FORECASTING THE ENERGY CONSUMPTION OF SECTORS UNDER DIFFERENT NGFS SCENARIOS AND ANALYZING THE EFFECTS ON TÜRKİYE'S GDP

by

Utku Gökçe

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ABSTRACT

FORECASTING THE ENERGY CONSUMPTION OF SECTORS UNDER DIFFERENT NGFS SCENARIOS AND ANALYZING THE EFFECTS ON TÜRKİYE'S GDP

Physical and transition risks of climate change will have an impact on countries' economies and sectors. With proper planning and taking the necessary steps, these impacts can be mitigated. Therefore, academic studies and analyzes in this field are important. In this study, it is examined how Türkiye's GDP will be affected by physical risks and transition risks under different climate scenarios. In addition, within the scope of these scenarios, it has been forecasted how the energy consumption of the sectors in Türkiye will be in the future. In cases where current policies are continued or the necessary measures are not taken at the right time, the impact of climate change on Türkiye's GDP will be huge. At this point, it is of great importance to limit GHG emissions and not to increase the global average temperatures compared to the pre-industrial revolution. Because the increase in the number of extreme weather events or the occurrence of irreversible physical events such as sea level rise can seriously affect the economies. The steps in transitioning to a low carbon economy and combating the effects of climate change will also be a huge burden for the economies. In this context, the use of renewable energy sources should be increased in Turkey and practices that can reduce emissions such as carbon tax should be introduced. In energy production, fossil fuel consumption should be reduced and alternative energy types should be used. It can be said that the Oil and Gas, Transportation and Automotive sectors will be more affected by this situation. In these sector renewable energy types may need to be used more in energy production.

ÖZET

FARKLI NGFS SENARYOLARI ALTINDA SEKTÖRLERİN ENERJİ TÜKETİMİNİN TAHMİNİ VE TÜRKİYE GSYİH ÜZERİNDEKİ ETKİLERİN ANALİZİ

Kuvvetle muhtemel iklim değişikliğine bağlı fiziksel riskler ve geçiş riskleri ülke ekonomileri ve sektörler üzerinde etkili olacaktır. Doğru bir planlama ve gerekli adımların atılmasıyla bu etkiler hafifletilebilir. Dolayısıyla bu alanda yapılacak akademik çalışma ve analizler önem arz etmektedir. Bu çalışmada Türkiye GDP'sinin farklı iklim senaryoları altında fiziksel riskler ve geçiş risklerinden nasıl etkileneceği ortaya koyulmuştur. Ayrıca bu senaryolar kapsamında Türkiye'deki sektörlerin enerji tüketimlerinin ileride nasıl olacağı tahmin edilmiştir. Mevcut politikalarla devam edildiği veya gerekli önlemlerin doğru zamanda ve şiddette alınmadığı durumlarda iklim değişikliğinin Türkiye GDP'si üzerindeki etkisi büyük olacaktır. Bu noktada GHG emisyonlarının kısıtlanması ve sanayi devrimi öncesine kıyasla küresel ortalama sıcaklıkların fazla yükselmemesi büyük önem arz etmektedir. Çünkü iklim değişikliğine bağlı ekstrem hava olaylarının artması veya geri dönüşü olmayan deniz seviyesi yükselmesi gibi fiziksel olayların meydana gelmesi ülke ekonomilerini ciddi boyutlarda etkileyebilecektir. Düşük karbon ekonomisine geçiş yapmak ve iklim değişikliğinin etkileri ile mücadele etmek için atılacak adımlar da ülke ekonomilerini etkilemektedir. Bu kapsamda Türkiye' de yenilenebilir enerji kaynaklarının kullanımı artmalı ve karbon vergisi gibi emisyonların azaltılmasını sağlayabilecek uygulamalar devreye alınmalıdır. Enerji üretiminde fosil yakıt tüketimi azaltılmalı alternatif enerji türlerine ağırlık verilmelidir. Petrol ve Gaz, Taşımacılık ve Otomotiv sektörlerinin bu durumdan daha çok etkileneceği söylenebilir. Bu sektörlerde yenilenebilir enerji türlerinin daha fazla kullanılması gerekecektir.

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LIST OF ACRONYMS/ABBREVIATIONS

CA	Climate Analysis
CDP	Carbon Disclosure Project
ETH	Eidgenössische Technische Hochschule Zürich
EU	European Union
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IAMs	Integrated Assessment Models
IIASA	International Institute for Applied Systems Analysis
MAR1	1st Mediterranean Assessment Report
NDCs	Nationally Determined Contributions
NGFS	Network for Greening the Financial System
NIESR	National Institute for Economic and Social Research
NIGEM	National Institute Global Econometric Model
OECD	Organisation for Economic Co-operation and Development
PIK	Potsdam Institute for Climate Impact Research
RCP	Representative Concentration Pathway
TCFD	Task Force on Climate-Related Financial Disclosures
UMD	University of Maryland

1. INTRODUCTION

Climate change is one of the biggest problems of our time. Nowadays most of the scientists are concerned about global tipping points, such as the melting of glaciers or large-scale changes in the circulation of the oceans, which can be counted among the consequences of climate change. Because exceeding the threshold values in natural systems can cause sudden and severe events that today's technology cannot overcome (Nordhaus, 2019). In this sense, in the data collected at a measurement station established near the Mauna Loa volcano in Hawaii in 1959 to monitor carbon dioxide and other emissions in the atmosphere, it was observed that the amount of carbon dioxide in the atmosphere was not sufficiently absorbed by the oceans and this amount has increased in an unprecedented way (Türkeş, 2008; Türkeş, 2012; Urry, 2015). This situation has shown how the world has been dragged into a change that is very difficult to return back due to human activities (Urry, 2015). Generally, the possible effects of climate change on ecosystems, people, settlements and infrastructure include an increase in the frequency and intensity of physical events such as temperature increases on land and oceans, heavy rains, drought and fires (IPCC, 2022). Naturally, this will also have economic effects on countries (Türkeş, 2008). With this study, it was desired to investigate the economic effects of climate change and to make an analysis on the energy consumption of the sectors.

In the following years, climate change will have many more effects in different ways. These effects may include damage to crops due to droughts, increased heat stress, increased energy demand for cooling and ventilation, faster crop growth due to carbon dioxide fertilization, reduced cold stress, reduced energy demand for heating, increased rate of spread of infectious diseases, or decreased species diversity (Tol, 2018). Undoubtedly, combating these effects will be costly for countries and will require serious planning. Also, data obtained from different geographies of the world indicate serious temperature increases on land and sea. It is thought that increasing greenhouse gas emissions are the source of these temperature increases and living com-

munities around the world will be seriously affected by these increases (Urry, 2015). Increasing temperatures and increasing frequency, severity and duration of extreme weather events in the coming period will expose many terrestrial, freshwater, coastal and marine ecosystems to the risk of biodiversity loss on a medium and large scale (IPCC, 2022).

In recent years, global warming and climate change have been a topic that researchers, governments, politicians, businesses and civil society are working on (Kılıç and Kuzey, 2019). For this reason, municipalities and governments have to identify their vulnerabilities and remove barriers to economic growth as they deal with the effects of climate change such as sea level rise, drought and floods (Chandio *et al.*, 2020). In addition, events such as drought, heat stress, forest fire and insect invasion, which are among the consequences of climate change, significantly affect forest ecosystems and agriculture and may cause the extinction of some valuable animal and plant species if necessary precautions are not taken (Varol *et al.*, 2021). Naturally, Turkey is a country that is heavily affected by these factors. In the last thirty years, an increase in the average temperatures and the frequency and severity of extreme weather events such as storms, hail and water whirlwinds has been observed in Turkey (Demircan *et al.*, 2017b). However, countries need to protect their economic structures while dealing with these factors. Turkey, an upper-middle-income developing country trying to increase its role in international platforms, does not keep up with the international regime in changing and improving its climate policies (Turhan *et al.*, 2016). Therefore, countries' energy policies and carbon emission levels gain importance. Many countries are reviewing their carbon dioxide emissions within the framework of climate policies, and they have goals such as increasing agricultural activities and ensuring economic growth (Chandio *et al.*, 2020). In the long run, electricity consumption and economic growth in Turkey will have a major impact on carbon emissions (Akadiri *et al.*, 2020). Since, electricity generation contributes 41% to global carbon emissions due to the fact that it mainly depends on the use of fossil resources (Akadiri *et al.*, 2020). In addition, it can be said that the increase in per capita income in Turkey in recent years has increased carbon emissions (Shan *et al.*, 2021). Studies show that Turkey is a develop-

ing country with rich biomass energy resources (Toklu, 2017). In recent years, Turkish governments have started to increase the share of renewable energy in total energy by implementing some legal regulations and many important policies in order to benefit from their potential in terms of renewable energy (Bulut and Muratoglu, 2018). Although Turkey, which has rich renewable energy resources, has increased the share of renewable energy in energy production in recent years, it is still largely dependent on fossil resources in electricity production (Bulut and Muratoglu, 2018). In some studies, it is seen that Turkey does not sufficiently benefit from the renewable energy potential like wind energy (Kaplan, 2015).

Surely, climate change is one of the biggest threats to today's societies. The importance of this danger has become clear to scientists with the introduction of the greenhouse gas theory (Urry, 2015). In this sense, scientists have created different climatic scenarios with the purpose of working on the consequences of climate change and carbon dioxide emission. In this study, it has been analyzed how the Gross Domestic Product (GDP) of Turkey and the energy consumption of sectors in Turkey will be affected in different climate scenarios. Also with the analysis made on a sectoral basis, it has been indicated which sectors will experience more changes in energy consumption.

2. LITERATURE REVIEW

2.1. Physical Risks

Climate change may cause some physical risks in different ways with the effects it creates. It is thought that climate change will affect human and natural systems due to possible effects on rain-fed agricultural areas, seasonally accumulating snowdrifts, coastlines affected by sea level rise, rivers' food sources or forest fires and erosions (Nordhaus, 2019; Türkeş, 2012). In many settlements, heat waves, extreme temperatures and air pollution will have adverse effects on human health, livelihoods and basic infrastructure (IPCC, 2022). Due to temperature increases, the risk of drought and forest fire increases in some areas (Calda *et al.*, 2020). Physical risks of climate change risks to cities, settlements and basic infrastructure will continue to increase in the future, especially in places currently exposed to high temperatures, on coastlines or in highly sensitive areas (IPCC, 2022). Communities that are currently vulnerable to the effects of extreme weather conditions will become more vulnerable and less resilient to climatic shocks in the future (Wheeler and Von Braun, 2013). For example, acute food insecurity and malnutrition associated with flooding and drought have increased in Africa and Central and South America in recent years (IPCC, 2022).

In addition, by 2100, sea levels may rise between 43 and 84 cm on a global scale with regional differences. It is estimated that this rise may exceed 1 m if more ice sheets melt in Antarctica (MedECC, 2020; Türkeş, 2008). Risks such as permanent soil loss, deterioration of soil structure, changes in the salinity of underground and surface waters and loss of natural drainage await some coastal areas due to rising sea levels (Görmüş, 2021; WWF, 2023a). Continued and accelerating sea-level rise will condemn coastal settlements, infrastructure and coastal ecosystems to flooding or disappearance (IPCC, 2022). Climate change can contribute to the emergence of major humanitarian crises, particularly where climate vulnerability is increasing (IPCC, 2022). With the impact of climate change on people's lives, mass climate migrations may be observed (Çetin,

2023). While global climate change can damage human and other living habitats, it can also create new ones (Haber Merkezi, 2020). In all climate scenarios, approximately 1 billion people living in low-lying cities, coastlines and small islands are projected to be displaced in the medium term due to climate risks (IPCC, 2022). Therefore, climate and extreme weather events may lead to massive displacements and migrations, particularly affecting some small island states (IPCC, 2022).

2.1.1. Acute and Chronic Physical Risks

Physical risks can be divided into two categories as acute and chronic physical risks. Acute physical risks, which refer to event-driven risks, include certain natural events such as heat waves, drought, heavy rains, floods, forest fires and storms (Bank For International Settlements, 2021; Paisley, 2022; Zhou and Wu, 2023; TCFD, 2017). Here, heat waves can cause crop losses, food crises, social unrest and market fluctuations (Paisley, 2022). Although it is thought that there will be regional differences, it is estimated that the global average precipitation will increase in the coming years by virtue of the increase in global temperature averages and climate change (Zhou and Wu, 2023). Flooding, tides, and heavy rainfalls can cause physical damage to property, infrastructure and agriculture (Bank For International Settlements, 2021; McKinsey Global Institute, 2020). The effects of these events occur directly and the extent of the damage can be high. For example, as a result of a series of floods in Thailand in 2011, computer hard disk manufacturers and automobile manufacturers were highly damaged. This has also affected electronics manufacturers in the European Union, Japan, and the United States (Paisley, 2022). The World Bank estimated the cost of these losses as approximately $45 billion (Zhou and Wu, 2023). As can be seen, these weather events can cause serious capital costs with the damage they cause to facilities and production centers (TCFD, 2017). Particularly, the extent and effects of these events may vary from region to region. For example, extreme weather events in the United States between 1980 and 2021 caused a total of approximately $2.15 trillion in damage, with tropical cyclones causing the most destruction and death (NOAA, 2022).

Chronic physical risks include long-term risks such as rises in sea levels, increases in average temperatures, changes in precipitation regimes or acidification of the oceans (Paisley, 2022, Zhou and Wu, 2023; TCFD, 2017). Although the repercussions of these risks may occur late, the extent of the effects may be high. Sea level rises can affect some coastal areas, which can cause damage especially to the real estate and tourism sectors (Zhou and Wu, 2023). For example, it is estimated that an area where around 200 million people live may fall below sea level by 2100 (Paisley, 2022). Further the absorption of carbon dioxide by the oceans, which has an increasing concentration in the atmosphere, may cause acidification of the oceans in the future, thus negatively affecting the fishing and tourism sectors and damaging the coastal economies (Zhou and Wu, 2023). At the same time, although the aspects vary from country to country, increasing temperatures may cause decreases in the productivity of employees (Zhou and Wu, 2023). For example, by the 2030s, approximately 400 million people on a global scale each year may not have suitable working conditions due to increasing temperatures (Paisley, 2022). This may lead to an increase in the costs allocated to the workforce and a decrease in incomes (TCFD, 2017).

2.2. Transition Risks

In addition to the physical risks caused by climate change, some transition risks may arise. While it is predicted that in the short term climate change may have some positive effects on developing countries as it reduces heating costs or because carbon dioxide fertilization makes plants more resistant to drought, it is thought that economic growth may be adversely affected due to the steps to be taken to reduce greenhouse gas emissions in the medium and long term (Tol, 2018). In this sense, it is widely accepted that greenhouse gas (GHG) emissions should be priced and preferably taxed (Tol, 2018). Under various climate scenarios, the potential impact of an uncontrolled transition to a low carbon economy on financial actors (e.g. pension funds, mutual funds and insurers, development banks) is remarkable and needs to be regularly monitored and evaluated (Monasterolo, 2020). According to a study, in a scenario where everything stays the same, climate change can have significant negative effects on firms' defaults,

banks' leverage and the prices of financial assets, and these effects are likely to become more severe if average temperatures rise by 2.5^{o}C. (Dafermos *et al.*, 2018). Moreover, inflationary pressures may occur on the economy due to the possible decreases in the supply of goods and the conditions that may occur as a result of weather events such as drought, flood, storm and sea level rise. So that these events can increase the costs of insurance companies and may adversely affect the owners by reducing the value of physical goods (Batten, 2018). Insurers may face large, unexpected payments due to climate change-related property damage and destruction (Debelle, 2019). Overall, the results of some researches indicate that climate-based financial risks may soon materialize for many investors. In particular, private and public financial risk holders will be able to change their positions according to the exposure of portfolios to climatic risks, the country's debt and the state of the economic structure (Monasterolo, 202). It is also possible that climate change will have a major impact on economies through local and specific events, such as the deterioration of agricultural crops, heatwaves or extreme summer heats. Such that, if the number of these specific events increases, there may be serious pressure on economic productivity and growth resulting economic instability (Batten, 2018; Monasterolo, 2020).

It is also thought that private and public investment decisions can have a great impact on the decarbonization of the economy and thus the achievement of climate targets (Monasterolo, 2020). Transitioning to a low-carbon economy with the purpose of adapting and mitigating climate change may create results that can affect people's lifestyles, production and manufacturing methods (T.C. Dışişleri Bakanlığı, 2022). Hence, climate change can create socioeconomic inequalities via as loss of livelihoods, risk of displacement or damage to industry; it may complicate the formation of an egalitarian and sustainable society structure (Gasper *et al.*, 2011). For example, climate migrations may occur in the southern regions of Europe towards the Nordic countries in the north (Aaheim *et al.*, 2012). Considering that poor countries are currently located in warmer places, these countries' ecosystems are close to their biophysical upper limits and may have difficulties in producing new technology (Tol *et al.*, 2004). However, it can be said that countries can make progress through trial and

error. For example, if the future climate of England will be like that of Spain now, England can adapt its economy and technology from the current situation of Spain (Tol, 2018). As expected, while sectors such as agriculture, forestry and fisheries are based on the consumption of natural resources that may be more affected by climate change, decreases in energy consumption may also be seen in some regions (Aaheim *et al.*, 2012). Therefore, there will be a tendency towards new technologies and an increase in the markets of green products (Urry, 2015). Although climate change may have some positive economic effects, its negative effects outweigh. Such that these effects may be more severe in underdeveloped countries struggling with poverty (Tol, 2018). Potential damages are expected to be concentrated in low-income countries and regions such as tropical Africa, Latin America, coastlines and the Indian subcontinent (Nordhaus, 2019). In case of transition to a low-carbon economy, investors' inability to adapt their investment strategies to climate policies may pose some financial risks (Batten, 2018). In this sense, poor countries generally have limited adaptation capacity. These countries; they may not have the opportunity to invest in new and modern technologies that can help them protect themselves from the negative effects of climate change, and the political will to use resources for areas such as infrastructure, irrigation and coastal protection (Tol, 2018).

Damages caused by climate change can lead to reallocation of portfolios and cause a gradual decrease in the price of corporate bonds (Dafermos *et al.*, 2018). In this sense, it is important for companies to be aware of the effects of climate change. The Carbon Disclosure Project (CDP), a UK-based non-profit organization, published a report titled as "Ready or not: Are Companies Ready for the TCFD Recommendations?", and examined 1,681 companies from 14 countries, 51 of them from Turkey, based on the steps they took regarding the risks related to climate change. According to a survey included in the report, the vast majority of these companies have acknowledged that climate change poses financial risks to their businesses (CDSB & CDP, 2018). For example, companies that cause significant pollution may face reputational damage or legal liability for their activities, and changes in regulation may render previously valuable assets stranded (Debelle, 2019). Within the scope of the transition to a

low carbon economy, 83% of the companies surveyed consider physical risks, while 88% consider policy changes and new regulations as the main risk factors (CDSB & CDP, 2018). In general, 90% of the companies participating in the survey consider physical risks as an important factor; 45% of companies consider carbon taxes and the development of an emissions trading system to be their top risk at the policy level (CDSB & CDP, 2018). In this manner, climate-induced financial instability may adversely affect credit expansion and exacerbate the negative impact of climate change on economic activities (Dafermos *et al.*, 2018).

In addition climate change may cause firms to increase the default rate of corporate loans, which may harm the stability of the banking system, by destroying their capital, reducing their profitability and liquidity (Dafermos *et al.*, 2018). For example, by 2100, global assets at risk of coastal flooding are estimated to be $7.9 and $12.7 trillion in the RCP4.5 scenario, and $8.8 and $14.2 trillion in the RCP8.5 scenario (IPCC, 2022). Studies show that if the average global temperatures increase by 2^oC compared to the pre-industrial revolution, a decrease between 0.2% and 2% in GDP can be experienced and European economies can be moderately affected by such a change (Aaheim *et al.*, 2012; Keen, 2020). Climate change is also likely to cause loss of income. Such as an increase of 2.5^oC in the global temperature average can cause a 1.3% decrease in the income of an average person (Tol, 2018). Moreover, it is thought that if the average temperatures increase by 4^oC, all regions of Europe will suffer economic losses and some southern regions may experience a 0.7% decrease in GDP each year (Aaheim *et al.*, 2012).

2.3. Climate Change Effects on Turkey

When physical risks and transition risks are considered together, it is thought that climate change will have significant effects on Turkey. Due to the increase in temperatures, food security problems and water stress may increase in Turkey. Also the number of severe natural disasters and climate events such as forest fires, droughts, floods, hail and heavy rains that have occurred more in recent years may increase

(Demircan *et al.*, 2017a; Görmüş, 2021; World Bank, 2022). For example, the severity of forest fires has increased in recent years due to the hotter and drier summers in the Mediterranean basin (Calda *et al.*, 2020). According to the data of the General Directorate of Meteorology, while less than 100 extreme weather events occurred annually in the 1940s; there has been a serious increase in these numbers, especially after the 2000s (Görmüş, 2021). As a result of the calculations made by an association called Ekosfer based on the data of the General Directorate of Meteorology, it has been observed that the number of weather events in Turkey has doubled in the last 10 years (Erdem, 2021). In this context, 984 extreme weather events occurred in Turkey in 2020, and it was observed that 30 percent of these weather events were heavy rain and floods, 27 percent storms and 23 percent hail (Erdem, 2021). These extreme weather events may be more severe especially in summer months in Mediterranean Basin (Ozturk at al., 2015). Along with these extreme weather events in the country, Turkey may be exposed to the negative effects of global warming such as the decrease in precipitation and water resources, desertification and ecological deterioration (Pilevneli *et al.*, 2023; Şen *et al.*, 2013; T.C. Dışişleri Bakanlığı, 2022).

When Turkey and other OECD countries are evaluated according to climate risk and vulnerability, it is seen that Turkey has a high level of vulnerability in 9 out of 10 climate-related vulnerability dimensions (World Bank, 2022). This level of vulnerability has emerged when the population's exposure to extreme events such as floods or forest fires, combined with socioeconomic and climatic factors (World Bank, 2022). For example, in a scenario where the global average temperature increases by more than 3 degrees towards the end of the current century, if the sea level rises by 50 cm in Istanbul and Izmir, it is estimated that floods and overflows (WWF, 2023a) will affect 252,000 people. Turkey, which is among the "countries in the risk group" in terms of the negative effects of climate change, faces risks such as drought, flood, decrease in the amount of water per capita and drinking water (Çetin, 2023; Şen *et al.*, 2013). In addition, risks such as decrease in water resources, desertification, loss of agricultural productivity, increase in the number and impact of forest fires and loss of biodiversity await Turkey in the coming years (iklimBU, 2023; Şen *et al.*, 2013).

Also, when historical data and climate models are examined together, it is seen that the Mediterranean Basin is more affected by global climatic trends (MedECC, 2020; Demircan *et al.*, 2017a; Öztürk *et al.*, 2015). In the First Mediterranean Assessment Report (MAR1) published in 2020, it was stated that the sea level in the Mediterranean has risen by 6 cm in the last 20 years due to climate change and global warming (MedECC, 2020). Similarly, Turkey's climate will shift towards a tropical climate and the incidence of irregular, sudden and heavy rains, floods, tornadoes, hurricanes, landslides and erosions will increase (Çetin, 2023). The projections indicate that the Mediterranean climate will shift its influence towards the northern regions (Şen *et al.*, 2013). For this reason, Istanbul may begin to have the characteristic features of the Mediterranean climate and it may be exposed to effects such as a decrease in precipitation, an increase in temperature and a long summer season (Şen *et al.*, 2013).

2.3.1. Possible Effects of Climate Change on Temperature and Precipitation in Turkey

In the last 70 years, the average temperature in Turkey has tended to increase and it has been observed that the Mediterranean and Southeastern Anatolia regions have warmed by 0.07-0.34 degrees every 10 years (Çetin, 2023). In the last 40 years, it has been calculated that 1 million 300 thousand hectares of wetland area, which is approximately three times the amount of Van Lake, has disappeared (Çetin, 2023; Türkeş, 2012). Researches shows that Turkey will have a dry and hot climate in the coming years, frequent and long-lasting droughts will be seen in Turkey, and the average temperature may rise by 2-3 degrees (Çetin, 2023; Kurnaz, 2014). As it can be seen in Table 2.1, the temperature increase may up to 5^oC in Turkey and 5.1^oC in Mediterranean region. Moreover, it is thought that the average temperature increase may be 4 degrees in the Aegean and Eastern Anatolian Regions, 5 degrees in the inner regions and between 2.5 and 4 degrees in Turkey (An *et al.*, 2023; T.C. Çevre ve Şehircilik Bakanlığı, 2012; iklimBU, 2023; Haber Merkezi, 2020). In particular, towards the end of the current century, it is estimated that an increase of up to 3^oC in

winter and 8^{o}C in summer can be seen in average temperatures in Turkey (Demircan *et al.*, 2017a). Especially in the eastern parts of Turkey, blistering summer days may be experienced (An *et al.*, 2023; Ozturk *et al.*, 2017). Some studies show that, in a situation where everything remains the same, the temperature increase for the summer months is 5-6 degrees in the west of Turkey, and 3-4 degrees in the Central and Eastern Anatolia and Southeastern Anatolia regions (An *et al.*, 2023; iklimBU, 2023).

Table 2.1. Temperature change projections for Turkey.

Year	**Location**	**Temperature Rise**	**Reference**
2050	Turkey	0,5^{o}C - 4^{o}C	(Bozoglu *et al.* 2019; Demircan *et al.* 2017a; Erdem, 2021; Turp *et al.* 2014)
2100	Mediterranean	1^{o}C - 5.5^{o}C	(Coskun *et al.* 2021, Giorgi and Lionello, 2008; Hertig and Jacobeit, 2008; Lange, 2020; MedEcc, 2020; Rojo *et al.* 2017; Rosa *et al.* 2012; Şeker and Gümüş, 2022; Yıldırım *et al.* 2021)
2100	Turkey	1,5^{o}C - 5^{o}C	(Bayram and Öztürk, 2020; Bozoglu *et al.* 2019; Coskun *et al.* 2021; Demircan *et al.* 2017a; Haber Merkezi, 2020; Önol and Unal, 2012)

Studies shows that precipitations may decrease in most of Turkey in the following years (Erdem, 2021; Türkeş, 2019). Also, it is predicted that precipitation in the coastal Aegean, Eastern Black Sea and Eastern Anatolia regions may increase during the winter months, and decreases of up to twenty percent may be observed in the

precipitation occurring in the spring months, except for some regions (An *et al.*, 2023; Erdem, 2021). Although the irregularity of precipitation regimes draws attention in the coming period, an increase in precipitation in winter months, a decrease in autumn precipitation, and serious decreases in precipitation in spring and summer seasons, except for some regions, are expected (Demircan *et al.*, 2017a). While it is stated that precipitation will decrease significantly throughout Turkey, this decrease may reach 30% in the southern parts; precipitation is expected to increase in northern parts, including the Black Sea region, which will be relatively less affected by the negative effects of climate change (An *et al.*, 2023; iklimBU, 2023; Şen *et al.*, 2013; Turp *et al.*, 2014; Türkeş, 2019; WWF, 2023b). In addition, the risk of excessive precipitation may increase, especially in the western and northern coastal regions of Anatolia. (Demircan *et al.*, 2017a; Turp *et al.*, 2014). With climate change, snowfall will gradually decrease in Turkey, along with the harshness of the winter season (Çetin, 2023). Due to the increasing temperatures, there may be cases such as rain instead of snow in winter or melting of snow accumulations in early spring (Demircan *et al.*, 2017a).

2.4. Effects of Climate Change on Sectors in Turkey

2.4.1. Agriculture

It is generally thought that climate change will only have serious effects on the agriculture; however, it is highly likely that these effects will be reflected in other areas of the economy as well. A temperature increase of 1.1 - 1.3^{o}C is estimated to cause a 1% decrease in real GDP of Turkey in 2030 - 2039 and 1.41% in 2040 - 2049 (Karapınar *et al.*, 2020; Özlü *et al.*, 2020). Underdeveloped and developing countries may be more exposed to climate change. Because generally, agriculture and water resources have a large proportion in the economies of poor countries (Tol, 2018). For example, the added value provided by the agricultural sector to Turkey's GDP was 9.9% in 2000 and 6.3% in 2018 (CMCC, 2023). In addition, the agriculture, forestry and fisheries sector added approximately 41 billion dollars in total in 2000 and 62 billion dollars in 2018 (CMCC, 2023). On the contrary, rich countries have a wider

range as they also focus on manufacturing and service sectors in their economies, and therefore they are less vulnerable to weather conditions (Tol, 2018). Although economic activities in the manufacturing and service sectors occur in largely controlled environments, economic activities such as agriculture, forestry, fishing and mining are exposed to weather conditions and are vulnerable to climate change. However, since all these activities are interconnected through markets, the effects of climate change on economic development and growth cover all sectors (Arent *et al.*, 2015). For example, inasmuch as Turkey is the main producer of hazelnut in the world, the effects of climate change on hazelnut yield in Turkey may affect the world's hazelnut sector after all (An *et al.*, 2020).

Conditions such as irregularities in precipitation, excessive precipitation, floods, insufficient water or an increase in the average temperature can be obstacles for agricultural activities (Görmüş, 2021). In the Southern Europe region, which includes Turkey, extreme heat events and decreases in precipitation and water are expected to prevent crop production in agriculture (Haber Merkezi, 2020). Decreases in precipitation and water resources and increases in temperature averages are expected affecting the south and west coastal regions, which are strong in the agricultural sector, and the South East Anatolia region, where irrigated agriculture is common, both in terms of energy and agricultural production (Bozoglu *et al.*, 2019; Şen *et al.*, 2013).

In a study examining the most cultivated crops in the world, which is the basis of human nutrition, it was found that a one-degree increase in global average temperature could reduce the average land productivity by 6% in wheat, 7.4% in corn, 3.2% in rice and 3.1% in soybean. (Görmüş, 2021; Özlü *et al.*, 2020). Climate models predict that if the global average temperatures increase by 3 degrees, the yield loss in agriculture may be between 25-50% in 2050 (Karapınar *et al.*, 2020; Özlü *et al.*, 2020). According to the RCP4.5 scenario, the direct impact of climate change on the agricultural sector will be +0.36% in 2035, -1.69% between 2035 and 2060, and -5.12% in the last 40 years of the century (CMCC, 2023). These situations show that agricultural activities are largely based on climate (Görmüş, 2021). Severe and prolonged heat waves and droughts can

cause serious losses in agriculture (Ozturk *et al.*, 2015). For example, due to the great drought experienced in 2007 - 2008, a huge damage was seen in Marmara, Aegean, Central Anatolian and Mediterranean regions (Kurnaz, 2014; Şen *et al.*, 2013). In fact, it is thought that the loss in the agricultural sector in 2007 and 2008 was around 2 million dollars and 435 thousand farmers were affected by this situation (Bolatova and Engindeniz, 2020). In addition, extreme weather events are likely to become more frequent in the future, which is highly likely to increase risks and uncertainties in the global food system (Wheeler and Von Braun, 2013). Changes in temperature and growing season, as well as severe weather events, can lead to the proliferation and spread of some vector species, invasive weeds, pests or diseases (Haber Merkezi, 2020).

Factors such as the total amount of precipitation received during the year in plant production and agricultural productivity, the distribution of precipitation throughout the year and the duration of sunshine should be taken into account as they affect the development periods of plants (Görmüş, 2021). Conditions such as drought and water scarcity may occur more frequently and severely in the future, and may cause the air to become more humid and oppressive, especially in regions where irrigated agriculture is carried out, together with high temperatures (Şen *et al.*, 2013). The scorching heat and drought will reduce the variety and quantity of agricultural products, and increases in agricultural diseases and pests will be observed (Çetin, 2023). In the near future, 40 degrees will be the seasonal normal in Turkey and 40 percent of the agricultural lands will be dry (Çetin, 2023).

Due to the changing climatic conditions, the same agricultural production in the same location may not be possible or may become impossible (Görmüş, 2021). As a result of climate change, food inequality may increase from local to global. Because the degree of climate change and the extent of its effects on people differ from one part of the world to another, from one community to another, and between rural and urban areas (Wheeler and Von Braun, 2013). It is estimated that tropical plants can be grown in the Mediterranean strip, and citrus cultivation can expand to the interior regions (Haber Merkezi, 2020). Crop production and harvest seasons may shift earlier

due to the increase in temperature, especially in the Black Sea region and other regions (Şen *et al.*, 2013). So, climate change may have positive effects such as enabling plants to be planted earlier and harvested later (Haber Merkezi, 2020).

2.4.2. Energy and Resources

Economists see energy as 5% of countries' GDP; because that is usually how much energy costs for countries. However, fossil-based energy types are non-renewable and they have the potential to have consequences that can greatly change the climate and future water and food supply when consumed as an energy source (Urry, 2015). Many cities around the world today; will face poverty, hunger and increasing resource demand, and will more frequently encounter situations such as the decrease in resources with limited supply such as drinking water due to climate change and rapid urbanization, or the decrease in the quality of the services provided (Gasper *et al.*, 2011). For example, a 10 percent decrease in water supply in the future may cost Turkey 6% of its GDP or approximately 50 billion dollars (World Bank, 2022).

In cities where the effects of climate change and global warming are felt more, energy, water and other services may be restricted; There may be violent conflicts from place to place and different migration patterns may arise. This may differentiate socioeconomic conditions and create challenges in governance (IPCC, 2022). In terms of population distribution and abundance of water resources, hydroelectric energy production is generally concentrated in the east of Turkey (Şen *et al.*, 2013). Studies show that Turkey's river basins have serious risks due to the decrease in precipitation amounts in the inner parts of Anatolia, the basins in the south and the Euphrates - Tigris Basins (Demircan *et al.*, 2017a). Due to the decrease in precipitation, the amount of water carried by the rivers, the water level of the dam lakes and thus the hydroelectric energy production may decrease (Çetin, 2023). Due to this decrease in water flows that are the source of Turkey's hydroelectric sector, strategies in the energy sector may need to be changed (Barak and Yanarocak, 2022). In addition, the impacts of climate change in cities can be the deterioration of infrastructure, including trans-

portation, water, sanitation and energy systems that may eventually result in economic losses, interruptions in services or reduced well-being (IPCC, 2022). Depending on the level of global warming in cities, the costs of maintaining and rebuilding urban infrastructure, including buildings, transportation and energy, are likely to rise enormously (IPCC, 2022). For example, the increase in temperatures during the summer months in Turkey means that more energy will be needed for cooling in these months (Şen *et al.*, 2013). In addition, considering the energy demands of residences and companies; since the increase in the energy demand for cooling purposes in Turkey will be much higher than the decrease in the energy demand for heating purposes, energy bills would have to rise (CMCC, 2023).

Turkey's energy production and energy needs are increasing day by day (An *et al.*, 2017, Bakirci and Kirtiloğlu, 2021). Therefore, it will be the right decision to make a transition towards the use of renewable energy in order to reduce the dependence on fossil fuels in the future. Turkey, which is currently highly dependent on coal and plans to build new coal power plants, needs to decarbonize its electricity generation by 2050 and significantly reduce the emissions of the electricity sector (Climate Action Tracker, 2019; World Bank , 2022). Currently the energy sector, which also feeds sectors such as electricity, transportation, construction and industry, has a three-quarter share in Turkey's total emissions (World Bank, 2022).

2.4.3. Tourism

Considering that tourism activities are generally dependent on natural resources, the negative effects of climate change will be seen more in countries where the tourism sector has a large share in their economy (Dogru *et al.*, 2019). For example, an increase of 2 degrees in average temperatures in the Mediterranean Basin may result in unexpected weather events, heat waves, an increase in the number and impact of forest fires, drought, loss of biodiversity, and a decrease in tourism revenues and agricultural yields (WWF, 2023b). Especially our coastal cities in the south may be more exposed to the negative effects of climate change and the high temperatures foreseen in the

climate projections may cause seasonal shifts, the change of the times when tourism is intense, and the decrease in tourism activities in coastal cities where tourism is intense (Oğur and Baycan, 2022). In this context, coastal provinces in the south such as Antalya may be seriously affected by extreme heat (CMCC, 2023). Therefore, in the future, tourism activities concentrated in the southern regions will shift to the northern regions; summer tourism will turn into spring tourism (Çetin, 2023). Since the tourism sector will be significantly affected by climate change, an increase of 1 degree in global temperature averages will reduce Turkey's GDP by 0.89%, an increase of 2 degrees will decrease it by 2.82%, and an increase of 3 degrees will reduce it by 5.37% (CMCC, 2023). On the other hand, less precipitation in summer and a slight increase in temperatures may have positive results in terms of tourism (Şen *et al.*, 2013). A positive impact on the tourism sector can increase revenues and support growth (World Bank, 2022). The increase in the average temperature in the winter months may increase the time allocated for cultural or historical tourism (Oğur and Baycan, 2022).

2.4.4. Fishing

It is foreseen that the water currents and temperature regimes in the seas will change with the increase in the average temperatures of Turkey (Çetin, 2023). Decreases in the amount of oxygen and food supply that can be seen in Turkey's seas due to the increase in temperatures and acidification may reduce the stocks of sea creatures and fish by 17-18% (WWF, 2023a). Situations such as increasing water scarcity or ocean acidification that may arise with global warming may decrease productivity and lead to the endangerment of the existence of some sea creatures and fisheries, which are protein stores for people. In addition, situations such as the deterioration of the migration routes of fish and negative effects on traditional fishing and hunting methods may be seen (Çetin, 2023; Görmüş, 2021; World Bank, 2022). Tropical species may migrate from the Red Sea to the Mediterranean, and species living in the Mediterranean may shift towards the Black Sea (CMCC, 2023). For this reason, the amount of anchovy fish consumed in abundance in Turkey may decrease. Anchovy prices, on the other hand, could rise significantly (CMCC, 2023).

3. METHODOLOGY

In this study, the effects of chronic physical risks and transition risks related to climate change on Turkey's GDP were analyzed. By making literature review, the risks related to climate change and the effects of climate change on Turkey and the sectors have been identified. For this purpose, a data set prepared by Network for Greening the Financial System (NGFS) was used. At the same time, analyzes and calculations were made on how the energy use of sectors in Turkey might change in the future under different climate scenarios.

3.1. The Network of Central Banks and Supervisors for Greening the Financial System (NGFS)

Established with the "One Planet Summit" in Paris in December 2017, NGFS is an organization of central banks, supervisors and observers that aims to channel mainstream financing resources towards a sustainable economy and support environmental and climate risk management (NGFS, 2023a; Ruijvan, 2022). Increasing the number of members and observers since its establishment, NGFS today consists of 125 members and 19 observers (NGFS, 2023b). NGFS contributes to the academy with a series of hypothetical scenarios it has designed together with an expert team of climate scientists and economists. In this way, they have prepared a comprehensive data set on how physical risks, climate policies and technology trends may change in the future (Ruijvan, 2022). NGFS has integrated the National Institute Global Econometric Model (NIGEM) into its process to provide macroeconomic data to the Climate Scenarios it has designed and to model the impact of climatic scenarios on the economy (NIESR, 2023a). NiGEM is a large-scale structural macro-econometric model developed by the National Institute for Economic and Social Research (NIESR) used to model and forecast the effects of economic events (NIESR, 2023b). It is used by both policy makers and the private sector around the world to make economic forecasts, create scenarios and perform stress tests (Hantzsche *et al.*, 2018). It consists of single country mod-

els for large economies that trade in goods and services and are interconnected by integrated capital markets (Hantzsche *et al.*, 2018).

3.1.1. NGFS Scenarios

Transition risks and physical risks related to climate change can be analyzed with 6 different scenarios prepared by NGFS:

(i) Net Zero 2050: It is a scenario in which strict climate policies and practices are put into effect immediately, and carbon dioxide emissions are brought closer to zero by 2050 with the use of energy sources such as sustainable bioenergy, biofuels or solar energy. It is assumed that by the end of the century, there is a fifty percent probability that global warming will be limited to 1.5^oC. In this scenario, physical risks are relatively low and transition risks are high (NGFS, 2023c),

(ii) Below 2^oC: A scenario where climate policies come into effect immediately and gradually become more stringent. It is assumed that there is a 67% probability that global warming can be kept below 2 degrees at the end of the century and that zero carbon dioxide emissions will be achieved after 2070. Both physical risks and transition risks are relatively low (NGFS, 2023c),

(iii) Divergent Net Zero 2050: In this scenario, net zero is reached by 2050. However, this is more costly due to policy differences between sectors and the different forms of discontinuing the use of fossil fuels (NGFS, 2023c). In the scenario, it is assumed that climate policies are tighter in the transportation and construction sectors and that the inability to coordinate strict policies in these sectors will create a burden on the consumer (NGFS, 2023c). Emissions are in line with a climate target to limit global warming to 1.5^oC by the end of the century, and the scenario includes significantly greater transition risks from Net Zero 2050 and the lowest physical risks in the six scenarios (NGFS, 2023c),

(iv) Delayed Transition: This scenario assumes that new climate policies will not be implemented until 2030 and then tougher and more expensive measures will be

taken to keep global warming below 2^oC. The scenario includes higher transition risks and physical risks compared to Net Zero 2050 and Below 2^oC scenarios (NGFS, 2023c),

(v) Nationally Determined Contributions (NDCs): This scenario includes policies that countries have not yet implemented but have committed to implement. Emissions will be reduced. However, even if the policies are implemented, it is assumed that the global warming will be around 2.6^oC. The adverse effects of climate change are projected to increase and the scenario includes moderate or severe physical risks, although transition risks are relatively low (NGFS, 2023c),

(vi) Current Policies: This is the scenario in which the currently implemented policies are preserved and the necessary steps are not taken within the scope of combating climate change. Emissions will continue to increase until 2080, leading to irreversible physical changes such as sea level rise (NGFS, 2023c). The scenario includes serious physical risks (NGFS, 2023c).

3.2. Dataset

3.2.1. Data Source

In this study, NGFS Climate Scenarios Data Set (NGFS Phase 3 v3.4) was used. Scenarios included in the dataset was produced by a joint academic consortium established between NGFS and Potsdam Institute for Climate Impact Research (PIK), International Institute for Applied Systems Analysis (IIASA), University of Maryland (UMD), Climate Analysis (CA), Eidgenössische Technische Hochschule Zürich (ETH) and National Institute for Economic and Social Research (NIESR) (Zenodo, 2022). Phase 3 scenarios were created using highly advanced embedded integrated assessment models (IAMs) such as GCAM, MESSAGEix- GLOBIOM and REMIND-MAgPIE (Zenodo, 2022). These models help to estimate the costs of mitigating climate change globally and regionally, analyze energy systems in transition, determine the amount of investment required in the transformation of energy systems, and define sustainable development steps (Zenodo, 2022).

3.2.2. Scope of Data

The data set used in the GDP analysis is NGFS Phase 3 v3.4 (Zenodo, 2022). In this dataset, there are variables that show the effects of chronic physical and transition risks on Turkey's GDP as a percentage. These percentages represent the impacts of the chronic physical and transition risks on Turkey's GDP in six different climate scenarios. How much Turkey's GDP is affected by these risks is displayed as a percentage change for the years 2022-2050. These percentages are given for three different integrated assessment models (GCAM, MESSAGEix-GLOBIOM, REMIND-MAgPIE), six NGFS scenarios and two assessment (Chronic physical risks and transition risk). In the results, the effects of chronic physical risks and transition risks on Turkey's GDP are shown by graphing these percentages.

The projections in this data set currently do not include acute physical risks (Monasterolo, 2023a; Monasterolo, 2023b). On the other hand, chronic physical risks are represented as the relationship between climate variables (temperature and precipitation) and regional GDP and this relationship basically capture impacts on labor productivity, land productivity and depreciation of capital (Monasterolo, 2023a; Monasterolo, 2023b). This can be characterized as quantifying the effect of changes in average temperatures on economic output (NGFS, 2022a). Transition risks measured in this dataset derived from the level of policy ambition, the timing of policy implementation, the distribution of policy measures and the technology change (NGFS, 2022b).

In the NGFS scenarios these transition risks is are represented by the introduction of carbon pricing which can be viewed as a proxy for stringency of climate mitigation policies (Monasterolo, 2023a; Monasterolo, 2023; NGFS, 2022b).

For forecasting the energy consumption of the Transportation, Agriculture, Individual Use, Fishing, Oil and Gas, Construction, Automotive and Food Industry sectors in Turkey, the consumptions of these sectors were taken from a report shared by the

International Energy Agency in 2019 (International Energy Agency, 2019). This report includes the types and amounts of energy consumed by these sectors in 2019 (International Energy Agency, 2019).

Taking into account the share of energy types in total consumption and the proportions of these energy types within sectors, forecasting of how the energy consumption of each sector was made by using the NGFS data set. The forecasting for each scenario was made as follows. For each energy type two variables, annual consumption amount and unit price, which are included in the data set, are multiplied with each other for the years 2025 - 2050. Then, considering the energy proportions of sectors, it was calculated how much these sectors would consume in the coming years. Here, the shares of energy types within the sectors is determined by the year 2019. In the next step, Current Policies scenario was accepted as the base scenario and how much the other scenarios deviated from this scenario was calculated. The deviations of the other scenarios from Current Policies scenario is in the form percentage difference.

3.2.3. Models

The GCAM energy system is a global model that reveals the interactions between water, agriculture and land use, economy and climate (NGFS, 2022a). MESSAGEix-GLOBIOM is mainly has two core models, MESSAGE and GLOBIOM. But it consists of five different models or modules. These are the energy model MESSAGE, land use model GLOBIOM, air pollution and greenhouse gas emission model GAINS, macroeconomic model MACRO and climate model MAGICC (NGFS, 2022a) These models interact with each other and produce input-output during the scenario development process (NGFS, 2022a). REMIND-MAgPIE is a comprehensive system that prospectively simulates the dynamic interactions between energy, land use, water, air pollution and health, economy and climate (NGFS, 2022a).

4. RESULTS

Most of the carbon emissions in Turkey originate from the use of fossil fuels, primarily coal, in electricity generation, heating and industry. Another contribution comes from the use of petroleum used in the transportation sector (Akadiri *et al.*, 2020). The limited petroleum-based fuel resources in Turkey highlight issues such as quality energy production and efficient use of energy (Toklu, 2017). The low level of use of renewable energy sources pushes Turkey to use fossil fuels intensively to meet the increasing energy demand. This situation causes a foreign trade deficit by increasing the import of fossil energy (Bulut and Muratoglu, 2018). However, Turkey has only implemented regulatory policies such as feed-in-tariff and biofuel obligations compared to other countries such as the USA, China and EU countries to support renewable energy (Kaplan, 2015).

In the short term, while other variables tend to increase carbon dioxide emissions, investments in renewable energy and green technologies seem to reduce emissions (Shan *et al.*, 2021). Nonetheless, Turkey does not sufficiently benefit from financial incentives such as capital subsidies, grants and discounts, energy production payment, and public finance instruments such as public investment loans and grants and competitive public tenders, which are currently implemented in some countries to support renewable energy (Kaplan, 2015). Failure to bring the use of renewable energy sources to the desired level will lead to excessive use of fossil energy sources, which have negative effects on the environment (Bulut and Muratoglu, 2018). Whereas, renewable energy sources such as hydro, wind and solar energy emit carbon emissions only during the production phase (Akadiri *et al.*, 2020). Besides, using natural gas in energy production has less negative impacts on the environment compared to using lignite and hard coal (Atilgan and Azapagic, 2015).

In the long run, investments in green technologies and renewable energy reduce carbon dioxide emissions, on the other hand increase in population, per capita income

and energy consumption increases carbon dioxide emissions (Shan *et al.*, 2021). Here, low carbon emissions of renewable energy sources draw attention. For each kilowatt-hour of electricity produced, a solar panel produces 60-150 grams of carbon dioxide (Akadiri *et al.*, 2020). For one kilowatt-hour of electricity, 3-22 grams of carbon dioxide is produced in a typical wind turbine, 4 grams of carbon dioxide in a hydroelectric power plant and 6 grams of carbon dioxide in a nuclear power plant (Akadiri *et al.*, 2020). However, these values are very low compared to 950 grams of carbon dioxide released from coal-fired thermal power plants (Akadiri *et al.*, 2020).

Considering these values, it is important to know what kind of energy resources that the sectors in Turkey depend on. Similarly, researches must be focus on how the energy consumption of these sectors may change in the future. In addition, how Turkey's GDP will be affected by climate change is an issue that needs to be examined. Here it is shown what these effects may be in different NGFS scenarios. NGFS incorporates transition, physical and financial risks into these scenarios (Boissinot *et al.*, 2022). Chronic physical risks are reflected by linking climate variables with regional GDPs. Transition risks are shown by taking into account aspects such as the speed or severity of policy implementation (Monasterolo *et al.*, 2023a. Understanding these results and interpreting them carefully will help to understand the importance of this topic.

4.1. Net Zero 2050

In this scenario, strict climate policies are put into effect immediately to achieve zero carbon dioxide emissions by 2050. Thus, there is a 50% probability that the global average temperature increase at the end of the century will be 1.5^{o}C (Monasterolo *et al.*, 2023b). Chronic physical risks and transition risks are relatively low compared to other scenarios. As it can be seen at Figure 4.1 and Figure 4.2, chronic physical risks are predicted to decrease Turkey's GDP by 1% in 2030 and 1.5-2% in 2050. The effects of transition risks will emerge more recently due to the immediate introduction of strict climate policies, and will affect Turkey's GDP by up to 2% by 2050.

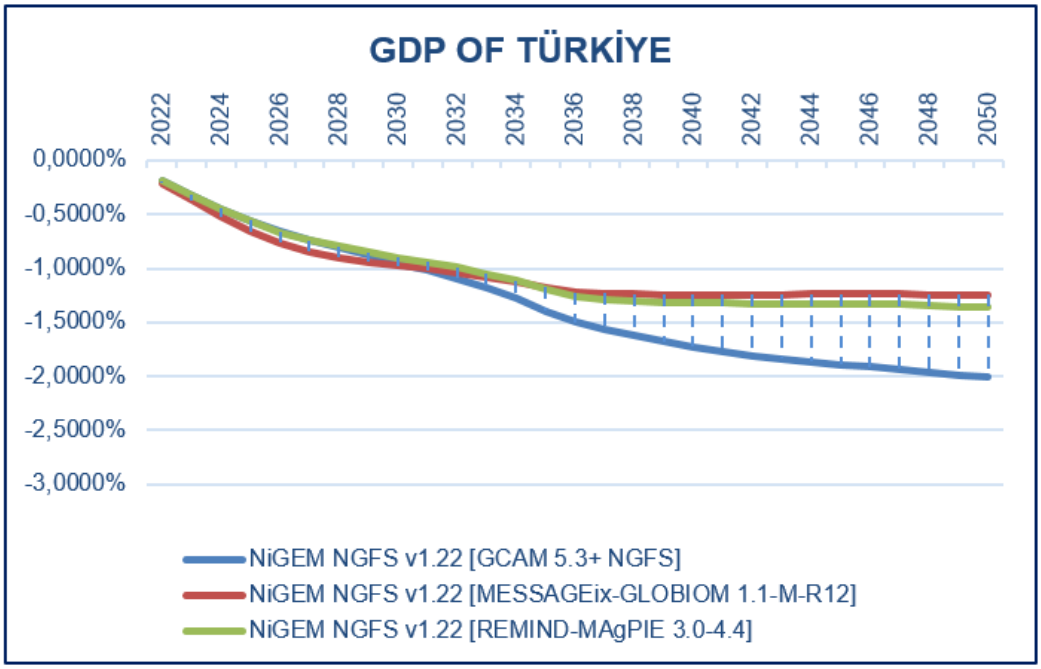

Figure 4.1. Chronic physical risk under net zero 2050.

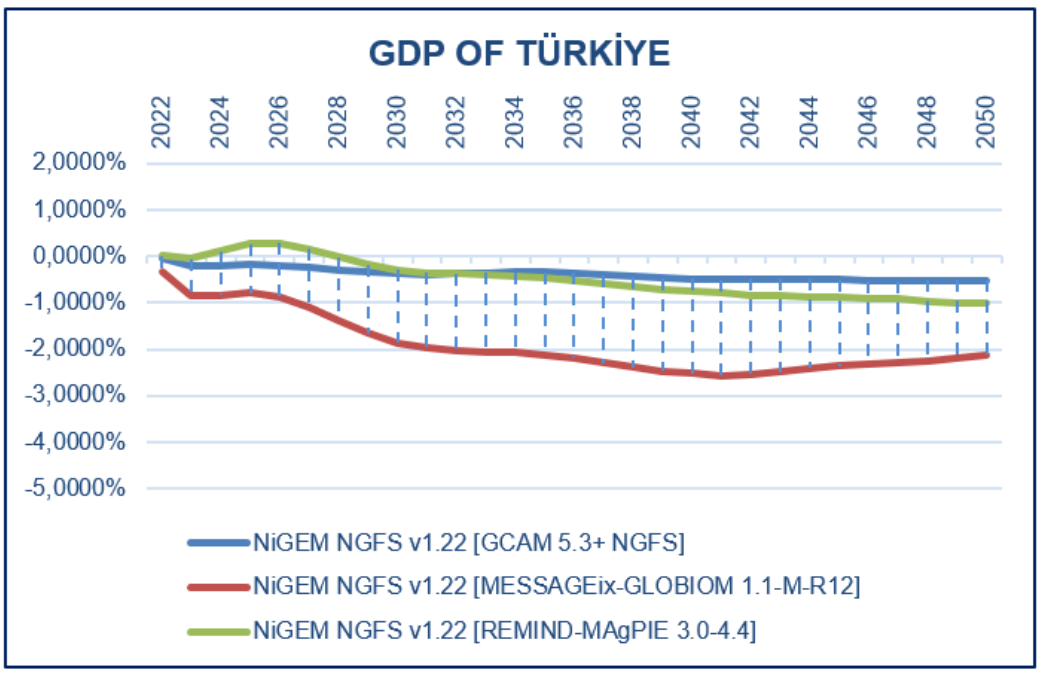

Figure 4.2. Transition risk under net zero 2050.

As seen in Figure 4.3 in this scenario, where zero carbon dioxide emissions are aimed in the 2050s, it is predicted that the consumptions of the Transport, Automotive and Oil and Gas sectors in Turkey's energy consumption will decrease when compared to a situation where current policies continue. It is estimated that the Transportation

sector will go from 20% to -10%, and the Oil and Gas sector will similarly decrease to -10%. It is estimated that the consumption of the Automotive sector, which is around 30%, will decrease to -50%. This is because these sectors are already dependent on fossil fuel consumption and need to shift their energy consumption towards renewable energy. On the other hand, the consumptions of Fishing, Agriculture, Construction, Food Industry and Individual uses in energy supply is expected to increase comparing to base scenario. When it comes to the 2050s, it is seen that the consumptions of the Fishing sector may increase by 5% and the consumption of the Agriculture sector by 15%. It is estimated that the consumptions of Construction, Food Industry and Individual uses could increase up to 35% by the middle of this century.

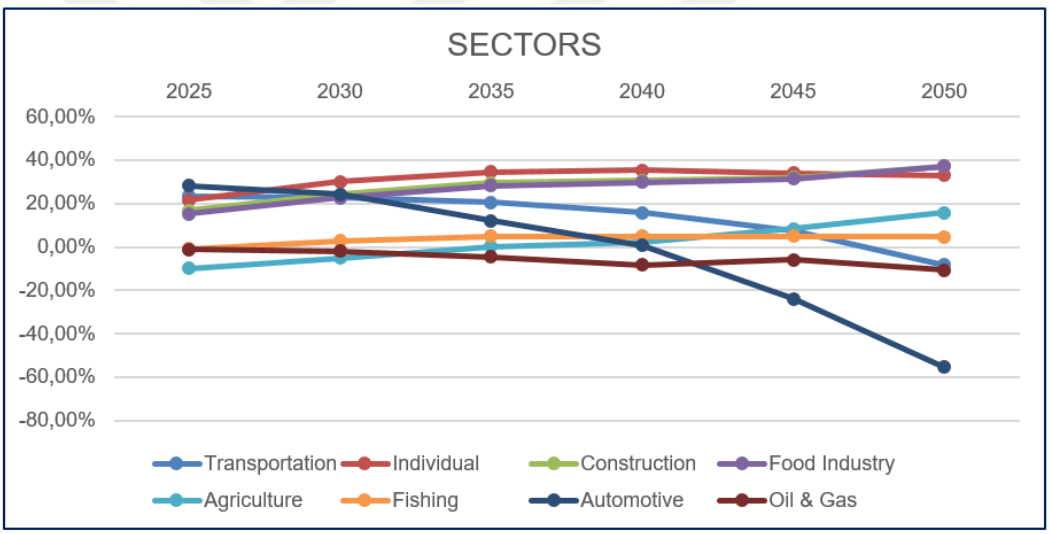

Figure 4.3. Energy consumption of sectors under net zero 2050.

4.2. Below 2°C

In this scenario, climate policies will be implemented immediately, but the severity of these policies will increase over the time. Thus, with a 67 percent probability, the global average temperature increase will be kept below 2°C (1.8°C) (Monasterolo *et al.*, 2023b). The effects of transition risks will increase over time as climate policies gradually become rigid. Figure 4.4 and Figure 4.5 show that as in net zero 2050, the impact of chronic physical risks on Turkey's GDP will be -1% in 2030 and between

-1.5% and -2% in 2050. The negative impact of transition risks on Turkey's GDP will increase over time and will not be more than 1%. This is the lowest transition risk in all of the scenarios.

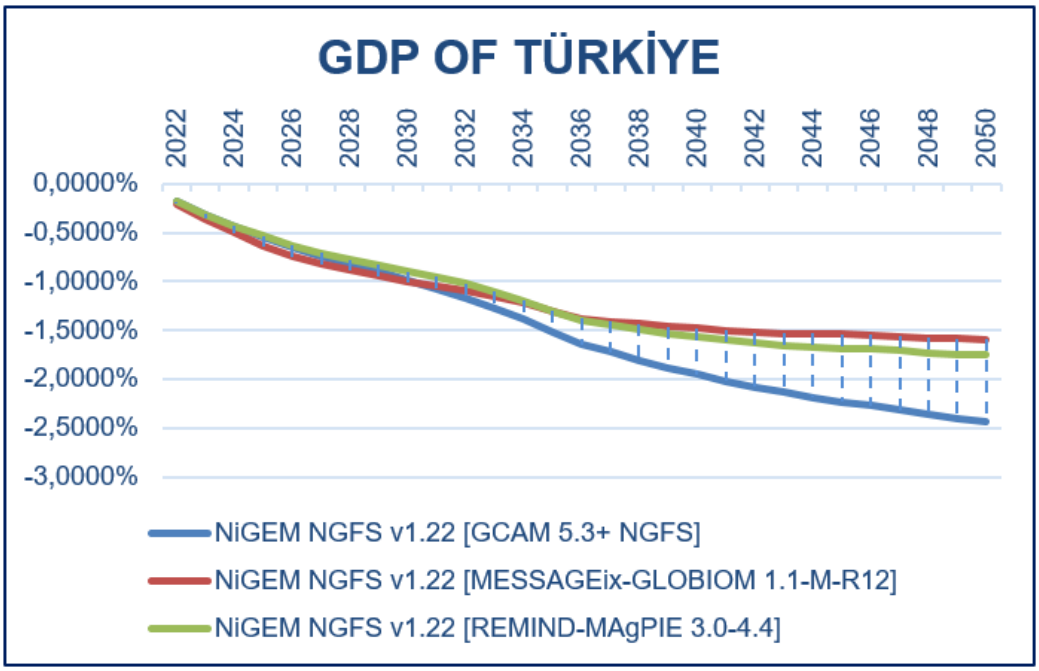

Figure 4.4. Chronic physical risk under below 2^{o}C.

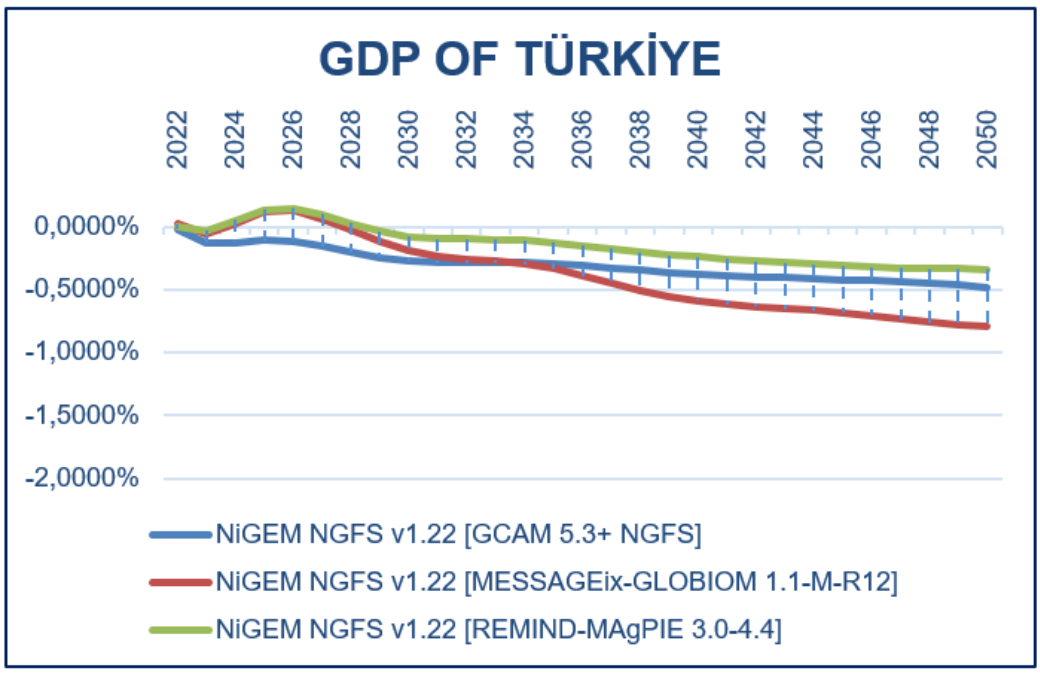

Figure 4.5. Transition risk under below 2^{o}C.

As seen in Figure 4.6 below, in this scenario it is seen that the consumption of the Transportation sector will increase by around 10% in the coming years comparing to Current Policies scenario. The consumptions of Individual Uses and the Construction and Food Industry in total energy supply will increase, and by 2050, these sectors will have increased their consumptions by nearly 50%. On the other hand, the consumption of Oil and Gas industry will decrease slightly. However, compared to a scenario where current policies continue and in this scenario where the global average temperature change is aimed to be kept below 2 degrees, the consumption of the Automotive sector in Turkey's energy consumption will decrease with each year. It is estimated that this value, which is around 50%, will decrease to 2% in the 2050s. Considering that the Automotive sector is dependent on the use of fossil resources, policies that will increase the use of renewable energy and limit the consumption of fossil fuels may have caused this situation.

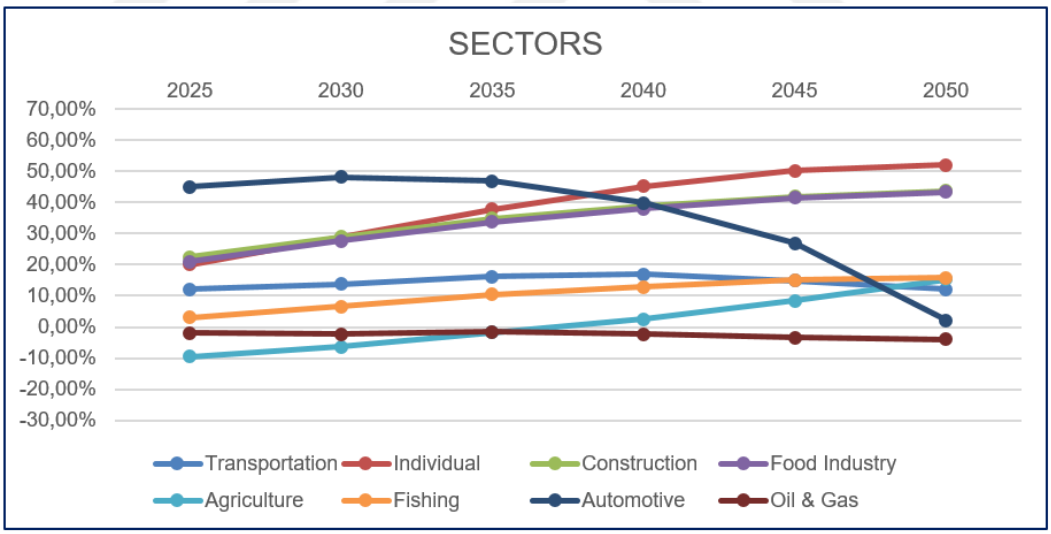

Figure 4.6. Energy consumption of sectors under below 2^{o}C.

4.3. Divergent Net Zero 2050

In this scenario, strict climate policies are implemented rapidly with the aim of achieving zero emissions by 2050. However, these policies will be implemented more costly due to the differentiation of climate policies between sectors and the rapid

abandonment of the use of fossil fuels (Monasterolo, 2023b). As it can be seen at Figure **??** and Figure 4.8, the impact of chronic physical risks on Turkish GDP will be like Net Zero 2050 and Below 2°C. It will be around -1% in 2030 and may not exceed -2% towards 2050. However, the effects of transition risks can be serious. The negative impact of these risks may be up to 10%.

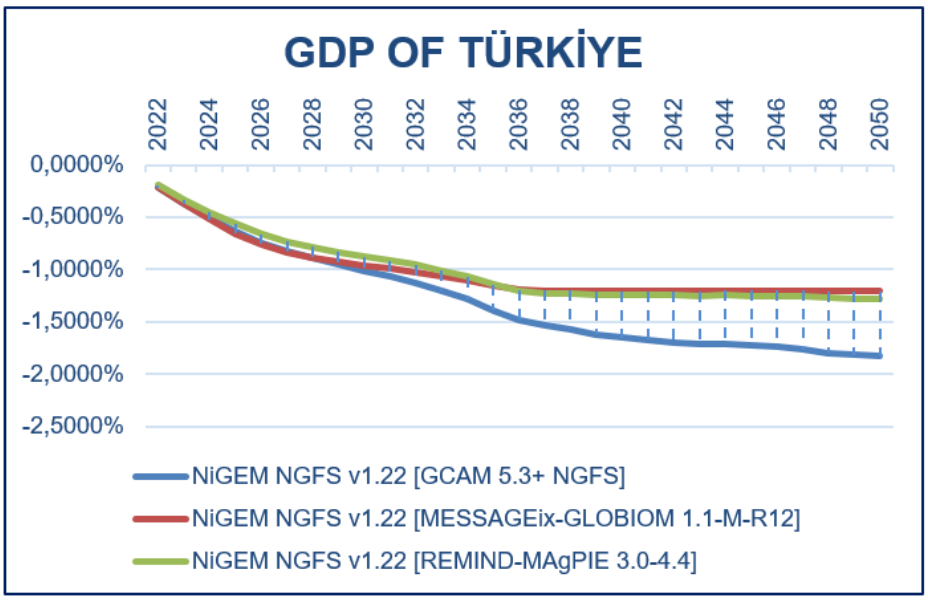

Figure 4.7. Chronic physical risk under divergent net zero 2050.

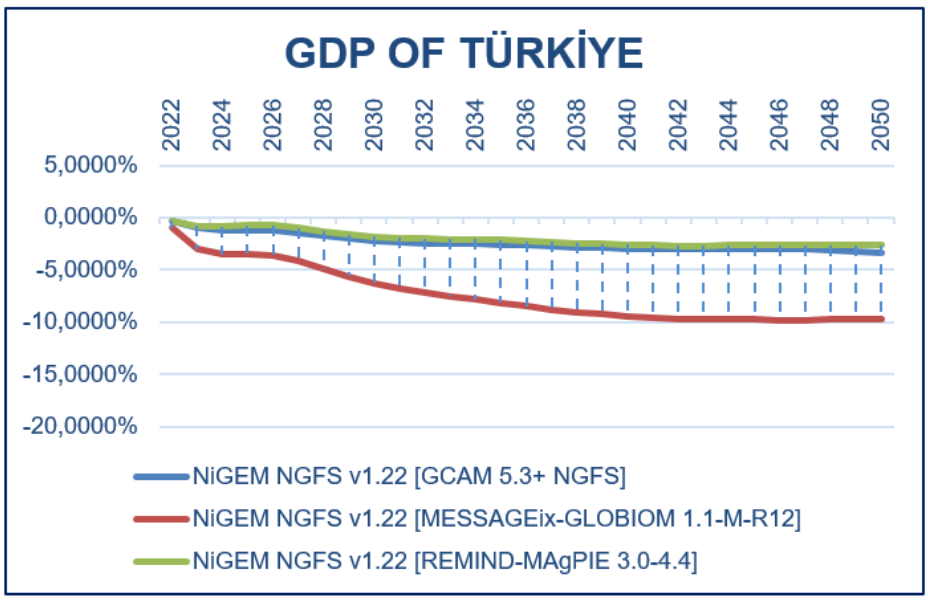

Figure 4.8. Transition risk under divergent net zero 2050.

As seen in Figure 4.9 in this scenario, where strict climate policies are implement rapidly, the costs of transition policies are higher due to the fact that climatic policies differ between sectors and the sudden abandonment of fossil resources. This situation affects the energy use of sectors differently. In this scenario, the consumptions of Individual uses, Construction and the Food Industry in total energy consumption shows a significant increase of approximately 50%. Similarly, Agriculture and Fishing sectors will slightly increase their consumptions. However, the Transportation, Automotive and Oil and Gas sectors will significantly reduce their energy consumption comparing to the base scenario. This decrease will be around 50% towards 2050. The fact that these sectors meet their energy needs from fossil resources has caused this situation.

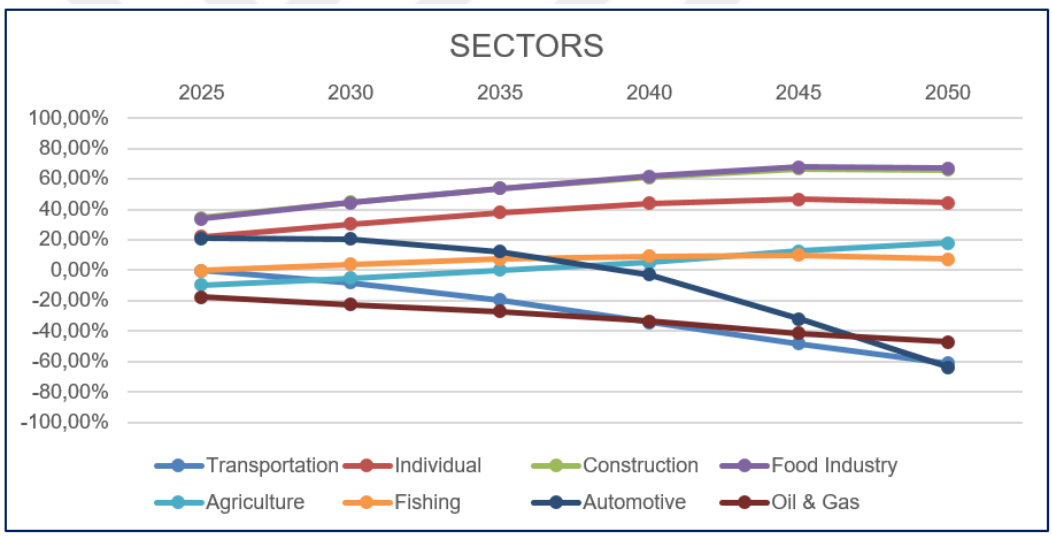

Figure 4.9. Energy consumption of sectors under divergent net zero 2050.

4.4. Delayed Transition

In this scenario, climate policies are not implemented until 2030. However, after that year, policies are being implemented quickly with the aim of keeping the global average temperatures below 2 degrees. In this scenario, where chronic physical risks increase their impact, transition risks are not observed until 2030 (Monasterolo, 2023b). However, after the rapid introduction of transition policies, transition risks starts to grow. Figure 4.10 and Figure 4.11 show that under this scenario, the impact of chronic

physical risks on Turkey's GDP will continue to increase in negative terms and will be around 2% by 2050. It is observed that the negative impact of transition risks is not observed until 2030, but will continue to increase after that year and will be around -3% and -8% in 2050.

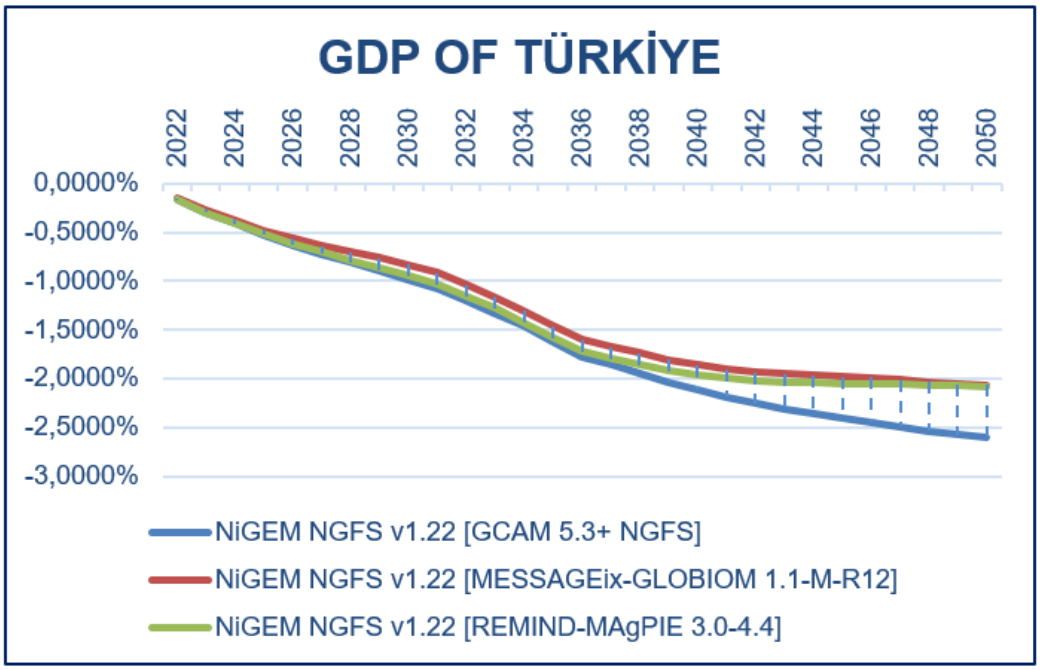

Figure 4.10. Chronic physical risk under delayed transition.

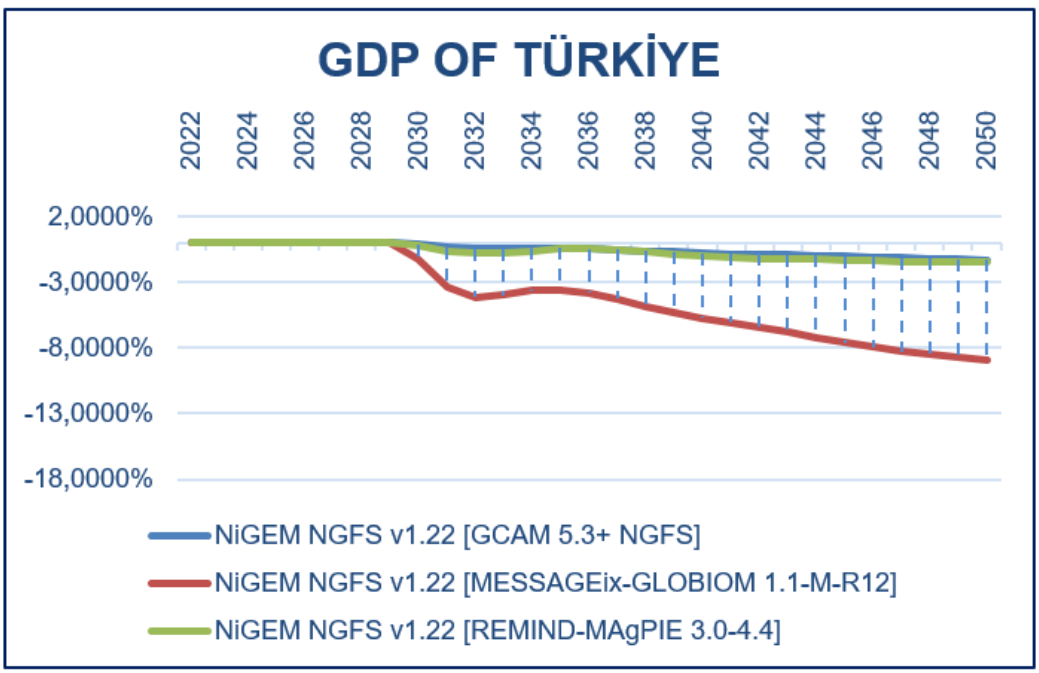

Figure 4.11. Transition risk under delayed transition.

As seen in Figure 4.12 below in this scenario, where transition policies are implemented with a delay, the consumptions of Fishing, Agriculture, Construction, Food Industry and Individual Uses in total supply will increase. This increase can reach up to 35% in Construction, Food Industry and Individual uses. However, the consumptions of the Transportation, Automotive and Oil and Gas sectors in energy consumption will decrease over the years. The biggest decrease will be seen in the Automotive sector and it will be from 50% to -35%. The energy consumption of these sectors, which depend on fossil fuel consumption, will need to be re-evaluated.

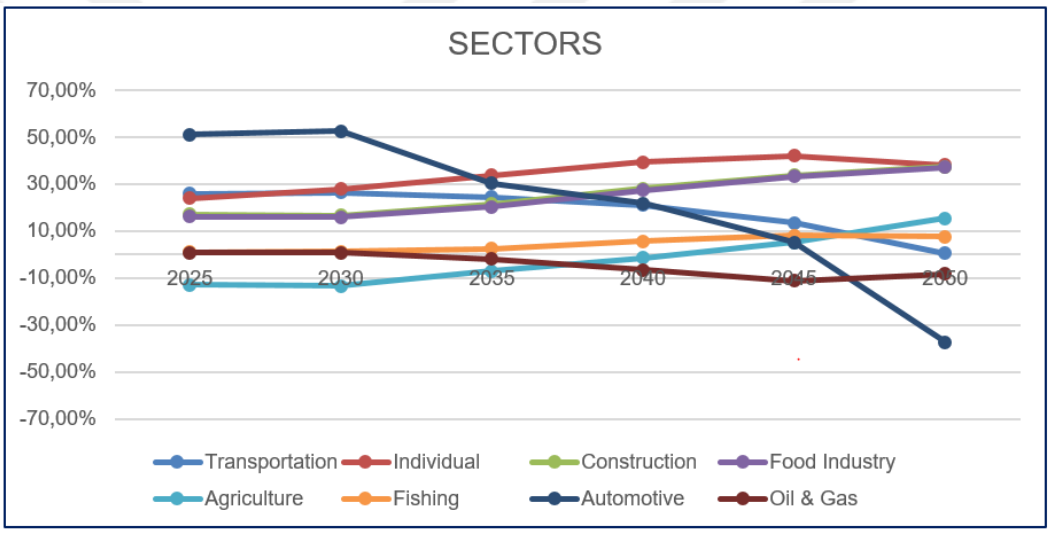

Figure 4.12. Energy consumption of sectors under delayed transition.

4.5. Natıonally Determıned Contrıbutıons (NDCs)

According to this scenario, countries will only fulfill the policies and targets they have already committed to the United Nations Framework Convention on Climate Change (UNFCCC). It is assumed that they will only fulfil the obligations they have already committed. According to this scenario, global average temperatures will rise by 2.5 degrees at the end of the century (Monasterolo *et al.*, 2023b). Therefore, this scenario has high chronic physical risks and low transition risks. As it can be seen at Figure 4.13 and Figure 4.14 Turkey's GDP would be significantly affected by chronic physical risks in such a scenario. These risks, which are increasing every year, will affect

Turkey's GDP by -4% by 2050. The absence of strict and strong transition policies indicates that the transition risks on the Turkey's economy will be low. The impact of transition risks on Turkey's GDP will be -1% by 2050.

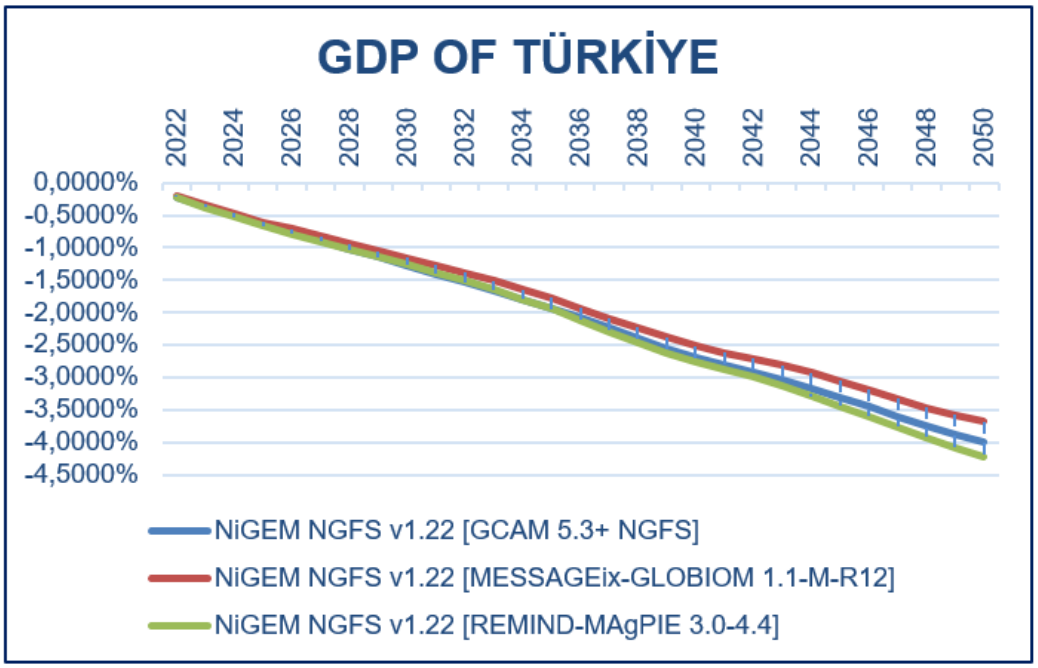

Figure 4.13. Chronic physical risk under nationally determined contributions.

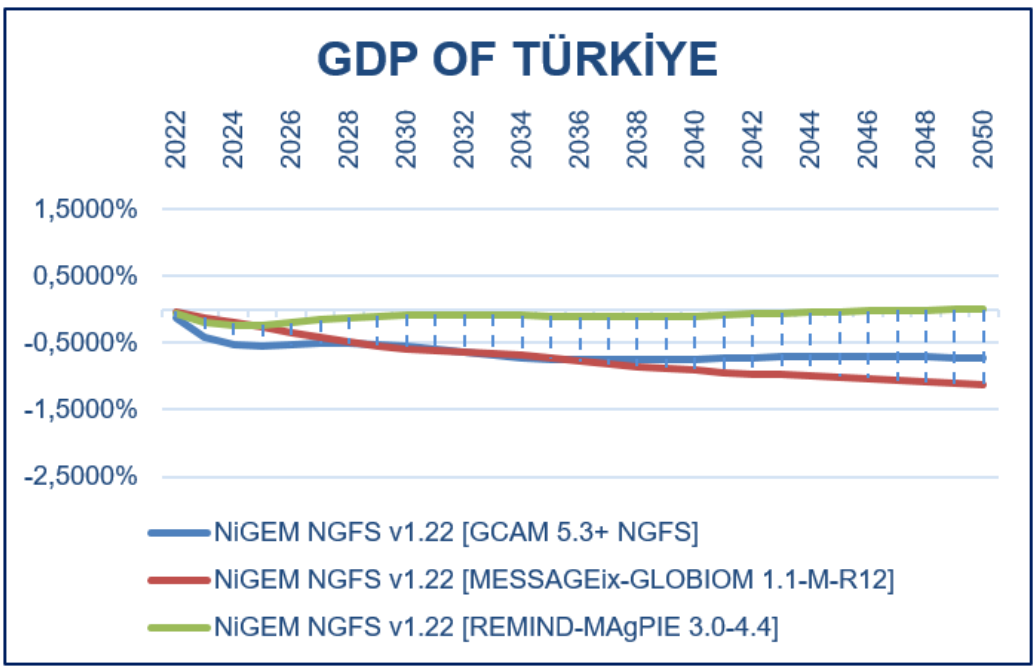

Figure 4.14. Transition risk under nationally determined contributions.

As seen in Figure 4.15 in this scenario, where countries will only implement the policies they are already committed to fulfill and new climate policies will not be implemented, weak transition policies take place. There will not be a serious differentiation in the energy consumption of the sectors due to the climatic policies and decisions. In such a scenario, it is seen that almost all of these sectors increase their energy consumption. It is seen that Automotive and Individual uses increase energy consumption by around 40% and the Transportation, Construction and Food Industry will increase it by 20%. Similarly, a slight increase is observed in the Fishing and Oil and Gas sectors, while a decrease in the energy consumption of the Agriculture may be observed.

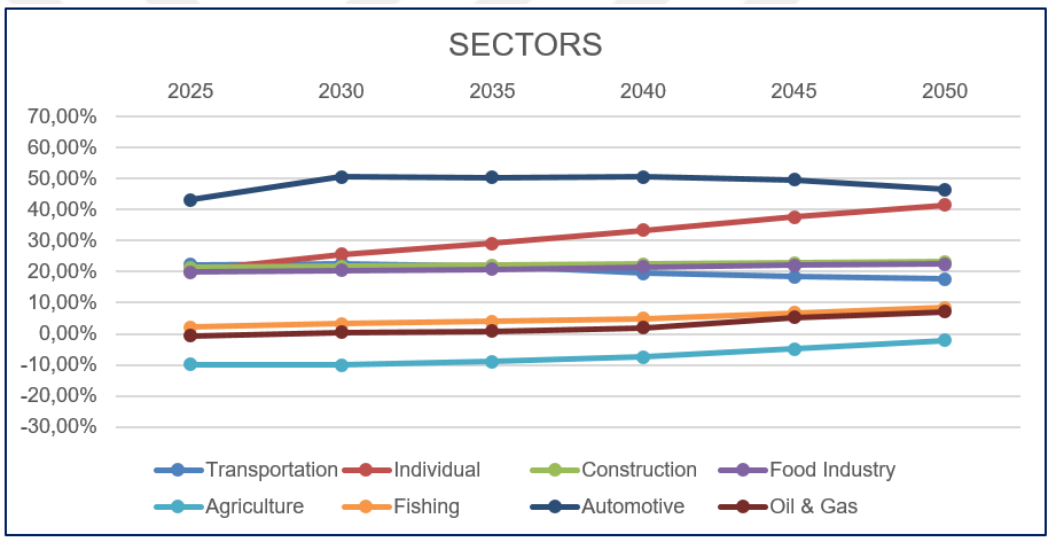

Figure 4.15. Energy consumption of sectors under nationally determined contributions.

4.6. Current Policies

This scenario assumes that no climate policy will be implemented after December 2020. Therefore, there is no fight against climate change and there is no transition risk for countries. But the physical risks are very high. Global average temperatures are assumed to rise by 3 degrees by the end of the century (Monasterolo *et al.*, 2023b). This situation increases the size of the negative consequences of climate change. The highest chronic physical risks are seen in this scenario. Figure 4.16 shows that the

impact of chronic physical risks, which increase its harshness every year, on Turkey's GDP by 2050 is around -4.5%. In addition, since there is no transition policy, no differentiation from the usual situation is expected in the energy consumption of the sectors.

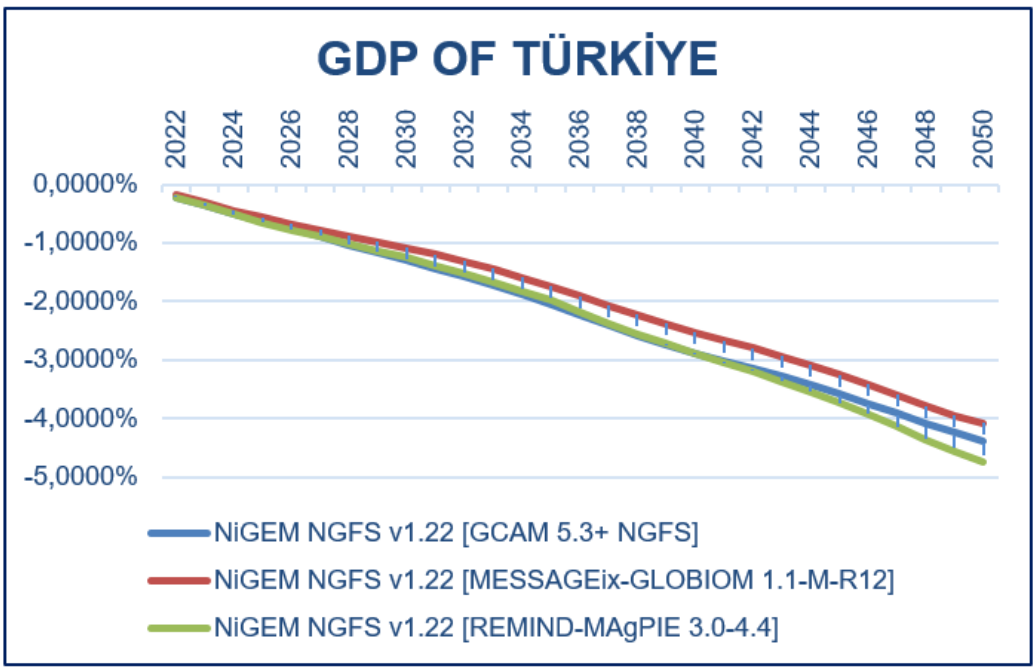

Figure 4.16. Chronic physical risk under current policies.

5. DISCUSSION AND CONCLUSION

Investing in renewable energy can have many benefits for Turkey. These benefits can be summarized as meeting energy needs in sustainable development, reducing air pollution caused by fossil fuel consumption, ensuring energy security, reducing foreign dependency by investing in renewable energy, and thus improving the current account balance (Bulut and Muratoglu, 2018). The amount of investment needed in the years 2022-2040, on the other hand, increases the investments in sectors such as electricity, housing and transportation by 34 percent and reaches 165 billion dollars (World Bank, 2022). These investments are estimated at around one percent of GDP by 2030 and could generate net gains in employment (World Bank, 2022). Increasing the share of renewable energy in Turkey can help meet the expectations regarding economic growth by alleviating environmental problems, positively affecting energy security, reducing foreign dependency on energy and contributing to the provision of the current account balance (Bulut and Muratoglu, 2018). Allocating more resources to the renewable energy sector with new technologies and capital investments in renewable energy may contribute to the establishment of the current account balance and the improvement of resource allocation in Turkey, and may have a positive effect on economic growth (Bulut and Muratoglu, 2018). Investing in renewable energies can reduce dependency on imported coal, natural gas and oil, help reduce greenhouse gas emissions, increase economic independence, and be a move that supports the country's growth targets (Bakirci and Kirtiloglu, 2021; World Bank, 2022). Focusing on renewable energies in electricity generation can reduce the consumption of lignite and hard coal in energy production and eliminate the negative environmental impacts they create (Atilgan and Azapagic, 2015). Low amount of carbon dioxide released in renewable energy shows how important it is to prioritize renewable energy sources (Akadiri *et al.*, 2020). In the process of decarbonizing the energy sector and transitioning to renewable energy sources, it may seem quite costly to install new wind turbines and solar panels at first. However, as dependency on fossil resources will decrease and a transition will be made to renewable energy resources, it may be possible to become profitable as a result

(Rosen and Guenther, 2015). Although renewable energy systems are initially costly, they have lower life cycle, maintenance and operating costs compared to traditional systems, and they can become more advantageous than fossil-based systems with some financial incentives applied today (Bakirci and Kirtiloglu, 2021). In this sense, Turkey is in a promising position in the use of renewable energy in the heating and electricity sector (Acaroğlu *et al.*, 2023, p). In the medium and long term, Turkey should benefit from the potential of wind and solar energy and make the necessary investments in renewable energy resources (Atilgan and Azapagic, 2015). Biomass can also be used to meet many energy needs such as electricity generation, heating of houses, refueling vehicles and meeting heat needs in industrial facilities (Toklu, 2017).

In order for Turkey to reach its net zero emission target by 2050, actions such as decarbonizing the energy sector, increasing energy efficiency in buildings, trying different modes of transportation, increasing carbon sequestration in forest areas and reducing emissions in areas such as agriculture, industry or waste management should be taken (World Bank, 2022). In cities vulnerable to climate change and weather events, there should be a planned and comprehensive shift towards low-carbon city structures; the growth rate of the urban population should be kept under control by considering the need for additional infrastructure (Batten, 2018). In order to have a low carbon energy system, Turkey needs comprehensive planning, financing and coordinated actions involving many stakeholders such as energy producers, distributors and consumers (Akadiri *et al.*, 2020). Delay in taking decisions, indecision in the steps taken and political conditions may cause Turkey to lag behind the current global policies in energy policies. (Turhan *et al.*, 2016). Risks arising from changes in fossil energy supply and fossil energy prices may cause problems in energy security in Turkey (Bulut and Muratoglu, 2018). Turning to renewable energy sources such as solar and wind in energy production, investing in battery and pumped storage facilities, focusing on gas-fired production with carbon capture and storage will help ensure energy security in Turkey (Climate Action Tracker, 2019; World Bank, 2022). Since wind energy provides energy security and is an important alternative in terms of carbon reduction measures, it can offer solutions against energy crisis, financial crisis and environmental

crises with its local, reliable, affordable and clean resource features (Kaplan, 20157). At the same time, building new coal-fired power plants may not be the least costly option to meet the growing electricity demand (World Bank, 2022). Steps that can be taken to reduce greenhouse gas emissions in the short term include improving energy efficiency in existing facilities and broader application of pollution control technologies (Atilgan and Azapagic, 2015). The Turkish government can impose taxes and subsidies on the relevant sectors of the economy within the framework of climate policies (Akadiri *et al.*, 2020). Long-term fixed price guarantees and local support such as tax exemptions should be on the government's agenda (Kaplan, 2015). Therefore, in order to achieve the climatic targets, countries will need to ensure their commitments to finance, technology transfer and capacity building (T.C. Dışişleri Bakanlığı, 2022).

Approaching the climatic targets in the electricity supply, road and rail transport and housing sectors, which are responsible for almost half of the greenhouse gas emissions in Turkey, can significantly reduce emissions throughout the economy (Climate Action Tracker, 2019). Steps that can be taken to decarbonize sectors in Turkey can significantly reduce greenhouse gas emissions, create job opportunities in the construction and manufacturing sector, create employment in the renewable energy sector, reduce pollution caused by traditional transportation and electricity generation methods, and support sustainable development goals (Climate Action Tracker, 2019). In terms of economic growth, development strategies can be built on the intensification of renewable energy industry, the transition to new technologies in energy and the widespread use of biochemical-based agricultural processes (Akadiri *et al.*, 2020). In order for Turkey to align its electricity sector with the Paris Agreement, it should lay a legal basis aiming to phase out coal use and move towards renewable energy sources by 2030 (Climate Action Tracker, 2019).

Combating climate change covers the steps that may affect the growth strategies, energy policies, health and agriculture programs, and use of water resources or food security studies of countries (T.C. Dışişleri Bakanlığı, 2022). For example, since the amount of water used for the agricultural sector corresponds to 70% of the country's

water consumption every year, it may be necessary to re-determine the water use areas within the country (Barak and Yanarocak, 2022; CMCC, 2023; Kurnaz, 2014). Extreme climatic events such as floods, storms, tornadoes and heat waves, the frequency and impact of which increase due to climate change, may cause losses in agriculture and livestock (Görmüş, 2021). It is estimated that by the middle of the century, in Turkey the average yield loss in agriculture is 8-9%, and that this effect in agriculture will also reflect on other areas of the economy (Karapınar *et al.*, 2020; Özlü *et al.*, 2020). For this reason, it may be necessary to take strict measures and make new regulations in the field of agriculture and animal husbandry (Barak and Yanarocak, 2022). In addition, since the greenhouse gas emissions that occur during agricultural activities may contribute to global warming, new applications can be made in the field of agriculture (Görmüş, 2021). Agricultural activities in Turkey need to be re-planned taking into account extreme climatic events and being prepared for adverse climatic conditions (Görmüş, 2021). Within the scope of RCP2.6, which can be described as an optimistic scenario involving all countries, the negative impact of climate change on the Turkish economy may be 0.07% (CMCC, 2023). Turkey can achieve net economic gains while fulfilling its climate commitments with manageable public and private sector investments (World Bank, 2022). In this context, compared to the baseline scenarios where there are no climatic targets, Turkey will need to make additional investments of 68 billion dollars between 2022 and 2030 in order to proceed on the path of durable and net zero emission development (World Bank, 2022). Moreover, in a pessimistic scenario involving all countries, the impact of climate change on the Turkish economy may result in a loss of 8 percent in GDP towards the end of the current century (CMCC, 2023).

The construction sector can be counted as one of the sectors that cause global climate change by emitting high levels of greenhouse gaseous (Hong *et al.*, 2015). The production of cement, which is an important part of concrete, is almost equivalent to 5-6% of anthropogenic carbon dioxide production (Rodrigues and Joekes, 2010). In developing countries, the construction sector is generally more active and most of the country's emissions come from this sector. However, social, governmental and economic

pressures await this sector to switch to low carbon operations in its processes (Akan *et al.*, 2017). In the construction sector, which has an important place in the Turkish economy and is a growing sector, the production of carbon dioxide originating in concrete production in Turkey is 45.31 million metric tons in 2011, and for that year, it was the fourth country in the world in this field (EMIS, 2014; Kajaste and Hurme, 2016). In order to adapt to sustainability and low carbon economy in the construction sector, targets such as limiting greenhouse gas emissions, making cement the main material in concrete production to reduce energy in material production, developing resource supply solutions such as fly ash, micro silica or steel slag, or recycling construction materials should be set (Akan *et al.*, 2017). Sustainable concrete plays an important role in the transition to a low carbon economy due to environmental reasons (Akan et al, 2017). For example Çimsa, an important cement producer in Turkey, produced 173,000 Gj of renewable energy and reduced its GHG emissions by 23,000 tons (ÇİMSA, 2016).

In addition, Turkey's automotive and transportation system is relatively more fragile than other countries due to climate change (World Bank, 2022). Thus, with the contribution of Turkey's investments in renewable energy in recent years, the carbon intensity of electricity, transportation and agriculture sectors is still below the EU average (World Bank, 2022). While decarbonization efforts in electricity generation are important, the transportation sector in Turkey also needs to go through a strong electrification process (Climate Action Tracker, 2019). The share of public transportation in the economy should be increased (Climate Action Tracker, 2019). However, due to climate change and global warming, the coastal structures of 27 provinces with a coastline and commercial activities such as fishing, maritime and tourism in these provinces may be damaged and there may be difficulties in the sustainability of the fisheries and aquaculture sectors (Çetin, 2023; World Bank, 2022). While the renewable energy sector will be positively affected by the transition to a low-carbon economy, sectors that have already faced the costs of such a transition and have begun to cover these costs may have less difficulty in the future (Debelle, 2019). Sectors or industries that carry out environmentally friendly processes and activities should be provided with credit opportunities with appropriate interest rates (Akadiri *et al.*, 2020). Sectors

that generate a certain level of pollution should be subject to environmental taxes, and subsidies should be given to sectors or industries that adopt clean and environmentally friendly technologies (Akadiri *et al.*, 2020).

As it can be seen, the Turkish economy will be affected in different aspects by physical risks and transition risks. Climate scenarios make it easier to carry out these analyzes in a more appropriate way and to deal with any situation that may arise from the differences in global trends. In these scenarios, it is seen that the energy consumption of the sectors will also change differently. While sectors such as the Food Industry, Construction, Agriculture and Fishing generally increase their share in energy consumption, in future it will be necessary to differentiate energy consumptions for sectors such as Automotive, Transportation and Oil and Gas.

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