implementation of the renewable energy projects.	Most significant positive impact on emission reduction: By 2030, it is expected that share of RES in total electricity production will be reach 25% (currently -10%), which means a significant reduction in emissions. By 2030, the objective is to build solar power plants (PVPPs) with a total capacity of 5,000 MW and wind power plants with a total capacity of 3,000 MW. Energy efficiency improvement; Improvement of the ecological situation.

Key reforms implemented in 1993-2020	Measures/channels of influence	Impact on emissions/ resource savings (qualitative assessment)
Increasing the financial stability of the electric power industry Cabinet of Ministers Resolution No. PKM-515 on Measures to Ensure Financial Recovery and Efficient Use of Assets of Organizations of JSC Uzbekenergo, 6 July, 2018 Presidential Resolution No. PP-3981 on Measures to Accelerate Development and Ensure Financial Stability of the Electric Power Industry, 23 October 2018. Presidential Resolution No. PP-4664 on Priority Measures to Improve the Financial Stability of the Oil and Gas Industry, 4 February 2020.	"Road Map" of financial recovery of JSC Uzbekenergo for 2018-2022: introduction of a modern IMS system for the management of the full production and financial cycle in all enterprises of the joint-stock company; publication of the annual financial statements of JSC Uzbekenergo and all its member companies; privatization of 72 assets nationwide owned by JSC Uzbekenergo. implementation of 7 projects for the modernization of existing and commissioning of new generating facilities with a total capacity of 1,984 MW and a design value of USD 2.6 billion; reconstruction of existing and construction of new electric networks with a total length of 7.1 thousand km, installation and modernization of 2,500 transformer points; a list of state shares in the authorized capitals of companies proposed for sale to investors (including foreign investors), including enterprises of the electric power industry (JSC Angrenskaya TPP, JSC Novo-Angrenskaya TPP).	Low impact on emission reduction

Key reforms implemented in 1993-2020	Measures/channels of influence	Impact on emissions/ resource savings (qualitative assessment)
Formation of a competitive energy market. Presidential Decree No. UP-5646 on Measures to Radically Improve the Management System of the Fuel and Energy Industry of the Republic of Uzbekistan, 1 February 2019 Presidential Resolution No. PP-4249 on the Strategy of Further Development and Reform of the Electricity Sector of the Republic of Uzbekistan, 27 March 2019. Presidential Resolution No. PP-4300 on Measures to Further Improve the Mechanisms for Attracting FDI to the Economy of the Republic, 29 April 2019.	Delineating the functions of government regulation and economic activity: creation of the Ministry of Energy gradual privatization of generation and retail distribution of electricity: three joint-stock companies have been organized under the umbrella of Uzbekenergo JSC: "Thermal Power Plants" (electricity generation), "National Electric Networks of Uzbekistan" (transportation of electricity and maintenance of main power grids, dispatching of power systems, centralized sale of electricity and export-import operations); "Regional Electric Networks" (distribution of electricity and maintenance of electrical networks, technological connection of power plants of consumers and sale of electricity to consumers). plan for shutting down old facilities. Until 2026, the operation of obsolete power units will be withdrawn. They will be replaced by new power plants; issue of USD 500 mln worth of Eurobonds by the end of 2021 to attract loans from energy companies without government sovereign guarantees, construction and commissioning of new facilities; proposals to create wholesale electricity and natural gas markets functioning based on the principle of commodity exchange trades starting from 1 May 2020, sales of petroleum products (gasoline AI-80 and diesel fuel) began through commodity exchanges Program of digitalization of electric power industry for 2019-2021. (Automation of Enterprise Resource Planning (ERP) and Supervisory Control and Data Acquisition (SCADA)).	The basis for introducing market principles and a competitive environment in the energy sector has been established. within one year, the attraction of foreign direct investment in the amount of USD 2 billion and the construction of 6 new power plants with a capacity of 2,700 MW were started under PPP. transition to a competitive energy market system by 2025, which would allow to modernize stations, increase energy savings, and reduce cost of electricity generation; liberalization of electricity prices (up to market level).

Source: Analysis and synthesis of authors.

ANNEX 2. KEY REFORMS IN AGRICULTURE AND THEIR IMPACT ON GHG EMISSIONS (CO2-EQ.), 1993-2020

Key reforms implemented in 1993-2020	Measures/channels of influence	Impact on GHG emissions/ resource savings (qualitative assessment)
Transformation of low-profit and unprofitable state farms (sovkhozes) into agricultural cooperatives (shirkats) Reduction of the State order for raw cotton, grain and cereals, meat, milk, eggs, skin, wool, scrawl, kenaf, tobacco up to 80%, for silk cocoons up to 70%, for fruit and vegetable products up to 50%. The rest of the production is sold at free prices. Cabinet of Ministers Resolution No. PKM-13 on Measures of Further Deepening Economic Reforms in Agriculture, 7 January 1993. Presidential Decree UP-978 on the Program for deepening economic reforms in agriculture for 1998-2000, 18 March 1998.	Shirkats did not meet the expectations for increased efficiency as market conditions in agriculture were not created. The profits of shirkats did not increase, so their adaptability to climatic shocks (purchase of more expensive technology, equipment and chemicals for adaptation) remained low. Emissions have not decreased. The reform was not completed. Raw cotton produced in excess of the state order was not sold at free prices, and wheat was sold partially.	No impact.
Reduction of areas under cotton and an increase in areas for winter wheat to ensure the country's independence from imports of food grains. Cabinet of Ministers Resolution No. PKM-597 on Measures to Optimize the Structure of Sown Areas for the 1995-1996 harvest, 12 December 1994.	Water saving (the volume of water used for irrigation is more than 2 times lower for wheat than for cotton). Less use of machinery and fuels and lubricants (the use of machinery during the vegetation period reaches 10 times in cotton fields, which is 3 times higher than in wheat fields).	It had a weak positive impact in terms of reducing the degree of negative impact on nature
Reorganization of shirkats into farms simultaneously with creation of technical, financial, logistical, material and other infrastructure, and expanding the independence of producers and eliminating administrative interference in their current activities. Cabinet of Ministers Resolution No. PKM-8 on Measures to Reorganize Agricultural Enterprises into Farms, 5 January 2002. Presidential Decree No. UP-3226 on the Most Important Directions for Deepening Reforms in Agriculture, 24 March 2003. President Resolution No. PP-215 on Measures to Transform Agricultural Cooperatives (Shirkats) into Farms in 2006, 8 November 2005.	The volume of emissions has not decreased. Cotton and wheat farmers were not able to reduce production costs due to high prices for oil products, seeds and fertilizers. Other reasons: a) interference of local authorities, b) problems with banks, c) inability to dispose of manufactured products, financial, or other assets. Farms that own vineyards and orchards have received more profit and were able to dispose of their products. These farmers' adaptability to climatic anomalies has increased.	This had a partial positive impact only on farmers owing vineyards and orchards.

Key reforms implemented in 1993-2020	Measures/channels of influence	Impact on GHG emissions/ resource savings (qualitative assessment)
Expansion of the area under intensive gardens and greenhouses using modern resource-saving technologies (e.g. drip irrigation and rainfed). Development of cooperation and clusters, including the whole chain of production, harvesting, sorting, grading, packaging, and marketing of fruit products. Presidential Resolution No. PP-4246 on Measures of Further Development of Horticulture and Greenhouse Facilities in the Republic of Uzbekistan, 20 March 2019	The use of greenhouses with resource-saving technologies (drip irrigation, rainfall, solar panels, hydroponics) is the most efficient way to: a) adapt to climate anomalies and b) reduce emissions (the use of equipment operating on fuels and lubricants is reduced / eliminated).	Significant positive impact on emission reductions.
Starting from the 2020 harvest, gradual cancellation of the practice of producing grain and cotton crops in accordance with the state order; and the state procurement prices for grain starting from 2021. Grain produced by farmers and other enterprises is sold to all consumers, including grain processing enterprises, grain-growing clusters, and traders, through exchange trading or on the basis of direct contracts (futures, forward and others) at free prices. Presidential Resolution No. PP-4634 on Measures for Large-Scale Introduction of Market Principles into Production, Purchase and Sale of Grain, 3 June 2020.	GHG emissions reduction by up to 30% by using advanced equipment and technologies. Cancellation of the state order would allow farmers to use their resources more efficiently. Obviously, farmers will save money, i.e. will use old equipment and fuels and lubricants to a lesser extent and buy new resource-saving equipmentю Water saving by introducing highly profitable and low-cost crops. Market prices will increase farmers' profits and their interest in drip irrigation systems. It is expected that this will halve the volume of water used to produce a unit of agricultural product.	Significant positive impact on emission reductions.

Source: Table prepared based of the report of Mr. Shukhrat Mukhamedzhanov, agricultural expert.

ANNEX 3. KEY REFORMS IN WATER AND HYDROPOWER SECTOR AND THEIR IMPACT ON GHG EMISSIONS (CO_2-EQ.), 1993-2020

Key reforms implemented in 1993-2020	Measures/channels of influence	Impact on emissions/ resource savings (qualitative assessment)
Introduction of water rationing (since the 2nd half of 1993). Water withdrawal rationing began to be introduced by the authorities of agriculture and water management, with consideration of the forecast and actual water content of irrigation sources 2 times a year for agricultural water users and once a year for non-irrigation water users. Cabinet of Ministers Resolution No. PKM-385 on Limited Water Use in Uzbekistan, 3 August 1993.	The average annual water withdrawal limit for Uzbekistan was 64 billion m3. In the 1980s, annual water consumption was within this limit. But due to global climate change and transboundary water use issues, the consumed annual volume of water began to decline and now amounts to 51-53 billion m3 (97.2% is taken from rivers and sais (mountain rivers), 1.9% – from collector networks, and 0.9% – from underground sources), i.e. 20% lower in relation to the allocated water intake limit. The adoption of the document is a recognition of the growing shortage of water resources. A consumption limit has been established for all water users with a water intake volume of no more than 100 m3 per day.	Contradictory impact: Reduced the scale of water consumption, BUT increased unauthorized water use; increased costs for the transportation of water to consumers and to the fields (pumps, water delivery) increased consumption of energy resources (diesel fuel) for additional equipment for water transportation.
State program for land reclamation for the period of 2008-2012. Measures to improve water saving by reducing filtration losses of water through improved technical condition of irrigation canals and collector-drainage network. Presidential Decree No. UP-3932 on Measures to Radically Improve the System of Land Reclamation, 29 October 2007	strengthening the material and technical base of water management organizations; upgrading reclamation machinery of water management organizations and water users associations; repair and restoration work of collector and drainage networks.	the reclamation condition of more than 1 mln 200 thousand hectares (or 28% of the total irrigated land area) has been improved; the area of irrigated land with a groundwater level of up to 2.0 m decreased by 117.6 thousand hectares
State program to improve irrigated land reclamation and rational use of water resources for the period of 2013-2017. Presidential Resolution No. PP-1958 on Measures to improve irrigated land reclamation and rational management of water resources for the period of 2013-2017, 19 April 2013.	1,771 km of the collector and drainage network were built / reconstructed, 24.7 thousand km of repair and restoration works were carried out; an outflow of collector and drainage waters from an additional area of 669 thousand hectares is provided; the reconstruction of hydrological stations on natural watercourses of Uzhydromet made it possible to strengthen monitoring of the water resources regime and improve the quality of information for hydrological forecasts (the basis for planning the operation of reservoirs and irrigation systems).	The efficiency of canals in the project areas increased up to 20%, which increased the water supply to about 1.0 mln hectares of irrigated land.

Key reforms implemented in 1993-2020	Measures/channels of influence	Impact on emissions/ resource savings (qualitative assessment)
Measures to reduce water losses in low-water years. Cabinet of Ministers Resolution No. PKM-74 on Urgent Measures to Prevent the Adverse Impact of the Expected Low Water Supply and Ensure Guaranteed Water Supply to the Sown Areas During the Vegetation Season of 2018, 02 February 2018.	use of polyethylene (film and plastic pipes) for sowing seeds under the film and for supplying water for irrigation; expanding the scale of the purchase of portable diesel pumping application to supply with additional water from collector and drainage networks to crop fields; cleaning of irrigation networks and repair of hydraulic structures.	Increase in emissions due to: a) increase in polyethylene production; b) sharp increase in demand for energy, fuel and lubricants and building materials.
The program of priority directions for the development of hydropower for 2017-2021. Presidential Resolution No. PP-2947 on the Program of Measures for the Further Development of Hydropower for 2017-2021, 2 May, 2017.	creation of new and modernization of existing generating capacities through the widespread use of renewable environmentally friendly energy sources; increasing the share of hydropower capacities in the structure of the country's energy balance by introducing modern solutions in the design and construction of large, medium, small and micro HPPs; conservation of flora and fauna during the construction of hydraulic structures; observance of ratified international treaties in protection and use of transboundary watercourses and international lakes.	Leads to lower GHG emissions, BUT: The design is much more expensive than the construction of the HPP. Low water reduces energy production at HPPs. This leads to an increased share of more expensive coal generation in the energy balance, and this leads to an increase in electricity prices and an increase in CO2 emissions.

Source: Table prepared based of the report of Ms. Nadezhda Gavrilenko, water resources management expert.

ANNEX 4. ELEMENTS OF INFORMATION DATABASE FOR ANALYSIS OF GLOBAL TRENDS IN TRANSITION TO LOW-CARBON DEVELOPMENT PATHWAY (FRAGMENT)

#	Country name	CO2 emissions/GDP using PPP (kg CO2/US dollar 2015 prices) EM								
		2000	2001	2002	2003	2004	2005	2006	2007	2008
1	Albania	0.173	0.167	0.185	0.179	0.178	0.161	0.151	0.142	0.129
2	Argentina	0.217	0.215	0.227	0.227	0.231	0.219	0.214	0.207	0.205
3	Armenia	0.357	0.329	0.245	0.242	0.231	0.242	0.215	0.218	0.225
4	Azerbaijan	0.69	0.594	0.536	0.531	0.478	0.396	0.298	0.216	0.211
5	Bangladesh	0.091	0.102	0.105	0.105	0.107	0.108	0.112	0.111	0.114
6	Belarus	0.646	0.602	0.572	0.54	0.514	0.475	0.449	0.402	0.383
7	Bolivia	0.179	0.178	0.179	0.192	0.195	0.2	0.213	0.22	0.224
8	Bosnia and Herzegovina	0.54	0.509	0.509	0.501	0.493	0.473	0.494	0.493	0.513
9	Brazil	0.138	0.139	0.134	0.13	0.131	0.127	0.123	0.122	0.123
10	Bulgaria	0.546	0.561	0.5	0.523	0.482	0.455	0.436	0.434	0.389
11	Burundi									
12	Cambodia	0.109	0.111	0.107	0.106	0.096	0.095	0.095	0.105	0.1
13	Chile	0.218	0.203	0.2	0.197	0.202	0.194	0.187	0.202	0.206
14	China	0.623	0.604	0.597	0.628	0.665	0.681	0.666	0.633	0.595
15	Colombia	0.152	0.151	0.141	0.134	0.128	0.125	0.117	0.111	0.109
16	Costa Rica	0.109	0.115	0.113	0.115	0.111	0.109	0.112	0.115	0.11
17	Croatia	0.22	0.225	0.228	0.231	0.215	0.21	0.2	0.202	0.189
18	Czech Republic	0.507	0.492	0.468	0.468	0.448	0.408	0.384	0.372	0.346
19	Dominican Republic	0.235	0.232	0.244	0.221	0.199	0.197	0.194	0.182	0.175
20	Ecuador	0.184	0.196	0.19	0.187	0.184	0.189	0.194	0.193	0.185
21	Egypt, Arab Rep.	0.181	0.196	0.194	0.195	0.205	0.221	0.217	0.218	0.212
22	El Salvador	0.147	0.151	0.149	0.161	0.166	0.167	0.169	0.176	0.154
23	Estonia	0.617	0.6	0.547	0.578	0.543	0.502	0.423	0.489	0.473
24	Georgia	0.289	0.201	0.159	0.153	0.154	0.178	0.181	0.194	0.162
25	Guatemala	0.114	0.116	0.12	0.118	0.116	0.12	0.114	0.116	0.101
26	Honduras	0.194	0.222	0.227	0.242	0.256	0.222	0.237	0.24	0.231
27	Hong Kong, China	0.167	0.17	0.162	0.168	0.148	0.139	0.133	0.13	0.124
28	Hungary	0.276	0.273	0.257	0.259	0.24	0.228	0.217	0.21	0.205
29	India	0.291	0.282	0.281	0.267	0.265	0.257	0.254	0.26	0.269
30	Indonesia	0.194	0.202	0.197	0.207	0.202	0.192	0.194	0.192	0.178
31	Iran, Islamic Rep.	0.337	0.35	0.342	0.328	0.339	0.356	0.364	0.36	0.364
32	Israel	0.3	0.306	0.324	0.33	0.315	0.291	0.29	0.284	0.275
33	Jamaica	0.435	0.43	0.428	0.426	0.42	0.417	0.463	0.457	0.365
34	Jordan	0.381	0.358	0.349	0.346	0.341	0.339	0.319	0.307	0.27
35	Kazakhstan	0.708	0.608	0.607	0.626	0.62	0.606	0.603	0.599	0.714
36	Kuwait	0.297	0.322	0.324	0.284	0.276	0.285	0.275	0.261	0.27
37	Kyrgyz Republic	0.41	0.329	0.415	0.43	0.396	0.374	0.362	0.408	0.442
38	Lao PDR	0.061	0.064	0.064	0.063	0.062	0.061	0.071	0.071	0.079
39	Latvia	0.24	0.239	0.223	0.212	0.196	0.179	0.17	0.161	0.158
40	Lebanon	0.322	0.336	0.324	0.313	0.297	0.275	0.265	0.218	0.255
41	Lithuania	0.225	0.224	0.211	0.191	0.19	0.189	0.177	0.162	0.157

42	Macedonia, FYR	0.448	0.47	0.435	0.462	0.427	0.425	0.404	0.398	0.369
43	Malaysia	0.285	0.297	0.296	0.293	0.303	0.306	0.301	0.312	0.318
44	Mexico	0.216	0.217	0.222	0.23	0.226	0.23	0.228	0.226	0.225
45	Moldova	0.599	0.591	0.557	0.565	0.524	0.508	0.467	0.448	0.411
46	Mongolia	0.752	0.729	0.743	0.673	0.625	0.673	0.696	0.661	0.604
47	Morocco	0.212	0.215	0.216	0.202	0.213	0.221	0.213	0.209	0.206
48	Nepal	0.079	0.082	0.065	0.068	0.061	0.067	0.052	0.052	0.055
49	Nicaragua	0.192	0.195	0.2	0.212	0.207	0.189	0.191	0.188	0.174
50	Oman	0.192	0.207	0.224	0.236	0.231	0.226	0.288	0.304	0.273
51	Pakistan	0.183	0.181	0.18	0.176	0.184	0.174	0.178	0.186	0.175
52	Panama	0.142	0.17	0.144	0.14	0.131	0.157	0.153	0.137	0.116
53	Papua New Guinea									
54	Paraguay	0.072	0.076	0.08	0.079	0.077	0.07	0.069	0.068	0.067
55	Peru	0.145	0.133	0.132	0.124	0.137	0.128	0.116	0.118	0.123
56	Philippines	0.194	0.187	0.178	0.175	0.168	0.162	0.141	0.14	0.138
57	Poland	0.484	0.477	0.457	0.458	0.441	0.425	0.417	0.387	0.366
58	Romania	0.352	0.355	0.334	0.348	0.305	0.288	0.274	0.248	0.223
59	Russian Federation	0.727	0.691	0.656	0.623	0.579	0.542	0.52	0.478	0.46
60	Saudi Arabia	0.246	0.253	0.278	0.261	0.256	0.256	0.264	0.274	0.281
61	Singapore	0.187	0.189	0.178	0.158	0.149	0.129	0.119	0.113	0.111
62	Slovak Republic	0.419	0.411	0.388	0.373	0.343	0.331	0.299	0.264	0.248
63	Slovenia	0.287	0.295	0.289	0.278	0.271	0.265	0.256	0.239	0.246
64	South Africa	0.602	0.661	0.659	0.682	0.703	0.662	0.63	0.626	0.653
65	Sri Lanka	0.095	0.095	0.096	0.099	0.097	0.099	0.081	0.083	0.074
66	Syrian Arab Republic	0.873	0.885	0.855	0.878	0.872	1.033	1.042	1.044	1.03
67	Tajikistan	0.277	0.245	0.218	0.198	0.214	0.188	0.191	0.216	0.19
68	Thailand	0.246	0.25	0.25	0.244	0.251	0.249	0.239	0.235	0.237
69	Turkey	0.209	0.202	0.2	0.199	0.186	0.177	0.184	0.194	0.19
70	Ukraine	1.171	1.083	1.04	1.03	0.852	0.794	0.759	0.723	0.681
71	United Arab Emirates	0.231	0.264	0.264	0.253	0.245	0.248	0.233	0.244	0.279
72	Uruguay	0.113	0.102	0.101	0.099	0.121	0.112	0.127	0.11	0.137
73	Uzbekistan	1.454	1.405	1.381	1.248	1.189	1.049	1.037	0.918	0.882
74	Venezuela, RB	0.322	0.325	0.376	0.392	0.343	0.328	0.295	0.263	0.265
75	Vietnam	0.201	0.209	0.231	0.227	0.258	0.258	0.249	0.256	0.273
76	Yemen, Rep.	0.18	0.188	0.182	0.202	0.206	0.206	0.2	0.205	0.211
	Average	0.331	0.325	0.317	0.314	0.303	0.295	0.287	0.281	0.274
	min	0.061	0.064	0.064	0.063	0.061	0.061	0.052	0.052	0.055
	max	1.454	1.405	1.381	1.248	1.189	1.049	1.042	1.044	1.03

Country groups ranked by specific GHG emissions

Group 1 (low level): specific GHG emissions from 0.07 to 0.17 (2018 kg CO2-eq./USD)		
65	Sri Lanka	0.07
72	Uruguay	0.08
61	Singapore	0.09
54	Paraguay	0.09
16	Costa Rica	0.09
52	Panama	0.09
27	Hong Kong. China	0.09
15	Colombia	0.10
55	Peru	0.11
1	Albania	0.12
76	Yemen. Rep.	0.12
41	Lithuania	0.12
25	Guatemala	0.12
5	Bangladesh	0.12
9	Brazil	0.13
22	El Salvador	0.13
19	Dominican Republic	0.13
39	Latvia	0.13
48	Nepal	0.14
58	Romania	0.14
17	Croatia	0.14
49	Nicaragua	0.15
56	Philippines	0.15
28	Hungary	0.16
12	Cambodia	0.16
69	Turkey	0.16
30	Indonesia	0.16
51	Pakistan	0.17

Group 2 (moderate level): specific GHG emissions from 0.18 to 0.26 (2018 kg CO2-eq./USD)		
62	Slovak Republic	0.18
32	Israel	0.18
4	Azerbaijan	0.18
3	Armenia	0.19
63	Slovenia	0.19
44	Mexico	0.19
20	Ecuador	0.19
68	Thailand	0.19
21	Egypt. Arab Rep.	0.19
26	Honduras	0.20
2	Argentina	0.20
13	Chile	0.20
47	Morocco	0.20
24	Georgia	0.21
42	Macedonia. FYR	0.23
67	Tajikistan	0.23
29	India	0.23
43	Malaysia	0.24
7	Bolivia	0.25
34	Jordan	0.26
18	Czech Republic	0.26
57	Poland	0.26

Group 3 (average level):specific GHG emissions from 0.28 to 0.37 (2018 kg CO2-eq./USD)		
10	Bulgaria	0.28
60	Saudi Arabia	0.28
71	United Arab Emirates	0.28
40	Lebanon	0.30
36	Kuwait	0.31
33	Jamaica	0.32
6	Belarus	0.32
45	Moldova	0.33
75	Vietnam	0.34
23	Estonia	0.36
38	Lao PDR	0.36
50	Oman	0.36
31	Iran, Islamic Rep.	0.37

Group 4 (high level): specific GHG emissions from 0.39 to 0.67 (2018 kg CO2-eq./USD)		
74	Venezuela, RB	0.39
14	China	0.40
73	Uzbekistan	0.40
59	Russian Federation	0.43
35	Kazakhstan	0.44
37	Kyrgyz Republic	0.45
70	Ukraine	0.49
8	Bosnia and Herzegovina	0.49
46	Mongolia	0.51
64	South Africa	0.57
66	Syrian Arab Republic	0.67

ANNEX 5 MATRIX OF PAIR CORRELATION COEFFICIENTS CALCULATED ON THE BASIS OF INDICATORS EXPRESSED AS AVERAGE MEDIAN ESTIMATES OF THEIR LEVELS, 2010-2018 (2019)

Correlation Probability	EM	EI	GFCF	LABIND	MANVE	COCOR
EM	1.000000					

EI	0.941294	1.000000				
	0.0000	-----				
GFCF	0.139537	-0.001267	1.000000			
	0.5254	0.9954	-----			
LABIND	0.121506	0.085137	0.018180	1.000000		
	0.5808	0.6993	0.9344	-----		
MANVE	-0.050936	-0.145910	0.606376	0.260938	1.000000	
	0.8175	0.5065	0.0022	0.2291	-----	
COCOR	-0.349022	-0.469476	0.054546	0.104885	0.014353	1.000000
	0.1026	0.0238	0.8048	0.6339	0.9482	-----
GE	-0.196401	-0.331037	0.204656	0.119209	0.173107	0.899860
	0.3691	0.1228	0.3489	0.5880	0.4296	0.0000
ROL	-0.330800	-0.428994	0.089299	0.203639	0.134781	0.935246
	0.1231	0.0411	0.6853	0.3514	0.5398	0.0000
RQ	-0.357129	-0.462222	0.074819	0.080348	0.170775	0.852549
	0.0943	0.0264	0.7344	0.7155	0.4359	0.0000
KOF	0.156688	0.086876	-0.121695	0.099439	0.151346	0.586165
	0.4752	0.6935	0.5802	0.6517	0.4906	0.0033
RES	0.281937	0.282652	-0.135148	-0.196020	-0.555145	-0.012074
	0.1925	0.1913	0.5387	0.3700	0.0060	0.9564

Explanation: statistically significant pair correlation coefficients (p-val <0.1) are highlighted

ANNEX 6. MATRIX OF PAIR CORRELATION COEFFICIENTS CALCULATED ON THE BASIS OF INDICATORS EXPRESSED AS AVERAGE MEDIAN ESTIMATES OF THEIR CHANGES, 2010-2018 (2019)

Correlation Probability	EM	EMPROC	EI	EIPROC	GFCF
EM	1.000000				

EMPROC	0.840868	1.000000			
	0.0000	-----			
EI	**0.912093**	**0.683108**	1.000000		
	0.0000	0.0035	-----		
EIPROC	**0.722335**	**0.782489**	**0.821819**	1.000000	
	0.0016	0.0003	0.0001	-----	
GFCF	0.044052	0.118506	-0.134328	-0.042926	1.000000
	0.8713	0.6620	0.6199	0.8746	-----
LABIND	0.182519	0.396998	0.084250	0.131606	-0.024550
	0.4987	0.1279	0.7564	0.6271	0.9281
MANVE	**-0.501860**	**-0.548413**	**-0.425381**	-0.380304	0.046686
	0.0476	0.0278	0.1005	0.1462	0.8637
COCOR	-0.186123	-0.000337	-0.213574	-0.172759	-0.421194
	0.4901	0.9990	0.4271	0.5223	0.1042
GE	0.075676	0.307129	-0.108223	-0.016621	0.079975
	0.7806	0.2472	0.6899	0.9513	0.7684
ROL	-0.084075	0.057195	-0.074849	-0.012698	-0.704520
	0.7569	0.8334	0.7829	0.9628	0.0023
RQ	-0.113721	0.067534	-0.204163	-0.155930	-0.345199
	0.6750	0.8037	0.4482	0.5642	0.1904
KOF	0.214992	-0.066591	0.157730	-0.094998	0.055330
	0.4239	0.8064	0.5596	0.7264	0.8387
RES	**0.568969**	0.251371	**0.692525**	**0.423295**	-0.215570
	0.0214	0.3477	0.0029	0.1023	0.4227

Explanation: EM (EI) – EM (EI) – indicators of changes in emissions (energy intensity), in physical units (kg CO2-eq./ USD), and EMPROC (EIPROC) – changes in percentage of increase to the previous year. All other factors are percentage point changes (changes to the previous year). All changes are averaged for 2010-2018 as median estimates.

ANNEX 7 EQUATION PARAMETERS OBTAINED FROM THE SAMPLE OF 76 DEVELOPING COUNTRIES (AVERAGE MEDIAN ESTIMATES FOR 2010-2018)

A. SAMPLE OF 76 DEVELOPING COUNTRIES (VARIABLES IN THE FORMAT OF LEVELS)

Equation № 1 (relationship between emission, EM and investments, GFCF, single variable regression)

Dependent Variable: EM
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 03/13/21 Time: 21:56
Sample: 1 76
Included observations: 71

EM=C(1)+C(2)*GFCF

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.181429	0.066182	2.741370	0.0078
C(2)	0.002259	0.002785	0.810898	0.4202
R-squared	0.009440	Mean dependent var		0.233648
Adjusted R-squared	-0.004916	S.D. dependent var		0.128337
S.E. of regression	0.128652	Akaike info criterion		-1.235653
Sum squared resid	1.142035	Schwarz criterion		-1.171916
Log likelihood	45.86569	Hannan-Quinn criter.		-1.210307
F-statistic	0.657555	Durbin-Watson stat		2.211176
Prob(F-statistic)	0.420213			

Equation № 2 (relationship of emission, EM with investments, GFCF, regulatory quality, RQ, resource rent, RES, share of employed in industry, LABIND, multiple regression)

Dependent Variable: EM
Method: Least Squares
Date: 03/13/21 Time: 21:57
Sample: 1 76
Included observations: 68

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GFCF	0.003219	0.002295	1.402345	0.1657
RQ	-0.031964	0.017513	-1.825116	0.0727
RES	0.003140	0.001540	2.039492	0.0456
LABIND	0.008572	0.002031	4.220177	0.0001
C	-0.056321	0.071424	-0.788542	0.4333
R-squared	0.315834	Mean dependent var		0.230500
Adjusted R-squared	0.272395	S.D. dependent var		0.122449
S.E. of regression	0.104449	Akaike info criterion		-1.609552
Sum squared resid	0.687303	Schwarz criterion		-1.446353
Log likelihood	59.72478	Hannan-Quinn criter.		-1.544888
F-statistic	7.270736	Durbin-Watson stat		1.917654
Prob(F-statistic)	0.000070			

Note: in the “Prob” column, statistically significant coefficients are bold (P-val <0.1)

Equation № 3 (relationship of energy intensity, EI with investments, GFCF, and regulatory quality, RQ, two variable regression)

Dependent Variable: EI
Method: Least Squares
Date: 03/13/21 Time: 21:58
Sample (adjusted): 2 74
Included observations: 24 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GFCF	-0.103441	1.812294	-0.057077	0.9550
RQ	-29.06537	13.44766	-2.161370	0.0424
C	130.0321	44.44387	2.925759	0.0081
R-squared	0.183106	Mean dependent var		129.0000
Adjusted R-squared	0.105307	S.D. dependent var		57.03774
S.E. of regression	53.95099	Akaike info criterion		10.93050
Sum squared resid	61124.90	Schwarz criterion		11.07775
Log likelihood	-128.1660	Hannan-Quinn criter.		10.96957
F-statistic	2.353567	Durbin-Watson stat		2.860868
Prob(F-statistic)	0.119602			

Equation № 4 (relationship of energy intensity, EI with investments, GFCF, and regulatory quality, RQ, regression with threshold value, thr for RQ variable, thr = 0)

Dependent Variable: EI
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 03/14/21 Time: 11:26
Sample (adjusted): 2 74
Included observations: 24 after adjustments
EI=C(1)+C(2)*GFCF*(0.0+RQ)+C(3)*KOF

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-9.439017	34.03223	-0.277355	0.7842
C(2)	-3.135341	0.604331	-5.188123	0.0000
C(3)	2.613593	0.629674	4.150710	0.0005
R-squared	0.566127	Mean dependent var		129.0000
Adjusted R-squared	0.524806	S.D. dependent var		57.03774
S.E. of regression	39.31858	Akaike info criterion		10.29774
Sum squared resid	32464.97	Schwarz criterion		10.44500
Log likelihood	-120.5729	Hannan-Quinn criter.		10.33681
F-statistic	13.70064	Durbin-Watson stat		2.597125
Prob(F-statistic)	0.000156			

Equation №5 (relationship of emission, EM with investments, GFCF, regulatory quality, RQ, resource rent, RES, economic globalization index, KOF, regression with threshold value, thr for RQ variable, thr = -0.2)

Dependent Variable: EM
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 03/11/21 Time: 22:03
Sample: 1 76
Included observations: 71

EM=C(1)+C(2)*GFCF*(0.2+RQ)+C(3)*RES+C(4)*KOF

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.054471	0.061794	0.881494	0.3812
C(2)	-0.002638	0.001058	-2.493646	0.0151
C(3)	0.004109	0.001714	2.396856	0.0193
C(4)	0.002880	0.001069	2.695294	0.0089
R-squared	0.187128	Mean dependent var		0.233648
Adjusted R-squared	0.150731	S.D. dependent var		0.128337
S.E. of regression	0.118270	Akaike info criterion		-1.377012
Sum squared resid	0.937175	Schwarz criterion		-1.249537
Log likelihood	52.88392	Hannan-Quinn criter.		-1.326319
F-statistic	5.141263	Durbin-Watson stat		2.152478
Prob(F-statistic)	0.002929			

Equation № 6 (relationship of emission, EM with investments, GFCF, regulatory quality, RQ, resource rent, RES, share of employed in industry, LABIND, regression with threshold value, thr for RQ variable, thr = +0.5)

Dependent Variable: EM
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 03/15/21 Time: 17:06
Sample: 1 76
Included observations: 68

EM=C(1)+C(2)*GFCF*(-0.5+RQ)+C(3)*RES+C(4)*LABIND

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.000287	0.049088	-0.005843	0.9954
C(2)	-0.001536	0.000716	-2.143814	0.0359
C(3)	0.003087	0.001524	2.025883	0.0470
C(4)	0.008613	0.002019	4.266402	0.0001
R-squared	0.307428	Mean dependent var		0.230500
Adjusted R-squared	0.274964	S.D. dependent var		0.122449
S.E. of regression	0.104264	Akaike info criterion		-1.626752
Sum squared resid	0.695748	Schwarz criterion		-1.496193
Log likelihood	59.30957	Hannan-Quinn criter.		-1.575020
F-statistic	9.469718	Durbin-Watson stat		1.959333
Prob(F-statistic)	0.000029			

Б. TIME SERIES FOR UZBEKISTAN (2000-2018, VARIABLES IN THE FORMAT OF CHANGES)

Equation № 7 (relationship of emission, EM with investments, GFCF, single variable regression)

Dependent Variable: EM
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 03/14/21 Time: 16:18
Sample (adjusted): 2002 2018
Included observations: 17 after adjustments
EM=C(1)+C(2)*GFCF(-1)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.059382	0.012721	-4.667947	0.0003
C(2)	0.003164	0.005163	0.612765	0.5492
R-squared	0.024421	Mean dependent var		-0.058882
Adjusted R-squared	-0.040618	S.D. dependent var		0.051311
S.E. of regression	0.052343	Akaike info criterion		-2.951862
Sum squared resid	0.041097	Schwarz criterion		-2.853837
Log likelihood	27.09083	Hannan-Quinn criter.		-2.942118
F-statistic	0.375481	Durbin-Watson stat		2.567831
Prob(F-statistic)	0.549210			

Equation № 8 (relationship of emission, EM with investments, GFCF, regulatory quality, RQ, economic globalization index, KOF, and control of corruption, CoCor, multiple regression with lagged variables)

Dependent Variable: EM
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 03/14/21 Time: 16:52
Sample (adjusted): 2003 2017
Included observations: 15 after adjustments
EM=C(1)+C(2)*(0.3*RQ(-1)+0.7*RQ(-2))+C(3)*KOF+C(4)*COCOR(-1)
+C(5)*GFCF(-2)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.059231	0.012122	-4.886391	0.0006
C(2)	-0.257728	0.114441	-2.252051	0.0480
C(3)	0.011413	0.005013	2.276900	0.0460
C(4)	-0.290781	0.139114	-2.090231	0.0631
C(5)	-0.005343	0.004828	-1.106679	0.2943
R-squared	0.470233	Mean dependent var		-0.064000
Adjusted R-squared	0.258326	S.D. dependent var		0.052619
S.E. of regression	0.045315	Akaike info criterion		-3.089139
Sum squared resid	0.020535	Schwarz criterion		-2.853123
Log likelihood	28.16855	Hannan-Quinn criter.		-3.091653
F-statistic	2.219056	Durbin-Watson stat		2.513303
Prob(F-statistic)	0.139836			

Equation № 9 (relationship of emission, EM with investments, GFCF, regulatory quality, RQ, economic globalization index, KOF, multiple regression with lagged variables and threshold value, thr for RQ variable, thr = -1.53)

Dependent Variable: EM
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 03/14/21 Time: 18:55

Sample (adjusted): 2003 2018
Included observations: 16 after adjustments
EM=C(1)+C(2)*GFCF*(1.53+RQL(-2))+C(3)*KOF(-2)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.072174	0.010770	-6.701578	0.0000
C(2)	-0.158692	0.062013	-2.559017	0.0238
C(3)	-0.009561	0.005075	-1.883829	0.0821
R-squared	0.474917	Mean dependent var		-0.061063
Adjusted R-squared	0.394135	S.D. dependent var		0.052175
S.E. of regression	0.040611	Akaike info criterion		-3.402177
Sum squared resid	0.021441	Schwarz criterion		-3.257316
Log likelihood	30.21741	Hannan-Quinn criter.		-3.394759
F-statistic	5.878994	Durbin-Watson stat		2.856714
Prob(F-statistic)	0.015187			

Equation №10. (relationship of emission, EM with investments, GFCF, control of corruption, CoCor, economic globalization index, KOF, multiple regression with lagged variables and threshold value, thr for CoCor variable, thr = -1.03)

Dependent Variable: EM
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 03/15/21 Time: 22:31
Sample (adjusted): 2003 2018
Included observations: 16 after adjustments
EM=C(1)+C(2)*GFCF*(1.03+COCORL(-1))+C(3)*(0.8*KOF(-2)+0.2*KOF(-1))

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.062996	0.011210	-5.619614	0.0001
C(2)	-0.070595	0.038261	-1.845089	0.0879
C(3)	-0.016560	0.006647	-2.491269	0.0270
R-squared	0.363980	Mean dependent var		-0.061063
Adjusted R-squared	0.266131	S.D. dependent var		0.052175
S.E. of regression	0.044696	Akaike info criterion		-3.210504
Sum squared resid	0.025971	Schwarz criterion		-3.065643
Log likelihood	28.68403	Hannan-Quinn criter.		-3.203086
F-statistic	3.719811	Durbin-Watson stat		2.859769
Prob(F-statistic)	0.052791			

ANNEX 8 ALGORITHM FOR CALCULATING THE SECTORAL CARBON FOOTPRINT

$$\Delta FCi = UZS1\ mln \rightarrow \langle mult\ (X)\rangle \quad \Delta X_i\ i = 1,2,3,\ldots n \rightarrow \Delta EM_i\ i = 1, 19, 22, 23, 33, 36, 40 \rightarrow CFP_i = \sum_i \Delta EM_i\ i = 1, 19, 22, 23, 33, 36, 40$$

where:

ΔFC_i – increase in i industry's final product,

mult (X) – final product output multiplier,

ΔX_i – i industry's output change.

EM_i – i industry's greenhouse gas emissions,

CFP_i – i industry's carbon footprint,

The calculation herewith *determines the carbon footprint of industry i as the amount of emissions growth in the economy in general* as its response to the growth in the industry's final product by UZS1 mln.

Unlike the traditional approach, which captures the volume of production (GDP) and emissions without taking into account the structure of the economy (the ratio of intermediate and final consumption), the algorithm focuses on the growth indicators rather than on volume. From this point of view, the algorithm provides a *more objective picture of the economy's green transformation*. It is no coincidence that a number of indicators of the Sustainable Development Goals are calculated under a similar scheme.[50]

The main steps for obtaining a carbon footprint estimate include:

- calculation of industry specific emissions for the year 2017 (emissions by industry in tons divided by industry output in mln UZS);
- estimates of the carbon footprint of industries and the economy as a whole for the year 2017 have been obtained by sequentially calculating the following matrices (dimension 78 x 78):

$$Z^d \rightarrow I \rightarrow I(1/xii) \rightarrow A^d = Z^d * I(1/xii) \rightarrow (I - A^d) \rightarrow D^d = (I - A^d)\text{-}1 \rightarrow D^d * EM(x) \rightarrow mult(em) = CFPi;$$

Here:

Zd – matrix of intermediate cost flows of domestic products,

I – diagonal identity matrix,

$I(1/x_{ii})$ – diagonal matrix with diagonal elements equal to the reciprocal amount of the output of the corresponding industry,

Ad – matrix of coefficients of direct costs of domestic production,

Dd – matrix of coefficients of total costs of domestic production,

EM(x) – matrix, the first (second, etc.) row is the specific emissions for the first (second), etc. industry,

mult(em) – vector of emission multipliers for final product, determined by the sum of each column of the matrix **Dd * EM(x).**

- calculation of the carbon footprint for the economy as a whole (**CFP**) as a weighted average of industry estimates **CFPi,** where the shares of industries in value added to the economy as a whole are used as weights.

[50] For example, SDG indicator metadata. Indicator 8.4.1: Material Footprint, material footprint per capita. https://unstats.un.org/sdgs/metadata/?Text=&Goal=8&Target=8.4

The use of the 3-B method has enabled obtaining a more adequate estimate of the carbon footprint (**596 kg** CO_2-eq. in **2017** or **3.5 kg** CO_2-eq./USD if we use the average annual exchange rate of the US dollar at UZS5,880/USD). This is higher compared to the traditional method of calculating the gross output of the economy as a whole (170,056 thousand tons of emissions/UZS506,576,954 mln = **336** kg CO_2-eq./mln UZS). Thus, the traditional estimate understates the emission volumes because it compares emissions not with final consumption (the result of economic activity), but with the entire output, which, in addition to final consumption, includes all intermediate costs.

ANNEX 9 STAGES OF USING TECHNICAL PARAMETERS OF WPP CONSTRUCTION PROJECT IN UZBEKISTAN TO GENERATE PARAMETERS OF INPUT-OUTPUT METHODOLOGY

a) Baseline parameters:[51]

- Installed capacity (IC) – 1.5 GW.
- Project cost is 1.8 billion dollars.

b) Calculations for the growth of power generation:

Annual power generation in billion kWh.

- at 20% of IC utilization rate[52]: 1.5*8.76*0.2 = 2.63;
- at 30% of IC utilization rate[53]: 1.5*8.76*0.3 = 3.94

Power generation in the baseline period (2016) – 59.1 billion kWh.

Increase in power generation upon commissioning of WPPs:

- at 20% of IC utilization rate: (59.1 + 2.63) / 59.1 = 4.45%
- at 30% of IC utilization rate: (59.1 + 3.94) / 59.1 = 6.67%

c) Calculations for reducing emissions and costs:

Reduction of specific GHG emissions in the power sector in the baseline period parameters:

- at 20% of IC utilization rate: 10.611*(1 – 4.45*0.01) = 10.138 t CO_2-eq./mln UZS of power, i.e. reduction by 10.611 – 10.138 = 0.473 t CO_2-eq./mln UZS of power:
- at 30% of IC utilization rate: 10.611*(1 – 6.67*0,01) = 9.903 t CO_2-eq./mln UZS of power, i.e. reduction by 10.611 – 9.903 = 0.708 t CO_2-eq./mln UZS of power:

Absolute reduction of emissions in thousand tons **upon introduction of WPPs** at constant power generation (at the level of the baseline period (2017) – **60,820** mln kWh):

- **31,005** thousand tons CO_2-eq. – emissions across the industry as a whole in 2017;
- **0.51 tons** CO_2-eq. / thousand kWh – specific emissions in 2017;
- 0.51 * (1-0.0445) = **0.4873** tons CO_2-eq. / thousand kWh – reduced specific emissions at 20% of IC utilization rate;
- 0.51 * (1-0.0667) = **0.476** tons CO_2-eq. / thousand kWh – reduced specific emissions at 30% of IC utilization rate;
- 0.4873 * 60,820 = **29,637** thousand tons CO_2-eq. – emissions across the industry as a whole with reduced specific emissions at power generation level of 2017, i.e. the absolute reduction of emissions at 20% of IC utilization rate is: 31,005 – 29,637 = **1,368** thousand tons CO_2-eq.;
- 0.476 * 60,820 = **28,949** thousand tons CO_2-eq. – emissions across the industry as a whole with a decrease in specific emissions at power generation level of 2017, i.e. the absolute reduction of emissions at 30% IC utilization rate is: 31,005 – 28,949 = 2,056

[51] Construction of Uzbekistan's first wind farm. https://www.spot.uz/ru/2021/04/02/wind/

[52] Installed capacity utilization rate in Russia in 2019 (website of the Ministry of Energy of the Russian Federation, https://minenergo.gov.ru/node/532)

[53] Corresponds to the best world practice (in the EU varies from 15% in Germany – 30% in Denmark. Source: BNetzA, German TSOs, Terna, REE, Energinet.dk, EDF and Eirgrid (2014) https://www.carecprogram.org/uploads/Smart-Grids-Smart-Meters-and-Renewables.pdf).

thousand tons CO_2-eq.; i.e. the absolute reduction of emissions with introduction of wind turbines and at constant power generation is from 1,368 to **2,056** thousand tons CO_2-eq..

The absolute emission reduction per 100 mln dollars investment (project cost is 1.8 billion dollars) would range from **76**to **114,2** thousand tons CO_2-eq.

d) Adjustment of coefficients of direct costs of gas consumption per unit of power generation: baseline coefficient of direct gas consumption (industry 5 – crude oil and natural gas) per unit of power generation (industry 33 – electric power, air conditioning, etc.) $a_{5\,33}$ **= 0.145**

If the **WPP** project is implemented with the same amount of gas consumption, power generation will increase by 4.45% (option with 20% utilization rate) or by 6.67% (option with 30% utilization rate). As a result, the coefficient of gas consumption per unit of power generation $a_{5\,33}$ **= 0.145** (Input-Output table) will decrease to:

- 0.145 / (1+0.01*4.45) = **0.139** (option with 20% utilization rate);
- 0.145 / (1+0.01*6.67) = **0.136** (option with 30% utilization rate).

Explanations and assumptions for Table 6 of the report:

1) The calculations are based on the *SNA (System of national accounts) balance sheet ratios and data from Input-Output table*. *A decrease in gas consumption per unit of power production* $\Delta a_{5\,33}$ [54] leads to a *decrease in intermediate consumption* ΔIC = $\Delta a5_{33}$ * **PO**, where **PO** is power output (generation) corresponding to the baseline period (UZS10,696.4 billion) for option No. 1, or output increased by 4.45% and 6.67% in options No. 2 and No. 3). In options No. 2 and No. 3 the new value of **intermediate consumption** is also calculated using the coefficient of intermediate costs of all types of intermediate products except for gas, equal to 0.454 (data from Input-Output table for 2016), increasing this part of costs by an amount proportional to the increase in output.

2) A decrease in intermediate consumption at a given output (see paragraph 1)) leads to an increase in the *added value of the industry* **AV** by the following amount: Δ**AV** = **PO** – Δ**IC.**

3) The value of the *conditional profit* (or mixed income) of the power industry **PR** is determined as: **PR** = **AV – DP – 2,078**, where UZS2,078 billion is the amount of wages (in option No. 1, 2,078*1.0445 in option No. 2 and 2,078*1.0667 in option No. 3), **DP** is depreciation.

4) *Depreciation* (in billion UZS) is determined for:

the baseline option as: **DP = AV * 0.08** (8% of added value, the industry average depreciation rate in 2016);

for option No. 1 (replacement of existing units with a CCGT unit), taking into account the cost of the investment project ($ 4 billion) as:

- **DP = AV*0.08 + (4,000/20)*3,700*0.001**, where USD4,000 mln is the cost of the project to replace existing equipment at the CCSGT unit, 20 years is the standard service life of new equipment, 3,700 is the exchange rate of UZS in 2016 (weighted, official and unofficial);
- for options No. 2 and No. 3 (implementation of the wind turbine project), taking into account the cost of the investment project of UZS1.8 billion) as:
- **DP = AV*0.08 + (1,800 / 20)*3,700*0.001**, where USD1,800 mln is the cost of the project to create a modern wind farm, 20 years is the standard service life of new equipment, 3,700 is the exchange rate of the UZS in 2016.

[54] For option No. 1 $\Delta a_{5\,33}$ = 0.145-0.103 = 0.042. For option No. 2 Δa_{533} = 0.145-0.139 = 0.006, and for option No. 3 Δa_{533} = 0.145-0.136 = 0.009.

ANNEX 10 CONDITIONS SET FORTH IN FORECAST CALCULATIONS FOR BGUS UTILIZATION

Section a, Table 8

Indicator 1. Estimates of the *expected number of cattle* are derived from the hypothesis of a limited forage base to expand the number of cattle by 2035 and reduction in the increase in cattle to 800 thousand heads from 2021 to 2025 (against 1.27 mln heads if the calculations use annual increase in cattle in 2020, which totals 254 thousand heads) to 400 thousand heads in 2025-2030 and to 200 thousand heads from 2031 to 2035.

Indicators 2, 3. *Production of meat* (p. 2) and *milk* (p. 3) is estimated in a simplified way: livestock * 0.2 for meat and * 0.87 for milk, i.e. without taking into account the improvement of breed and productivity of livestock.

Indicator 5 – *Percentage of coverage of livestock* with BGUs was formed based on the different rates of the expected increase in BGUs (i.e., at different scales of introduction of new green technologies); moderate in option 1, medium in option 2 and high in option 3.

Indicator 6 – The number of required BGUs with a volume of 6 cubic meters is determined based on the standard: one unit *serves* 25 cows. This type of unit with minimal biogas and fertilizer production capacity is chosen due to the fact that small farms prevail now in livestock industry and can't afford to purchase and master more productive units (with a capacity of 10, 30, 60 cubic meters or even more industrial units with a capacity of 120 cubic meters).

Indicator 7 – *The accumulated costs for the purchase of imported BGUs* in the absence of domestic production are estimated based on the cost of one biogas plant at 6.5 thousand dollars and the forecast of their number at the end of the five-year period. Starting from 2030, a factor of writing off 5% of biogas plants is taken into account by thus increasing the incurred costs by 5%.

Indicator 8 – *Costs for the purchase of imported BGUs* while deploying domestic production are based on Indicator 7 and the terms of import substitution: 10% of domestic production from the needs in BGUs in 2025, 30% in 2030, 50% in 2035 and 60% in 2040.

Indicator 9 – *Investments in domestic production* are determined based on import substitution benchmarks (see Indicator 8: 10% in 2025, 30% in 2030, etc.) and the parameters of the Resolution of the Cabinet of Ministers No. 338 dated 1.06.2017 "On measures to further stimulate production and introduction of BGUs in the Republic in 2017–2019". The Resolution is aimed at creating a joint production facility with China on the production of BGU. It states the need to produce BGUs for 726 large livestock and poultry farms of the country within 3 years, which will cover at least 72.6 thousand heads of cattle with BGUs. Ten million dollars will be allocated for these purposes. Investment needs for 2025-2040 are determined based on these proportions (7.26 thousand cattle per 1 mln dollars of investment). For example, the projected estimate of investment demand for 2025 in option No. 1 will be: 13,412 (number of cattle in thousands) * 0.05 (% coverage) / 7.26 (thousand heads per mln dollars of investment) = $92.4 mln. The demand for 2030 and subsequent years should factor in the investments already made. Thus, the investment estimate for 2030 in option No. 1 will be: 13,812 *0.1/7.26 – 92.4 = $190.3 – 92.4 = 97.9 mln dollars. Other years and options (No.2 and No.3) are calculated similarly.

Algorithms for estimating effects of BGUs utilization on natural resources conservation and employment for the period up to 2040 (Section B, Table 4).

Indicator 10 – *Total gas savings* is determined by the number of BGUs multiplied by 15 m³ of biogas production (capacity per day[55]) and by 0.73 (coefficient of equating biogas to natural gas in terms of calorific value[56]). The result is multiplied by 365 days (conversion to an annual estimate) and by BGU utilization factor (20-30%).

Indicator 11 – *Total agricultural emissions*. The latest year for which emission statistics are available across the industry is 2017 (29,342 thousand tons CO_2-eq.). The 2020 emissions estimate are based on the following considerations. The annual increase in emissions in 2014-2017 in the absence of cattle waste technologies ranged from 500 to 1,240 thousand tons CO_2-eq. Based on this, an annual increase estimate of 500 thousand tons was used for 2018-2020, with annual emissions estimates for the industry totaling 29,842 thousand tons CO_2-eq. (in 2018), 30,342 thousand tons CO_2-eq. (in 2019), and 30,842 thousand tons CO_2-eq. (in 2020). Emissions estimates for the forecast period were determined as 2020 emissions multiplied by livestock growth rate and multiplied by the share of livestock not covered by biogas plants (for example, 100% in 2020, 95% in option 1 in 2025, etc.).

Indicator 12 – *Specific agricultural emissions* are estimated by dividing emissions from total industry (Indicator 11) by total meat and milk production (Indicator 4).

Indicator 13 – *Fertilizer savings* is determined similarly to the indicator 10 based on the number of BGUs multiplied by the capacity (375 kg per a BGU, see footnote 2), multiplied by 365 days (conversion to an annual estimate) and multiplied by the plant utilization rate (20-30%). At the same time, unlike biogas, which is generated continuously during the operation of the BGU, the technological cycle for the production of organic equations is 2-3 days. At the same time the yield of the solid fraction, which can be used to improve the fertility of the land is 20%-30%.[57] Thus, the result obtained by the foregoing scheme, should be reduced (multiplied) by a factor of 1/3 and by 0.2.

Indicator 14 – The number of new jobs without localization and domestic production of BGUs was estimated based on the ratio of the number of service personnel to the number of units (2-3 technologists and technicians per 100 units[58] given the high degree of territorial dispersion of service facilities).

Indicator 15 – *The number of new workers in the transition to domestic production of BGUs* is determined based on the following parameters. The output in the C28 industry (production of machinery and equipment without electronics, electrical engineering, automotive industry) totaled UZS1,778,830 mln in 2017. The number of people employed in the industry is 8,041 persons, i.e. the cost of one workplace was 17,798,830/8,041 = UZS221.2 mln. The average annual exchange rate of the dollar in 2017 was UZS5,880/USD. The estimate of employment growth due to the deployment of domestic production is determined based on production indicators (the number of BGUs – indicator 6 multiplied by the share of import substitution – explanations for indicator 9), multiplied by the cost of the plant (6.5 thousand dollars) and the exchange rate. The result obtained is divided by the cost of one workplace and added to the number of people employed in maintenance of biogas plants (indicator 14).

[55] Technical characteristics of a biogas plant with a capacity of 6 cubic meters

[56] 6.5 / 8.9 = 0.73 (see expert report by Shukhrat Mukhamedjanov “Study of the main factors affecting agricultural production and related GHG emission reductions” from 12.4.2021, p. 9).

[57] These are the most general estimates drawn from the literature. Their specification in relation to Uzbekistan requires additional field research in specific regions of the country.

[58] Under market conditions, there are no regulatory requirements for the number of personnel serving farmers’ machines and mechanisms.

For example, for the year 2040 under option 2, the number of required BGUs is 280.2 thousand units. At 60% localization level, the production volume will be 280.2*0.6 = 168.1 thousand units. At the cost of 6.5 thousand dollars and the exchange rate of UZS5,880/ USD, the output cost estimate will be 168.1*6.5=USD1,093 mln, or UZS6,424.8 billion, against the output in the C28 industry (output of machinery and equipment without electronics, electrical engineering, automotive) of UZS1,778.6 billion, (baseline period). Therefore, the necessary output growth and, consequently, employment will be 6,424.8 / 1,778.6 = **3.61** times, and new employment will be 8,041 * 3.61 = 29,046 persons. The total employment shall increase to 29,046 + 7,010 = **36,056** (see indicator 15, option 2), including service personnel (7,010 people).

ANNEX 11 SECTOR-SPECIFIC GHG EMISSION MULTIPLIERS (TONS CO_2-EQ./MLN UZS OF FINAL PRODUCTS, IN 2017 PRICES)

		Sector-specific GHG emission multipliers (tons CO2-eq./ mln UZS of final products, in 2017 prices)					
			2020	2025	2030	2035	2040
1	A01	Agricultural and hunting products and services	0.416	0.384	0.330	0.239	0.171
2	A02	Forestry, logging products and services	-1.245	-1.247	-1.247	-1.247	-1.247
3	A03	Fish and other fishery products; fish farming products; services related to fishing and fish farming	0.195	0.191	0.191	0.190	0.190
4	B05	Bituminous coal and brown coal (lignite)	0.610	0.610	0.610	0.610	0.610
5	B06	Crude oil and natural gas	0.419	0.418	0.418	0.418	0.418
6	B07	Metallic ore	1.054	1.054	1.054	1.054	1.054
7	B08	Other mining products	0.415	0.415	0.415	0.415	0.415
8	B09	Mining services	0.460	0.459	0.459	0.459	0.459
9	C10	Food products	0.268	0.254	0.253	0.250	0.248
10	C11	Beverages	0.362	0.349	0.348	0.345	0.343
11	C12	Tobacco products	0.159	0.158	0.157	0.157	0.157
12	C13	Textiles and textile products	0.303	0.282	0.281	0.276	0.274
13	C14	Clothing	0.346	0.337	0.337	0.335	0.333
14	C15	Leather and leather products	0.223	0.215	0.214	0.212	0.211
15	C16	Wood and wood products and cork (excluding furniture); products from straw and plaiting materials	0.134	0.133	0.133	0.133	0.133
16	C17	Paper and paper products	1.339	1.338	1.338	1.388	1.388
17	C18	Printing services and reproduction services of recorded materials	0.315	0.315	0.315	0.315	0.315
18	C19	Coke and petrochemicals	0.399	0.399	0.399	0.399	0.399
19	C20	Chemical products	1.777	1.776	1.776	1.776	1.776
20	C21	Basic pharmaceutical products and pharmaceutical preparations	0.166	0.115	0.115	0.115	0.115
21	C22	Rubber and plastic products	0.373	0.372	0.372	0.372	0.372
22	C23	Other non-metallic mineral products	1.070	1.070	1.070	1.070	1.070
23	C24	Basic metals	0.632	0.632	0.632	0.632	0.632
24	C25	Finished metal products, except machinery and equipment	0.255	0.255	0.255	0.255	0.255
25	C26	Computers, electronic and optical equipment	0.229	0.228	0.228	0.228	0.228
26	C27	Electrical equipment	0.250	0.249	0.249	0.249	0.249
27	C28	Machinery and equipment not included in other categories	0.287	0.287	0.287	0.287	0.287

		Sector-specific GHG emission multipliers (tons CO2-eq./ mln UZS of final products, in 2017 prices)					
			2020	2025	2030	2035	2040
28	C29	Motor vehicles, trailers and semi-trailers	0.066	0.066	0.066	0.066	0.066
29	C30	Other vehicles and equipment	0.429	0.429	0.429	0.429	0.429
30	C31	Furniture	0.142	0.139	0.139	0.139	0.138
31	C32	Other products	0.389	0.388	0.388	0.388	0.388
32	C33	Repair and installation services for machinery and equipment	0.290	0.290	0.290	0.290	0.290
33	D35	Electricity, gas and air conditioning	10.458	10.457	10.457	10.457	10.457
34	E36	Natural water; water treatment and water supply services	1.927	1.926	1.926	1.926	1.926
35	E37	Sewage system services; sewage sludge	1.885	1.884	1.844	1.844	1.844
36	E38	Waste collection, treatment and disposal services; recycling services	4.827	4.823	4.823	4.822	4.822
37	E39	Reclamation and other waste management services	0.335	0.333	0.333	0.333	0.332
38	F	Constructions and construction works	0.289	0.289	0.289	0.289	0.289
39	G	Wholesale and retail trade services, repair of vehicles and motorcycles	0.390	0.390	0.390	0.389	0.389
40	H49-51	Transportation services	0.833	0.832	0.832	0.832	0.832
41	H52	Warehousing services and auxiliary transportation services	0.406	0.406	0.406	0.406	0.406
42	H53	Postal and courier services	0.518	0.517	0.517	0.517	0.517
43	I55	Accommodation services	0.383	0.380	0.379	0.379	0.378
44	I56	Food and beverage provision services	0.156	0.155	0.155	0.154	0.154
45	J58	Publishing services	0.310	0.310	0.310	0.310	0.310
46	J59	Film, video, and television program production services	0.134	0.134	0.134	0.134	0.134
47	J60	Programming and broadcasting services	0.438	0.437	0.437	0.437	0.437
48	J61	Telecommunication services	0.154	0.154	0.154	0.154	0.154
49	J62	Software production, consulting, and other services	0.182	0.182	0.182	0.182	0.182
50	J63	Information services	0.150	0.150	0.150	0.150	0.150
51	K64	Financial services, except for insurance and pension services	0.042	0.042	0.042	0.042	0.042
52	K65	Insurance, reinsurance and pension services, except mandatory social services	0.089	0.089	0.089	0.089	0.089
53	K66	Services auxiliary to financial and insurance services	0.100	0.100	0.100	0.100	0.100
54	L68	Real estate services	0.467	0.467	0.467	0.467	0.467

		Sector-specific GHG emission multipliers (tons CO2-eq./ mln UZS of final products, in 2017 prices)					
			2020	2025	2030	2035	2040
55	M69	Legal and accounting services	0.083	0.083	0.083	0.083	0.083
56	M70	Parent company services; management consulting services	0.200	0.200	0.200	0.199	0.199
57	M71	Services in the field of architecture, engineering surveys, technical testing and analysis	0.224	0.223	0.223	0.223	0.222
58	M72	Research and development services	0.227	0.226	0.226	0.225	0.225
59	M73	Advertising and market research services	0.336	0.335	0.335	0.335	0.335
60	M74	Other professional, scientific and technical services	0.203	0.203	0.203	0.203	0.203
61	M75	Veterinary services	0.136	0.136	0.136	0.135	0.135
62	N77	Rental and leasing services	0.405	0.405	0.405	0.405	0.405
63	N78	Employment services	0.113	0.113	0.113	0.113	0.113
64	N79	Travel agency, tour operator and other booking and related services	0.420	0.419	0.419	0.419	0.419
65	N80	Security and investigation services	0.080	0.079	0.079	0.079	0.079
66	N81	Building maintenance and landscaping services	0.173	0.172	0.172	0.172	0.172
67	N82	Administrative, managerial, economic, and other support services	0.455	0.455	0.455	0.454	0.454
68	O84	Public administration and defense services; compulsory social security services	0.819	0.816	0.816	0.815	0.815
69	P85	Education services	0.142	0.142	0.142	0.141	0.141
70	Q89	Health services	0.097	0.097	0.097	0.097	0.097
71	Q87	Residential care services	0.567	0.562	0.562	0.561	0.560
72	Q88	Social services without accommodation	0.246	0.245	0.245	0.245	0.245
73	R90	Services in the field of creativity, arts and entertainment	0.394	0.393	0.393	0.393	0.393
74	R91	Libraries, archives, museums and other cultural services	0.317	0.317	0.317	0.316	0.316
75	R93	Sports and entertainment and recreation services	0.652	0.650	0.650	0.650	0.649
76	S94	Services provided by member organizations	1.502	1.500	1.500	1.500	1.500
77	S95	Repair services for computers, personal and household goods	0.429	0.429	0.429	0.429	0.429
78	S96	Other individual services	0.726	0.726	0.726	0.725	0.725
		Total carbon footprint across the economy	**0.593**	**0.582**	**0.564**	**0.535**	**0.513**