SHURA Energy Transition Center

Socioeconomic impact of the power system transition in Turkey

About SHURA Energy Transition Center

SHURA Energy Transition Center, founded by the European Climate Foundation (ECF), Agora Energiewende and Istanbul Policy Center (IPC) at Sabancı University, contributes to decarbonisation of the energy sector via an innovative energy transition platform. It caters to the need for a sustainable and broadly recognized platform for discussions on technological, economic, and policy aspects of Turkey's energy sector. SHURA supports the debate on the transition to a low-carbon energy system through energy efficiency and renewable energy by using fact-based analysis and the best available data. Taking into account all relevant perspectives by a multitude of stakeholders, it contributes to an enhanced understanding of the economic potential, technical feasibility, and the relevant policy tools for this transition.

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This report is available for download from www.shura.org.tr. For further information or to provide feedback, please contact the SHURA team at info@shura.org.tr

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LIST OF ABBREVIATIONS

BAU	Business-as-usual
CBAM	Carbon border adjustment mechanism
CGE	Computable General Equilibrium
C&I	Construction and Installation
COP 21	The 21st Conference of the Parties
CO_2	Carbon Dioxide
CO_2e	CO_2 equivalent
ESCO	Energy Service Companies
EV	Electric Vehicle
EXIST	Energy Exchange Istanbul
FiT	Feed-in Tariff
GDP	Gross Domestic Product
GEP	Generation Expansion Planning
GHG	Greenhouse Gas
GTAP	Global Trade Analysis Project
GW	Gigawatts
GWh	Gigawatt-hour
DFI	Development Finance Institutions
IASS	Institute of Advance Sustainability Studies
ICT	Information and Communication Technologies

IEA	International Energy Agency
ILO	International Labour Organization
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contribution
IRENA	International Renewable Energy Agency
I/O	Input-output
IPC	International Petroleum Corporation
IPCC	Intergovernmental Panel on Climate Change
kWh	Kilowatt-hour
MENR	Ministry of Energy and Natural Resources of Turkey
MW	Megawatt
MWh	Megawatt-hour
NREL	National Renewable Energy Laboratory
O&M	Operational and Maintenance
OECD	Organisation for Economic Co-operation and Development
PV	Photovoltaic
PPP	Purchasing Power Parity
RE	Renewable Energy
RNE	Renewable and New Energy
SDG	Sustainable Development Goal
SDSN	Sustainable Development Solution Network
TEİAŞ	Turkish Electricity Transmission Corporation
TL	Turkish Lira
TURKSTAT	Turkish Statistical Institute
TWh	Terawatt-hour
UNFCCC	United Nations Framework Convention of Climate Change
US$	United States Dollar
YEKA	Renewable Energy Auctions
YEKDEM	Renewable Energy Sources Support Mechanism
YTBS	Load Dispatch Information System

Key messages

- Turkey continues to grow its economy while achieving power system transition goals and reducing greenhouse gas emissions along with an improved trade balance. The socioeconomic benefits of the transition exceed the financial costs by a factor of three to one.
- The transition creates significant improvement in social welfare with net socioeconomic benefit at 1.1% of GDP. Growth in wage income is the most pronounced welfare effect of the transition in addition to better health and environment. The transition creates potential for higher skilled and better paid employment opportunities.
- A long-term policy vision, including a climate action plan with goals for 2030 and 2050, will enable the transition and form the basis for achieving the benefits implied in the modelling study.
- The investments and enabling policy actions will provide the realization potential of income and productivity increases; however, production and employment in sectors directly related to power generation from fossil fuels and those that do not benefit from overall efficiency gains will be lower. Both national and local solutions will be required for ensuring maximised and equitably shared potential benefits.

Executive Summary

The Turkish energy system, particularly the power sector, has undergone a major transformation having transitioned from a mainly public supply-focused system to a market-dominated sector over the past two decades. During this time, the share of renewables in electricity generation grew from 25% to 42% in 2020, while power demand increased 2.5-fold. The growth of non-hydro renewables has been particularly successful, with installed capacities growing from a negligible amount to 20% in less than a decade. In addition, energy intensity has declined at an annual rate of more than 1%. However, energy end-use sectors have struggled to replicate the successes of the power sector, and the share of renewables in primary energy supply has remained at around 10%, warranting increased attention to the transformation potential of transport and heating. As policymakers and businesses begin to recognise the potential of Turkey's vast local energy efficiency resources, the rate of efficiency improvements is expected to accelerate.

The transition thus far has been rooted in dedicated policy frameworks regarding renewable energy, energy efficiency and climate change. Although Turkey signed the Paris Agreement, it has yet to ratify the agreement, and its Intended Nationally Determined Contribution (INDC), submitted in 2015, remains the main climate plan by 2030. The country remains committed to the transition, however, with commitment of President Erdogan in April 2021 to update Turkey's climate change strategy and adaptation plan by 2030 and 2050. Recent policy developments have also seen new legislation targeting energy efficiency improvements. At the start of 2020, the government issued a vision for the transport sector, aiming for at least 1 million electric vehicles on the road and 1 million charging points by 2030. Additional government-enabled efforts are ongoing to blend in 5% clean hydrogen to the gas grid.

This study, the first of its kind in Turkey, aims to deepen the understanding of the impacts of a low-carbon energy transition, consistent with SHURA's vision for 2030, to contribute to an enhanced policy dialogue associating the benefits of better human health and environment quality and a more secure energy system with the broader socio-economic aspects of this transition. From an energy sector perspective, the study answers major questions confronting Turkey's economy, such as how value-added is impacted if renewable energies substitute fossil fuels. How would the transition impact manufacturing industries or wage and income distribution? Where will new jobs be created, and will there be losses? How will wage and income distribution be impacted? And what is the economic benefit of better human health and environmental quality?

Policy recommendations focus on how Turkey can reap these benefits and propose pathways to unlocking the significant opportunities for energy system transformation. Long-term, system-oriented planning looking to 2050 will be needed to realise a full transformation that is consistent with global climate goals. At the same time, establishing this long-term perspective can help shaping the immediate green recovery strategy that can stimulate the economy recovery from the CoVid pandemic.

SHURA's vision for energy transition

SHURA supports the transition of Turkey's energy system from a traditional import-dependent and carbon-intensive structure to an innovative low-carbon system that is more affordable, cleaner, and more secure. Similar to the energy transition paradigm shift that is happening in many other world regions, Turkey's transition comprises energy efficiency, local use of renewable energy resources, and the development of sustainable alternatives for heating and transport, including the use electrification boosted with renewable power.

Since 2017, SHURA's various scenario analyses have provided an evidence base for a new pathway to accelerate this transition to 2030. The power system transition envisaged by SHURA for 2030 shows that at least 50% share of renewables in total generation is technically and economically viable, where wind and solar energy comprising about 30%. In conjunction with electrification, a 10% reduction in total power demand by 2030 compared to current government plans is possible through savings in industry, buildings and the rest of the electricity supply chain creating potential net-benefits for the economy. The main components of this vision are summarised in Figure ES1.

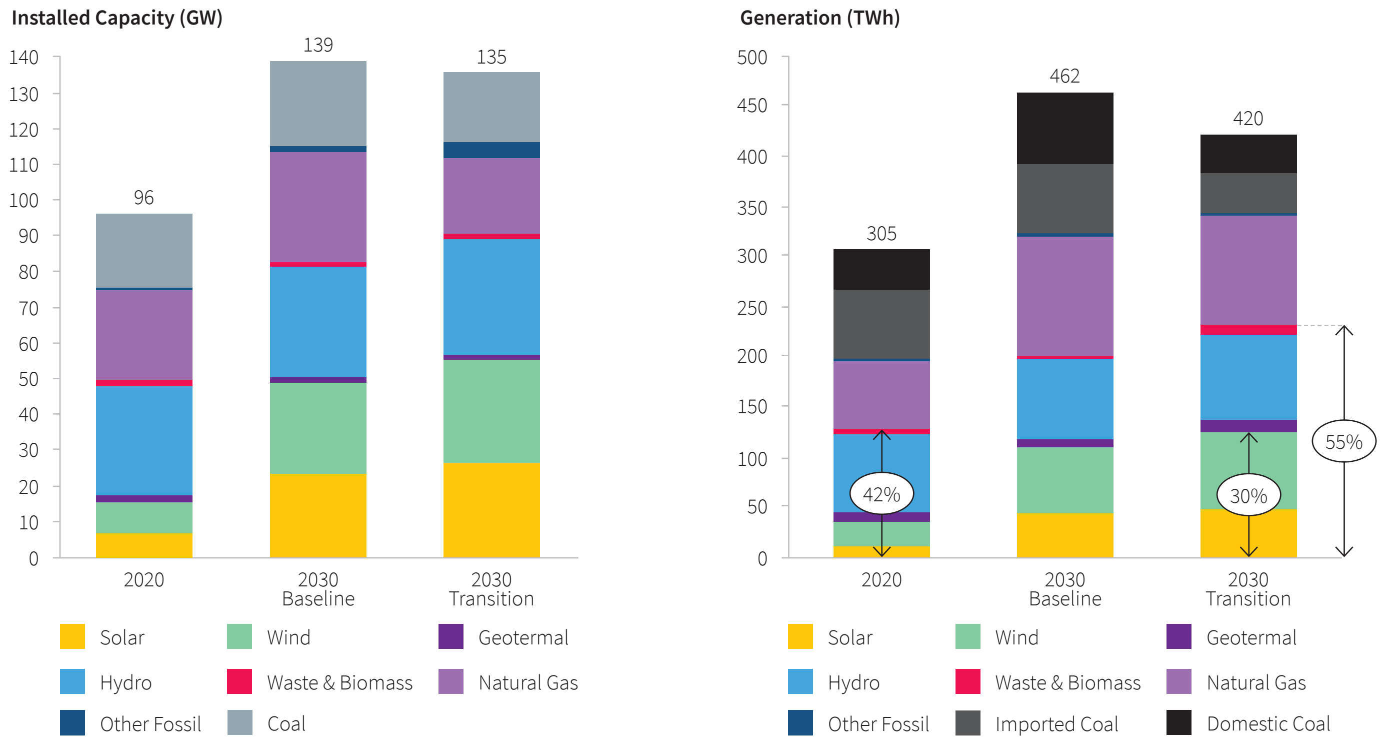
Figure ES 1: *SHURA's 2030 Vision for Power System Transition*

Electrification of end-use	Efficiency gains of 10% compared to the baseline	50% renewable energy share in total output
2.5 million EVs & 1 million charging points + 2 million heat pumps & smart homes = **7-9 TWh of additional electricity demand**	17.3 TWh savings in industry + 19.3 TWh savings in buildings + 6.0 TWh savings in the distribution system = **42 TWh of net demand reduction**	Improved market design + 2000 MW energy storage + Demand-side response reduction of peak demand by up to 10 GW + System-friendly wind & solar location + Flexible power plant fleet = Flexible grid for integration of 30% share in wind & solar

To investigate the socioeconomic impacts of this transition pathway, this study uses an electricity system and a macroeconomic model that are soft-linked to investigation of comparative impacts of this Transition scenario with a Baseline scenario. The Baseline scenario reflects current government plans for renewable energy, energy efficiency and electrification in end use sectors and brings considerable benefits on its own and are expected to provide a 15% reduction in the carbon intensity of power generation by 2030, compared to today. Focusing predominately on the power sector, the Transition scenario seeks to accelerate the Baseline trends through the implementation of a carbon price, continued policy support for renewable deployment, accelerated energy efficiency improvements, and the deployment of energy storage technologies along with improved market designs.

The policies enacted in the Transition scenario result in the replacement of fossil-fuel capacity by a suite of renewable energy technologies, led by new wind and solar installations. Small increases in bioenergy, geothermal and some planned run-of-river hydropower also occur (See Figure ES2). By 2030 wind and solar account alone will account for 30% of total power generation, with all renewables accounting for 55%.

Figure ES 2: *Installed capacities (left) and generation (right) by technology in 2020 and in 2030 for the Baseline and Transition scenarios.*



Source: TEIAS, 2020 and EMRA, 2020

Macroeconomic Impacts of Energy Transition

Overall, the accelerated transition embodied by the Transition scenario results in net gains compared to the government Baseline, both in terms of Gross Domestic Product (GDP) and net employment. Total growth in employment between 2018 and 2030 is about half the growth of GDP. The slower growth rate in employment compared to value added is a result of the capital-intensive nature of the power system transition, but also of efficiency gains. The transition drives capital investment into increasingly automated technologies, and as the transition progresses, the greatest impacts occur in other industries and eventually in service sectors.

A summary of the overall net impacts measured in real 2018 values is shown in Table ES1. The impacts of the Transition are defined in relative terms to the government Baseline. The socioeconomic benefits of the transition is about 10% larger than its overall impact on GDP. By comparison, the benefit on Turkey's overall trade balance is nearly as large as the impact on GDP. The impacts of the power system transition are also seen in the transformation of industry; industrial value added grows by 41 billion US$ in the Transition compared to the Baseline. The benefits summarised in Table ES1 exclude the potential gains from the phase-out of fossil fuel subsidies that currently account for about 1% of the total GDP and those benefits from non-power sectors that represent 80% of Turkey's total final energy consumption.

Table ES 1: *Target Year Annual Transition Impact Summary (billion US$)*

	Baseline (2030)	Transition (2030)	Transition Impact (Transition-Baseline)
National Income Impact			
Real GDP	1131.6	1142.6	11.0
As percentage of Baseline GDP			***1.0%***
Overall Trade Balance Impact			
*Trade Balance**	-7.8	2.4	10.2
As percentage of Baseline GDP			***0.9%***
*Net Energy Trade Balance for Power Generation**	-6.2	-5.2	1.0
As percentage of Baseline GDP			***0.1%***
Industrial Transformation			
Industrial Value Added	730.1	770.8	40.7
As percentage of Baseline GDP			***3.6%***
Socioeconomic Welfare Impact			
Wage Income	332.8	341.5	8.7
*Net Energy External Trade Balance for Power Generation**	-6.2	-5.2	1.0
*Net Investment Goods External Trade Balance for Power Generation**	-2.9	-2.5	0.4
*Health Impact (Air Pollution)***	-2.5	-1.1	1.4
*Climate Change Impact (CO_2 Emissions)***	-5.1	-3.8	1.3
TOTAL Socioeconomic Welfare Impact			12.8
As percentage of Baseline GDP			***1.1%***

**Negative sign indicates that the trade balance is negative, meaning that imports exceed exports.*
***Negative sign indicates that the value is a cost.*

Impact on National Income

The Transition has a net positive impact on GDP by 2030. GDP grows by a total of 12.8% (real, in fixed 2018 prices) and reaches to 1,143 billion US$ dollars, representing a 1% increase over the government baseline. This growth is mainly due to efficiency gains and increased real wage incomes, both of which drive higher disposable income.

Impact on External Trade Balance

The Transition has a significant impact on Turkey's trade balance and goes beyond simply reducing net-energy imports and extends to increasing the competitiveness of export-oriented sectors due to efficiency gains. While the trade deficit also improves along the government Baseline, the Transition has a four times larger impact. The combination of energy efficiency improvements and greater use of renewable energy leads to reduced energy import costs allowing Turkish industries greater access to foreign currency savings for expanded investments and capital accumulation. As a result, the Transition exhibits a 9% increase in industrial exports over the Baseline, while increased renewables usage and energy efficiency lead to cumulative avoided imported fuel costs of around 1 billion US$ annually in 2030.

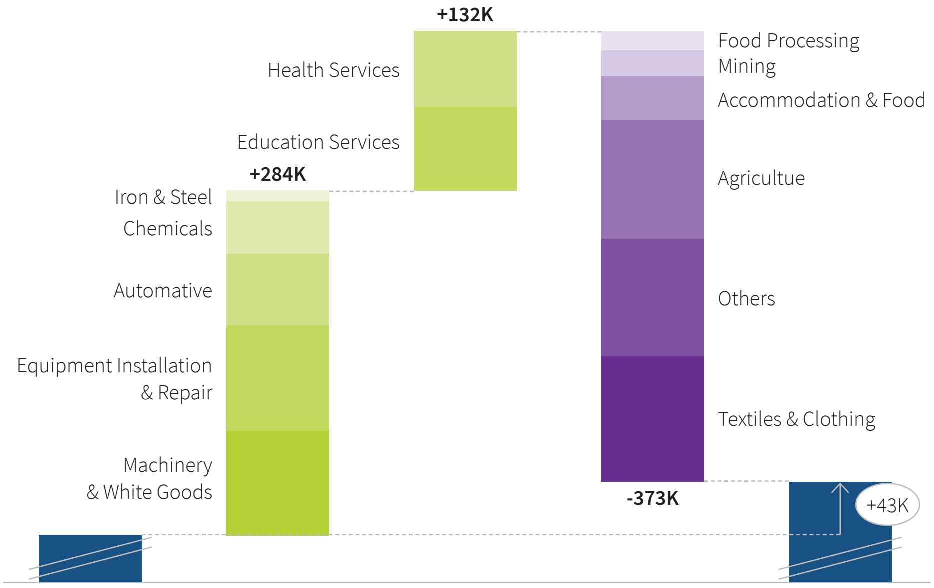
Impact on Manufacturing and Services Sectors

While the Transition will create winners and losers among industrial sectors, the overall impact on industry is large and positive; industrial value added in 2030 in the Transition Scenario is 5.6% higher than the Baseline and reaches 3.6% of GDP. At sectoral level, Transition stimulates the largest growth on sectors that are classified as high-medium technology, especially in the internationally competitive and export oriented automotive and machinery sectors. As such, the energy transition is expected to raise the technology level of production and Turkish exports significantly. Conversely, more traditional, labour-intensive sectors such as agriculture, food processing and textiles do not experience such growth. Education and professional service sectors also benefit from the Transition, as these sectors are associated with skills development driven by innovations enabling the transition, as well as upgrades in social services due to the improved wages and quality of life. By 2030, total real growth in professional services is expected to be 2.5 percentage points higher than the Baseline, and 5.4 percentage points higher in education, health, and social services. Negative impacts of the Transition occur predominately in mining and electricity production from fossil fuels. In the Transition scenario, real growth of the mining sector is limited to 30% by 2030, compared to 45% in the Baseline. As efficiency gains reduce total power demand, the real growth in the electricity sector is reduced to 35% compared to the Baseline's 48%.

Impact on Employment

Overall, Transition has a net-positive impact on employment, creating an additional net 43 thousand cumulative jobs compared to the Baseline in 2030 (see Figure ES3), equivalent to a net increase of 0.1% and significantly lower than GDP growth. As the increase in the ratio of value-added to the level of growth in employment is an indication of significant productivity growth over time, the effect on social welfare needs to be considered. Nevertheless, from the point of view of energy transition, the overall employment impact is deemed neutral while there is considerable variation in individual sectors.

Figure ES 3: *Cumulative change in jobs by economic sector in 2030, Transition scenario*



With energy transition, the largest employment gains occur in high growth and technology sectors where energy efficiency gains are best realised, including machinery and white goods, installation & repair, automotive and chemicals, where some of these sectors, including iron & steel, provide intermediate goods for energy transition. Employment gains in the service sectors are associated with skills development required by the transition as well as upgrading in social services with improved quality of life afforded by health and environment benefits. Reduced electricity demand and fossil-fuel use in the Transition scenario means that employment in the mining sector is reduced by 20.5 thousand with respect to the Baseline, but still 2-3 thousand higher than today. This trend also observed in the electricity sector which grows by 38 thousand compared to today but employs 2 thousand less in the Transition scenario in 2030. It is important to note that this analysis struggles to fully take into account additional jobs which may be created due to digitalisation and energy management, distributed generation or energy efficiency improvements.

New investments in renewable energy can generate 590 thousand renewable energy jobs between 2018 and 2030, corresponding to 68 thousand more jobs over the Baseline. The majority of jobs created by renewable energy occur at the investment stage, e.g., in equipment manufacturing. Distributed energy, especially rooftop solar, is expected to create jobs initially in construction & installation, and later in operation and maintenance. Energy efficiency, while reducing employment in power generation due to less overall demand, is still expected to create 36 thousand additional jobs across different sectors compared to the Baseline scenario.

Impact on Health, Social Welfare, and Climate Change

A Transition that combines an ambitious long-term policy vision with economic development can maximise benefits and ensure that these are shared equitably across Turkish society. By 2030, annual real wage income is estimated to be 8.7 billon US$ greater than the Baseline (see Table ES1). Functional income distribution also improves with the Transition as the share of urban labour income increases in comparison to urban capital. Social welfare also grows thanks to avoided health and environmental impacts due to reduced air pollution. Total avoided externalities due to the Transition are equivalent to 0.2% of GDP in 2030, or around 2.7 billion US$, mostly through reduced coal use in power generation. The avoided health and environmental costs due to air pollutants is estimated at 1.4 billion US$ compared to the Baseline, which is equivalent to 4.6% of the annual health expenditure of Turkey in 2018. The value of avoided carbon dioxide (CO_2) emissions, on the other hand, is estimated at 1.3 billion US$ per year, comprising 0.1% of GDP.

The SHURA Transition focuses on a structural transformation of the power sector. As a result, power sector emissions stabilise and remain constant between 2018 and 2030, while growing 30% in the Baseline. This translates to a 22% reduction in carbon intensity of power generation.

Conclusions and Policy Implications

The SHURA scenario, effects of which are explored in this study, would result in significant reduction in greenhouse gas emissions; however, a zero-carbon pathway would require further effort. Comparison with international studies on the targets required for a zero-carbon pathway indicate that while share of renewable energy targets for 2030 in the SHURA scenario are in line with the global median of relevant Paris-consistent scenarios, energy intensity and reliance on fossil fuels need to be reduced further in order to approach international zero-carbon benchmarks.

While transition brings environmental and economic benefits, there will also be additional costs which have to be weighed against the benefits. This study has concentrated mainly on the socioeconomic costs and benefits of the transition and found that the net effect will be small and positive. These benefits have to be weighed against the financial costs to be incurred by the Transition scenario. Based on previous work by SHURA, the study reveals that the socioeconomic benefits of the Transition will exceed the financial costs by a factor of three to one.

The total average annual investment level required to achieve the SHURA transition vision for 2030 has been calculated to be 12.3 billion US$, which is double the current and baseline level of investment. In addition to the challenges brought by the partial shift from fossil fuels to renewables, the main challenge for realizing scenario targets will be securing financing for the necessary investments. Apart from the amount of additional financial resources required for the transition, the general economic and financial climate in Turkey presents challenges. Turkey has been facing a series of financial difficulties since 2018 with currency depreciation and economic slowdown, further exacerbated by the Covid crisis.

Globally, the health impacts of the pandemic and the economic slowdown due to lockdown measures have resulted in heightened awareness of climate change issues. Green recovery, encompassing investments in renewable energy, efficiency and decarbonisation with particular emphasis on green employment, has become the leading concept for post-pandemic economic revival around the world. Over the long-term, the financing climate in Turkey will be particularly influenced by the challenges and opportunities presented by the European Green Deal. The global context discussed, and the benefits of the low carbon transition implied by the results of this study show that a green recovery needs also be a core element in Turkey's immediate economic planning agenda.

It is important for Turkey to continue in the energy transition path charted by national policy documents in order to reap the benefits afforded by the transition and make use of international financing opportunities. To enable this, a long-term plan taking 2030 as the earliest target year to 2050 is needed, as a full transformation requires planning for the long-term in line with the climate objectives. Such a plan, providing visibility for all the actors involved, will serve the dual objective of climate change mitigation and economic development.

As the power system transition will need a doubling of the level of investment, how to secure financing is an impending question. Building upon the recommendations in SHURA's 2019 energy transition financing study and the developments over the past two years confirming the proposed direction, it will be important to mobilise climate finance and increase access to financing from development finance institutions (DFIs) and institutional investors. Coordination and cooperation between major stakeholders, namely the public sector (government), international financial institutions, local financial institutions, energy companies and technology providers is a critical component of sustained and sustainable financing. An integrated approach with long-term planning that links financing mechanisms with climate action, together with the new renewable energy sources support mechanism (YEKDEM) and renewable energy auctions schemes can provide a sustainable pathway to financing renewable energy. Nevertheless, development of additional tools and approaches will be needed for financing the additional investments in energy efficiency and electrification.

Active policies will be needed to realize the potential benefits implied by the modelling study. To be effective and predictable, the policies and actions will function best as part of a long-term Climate Action vision to 2030 and 2050. Predictability is particularly important from the perspective of both investors and financers at national and international level. The policy actions listed below are the main components of an enabling framework for achieving the 2030 vision for shifting from fossil fuels to renewables in power generation:

- Implementing carbon pricing
- Together with market-based mechanisms, applying renewable energy subsidies as needed
- Eliminating ineffective support and subsidies for fossil fuels
- Long-term planning and market-based policies for energy efficiency

The results of the study show that the overall socioeconomic impact of Transition will be positive with significant benefits for health, environment, and wage income. The investments and enabling policy actions will provide the potential for income and productivity increases to take place. Nevertheless, production and employment in sectors directly related to power generation from fossil fuels and those that do not benefit from overall efficiency gains will be lower in comparison to the baseline scenario. Policies such as work force retraining and compensation programs for reorienting production and employment toward sectors that would benefit from the transition will be necessary to alleviate losses.

Enabling policies and related actions as well as appropriate education and training will be needed for transition from an economic growth model based on cost minimization, wage suppression and capital injections dependent on imports to one based on increasing total factor productivity with higher value-added domestic production and resources. The Transition scenario coupled with economic policies supporting domestic production of renewable energy and energy efficiency equipment and social policies supporting a just transition will be the main pillars of policy action in the period to 2030.

1. Introduction

In order to manage the transition in the best possible manner, the economic and social impacts to which countries and sectors will be exposed should be evaluated.

1.1 A Global Perspective

The global energy system is going through a very dynamic period of change. The transition entails a rapid rise of renewable energy and a corresponding fall in fossil fuel use. An energy system dominated by renewables could engender a new industrial revolution with significant potential for improved energy access, health, safety, environmental quality, and employment growth for all (IRENA, 2014). The speed and success of this transition will ultimately rely on the policies that will be pursued over the long run. In order to manage the transition in the best possible manner, the economic and social impacts to which countries and sectors will be exposed should be evaluated while considering renewable energy initiatives. Problems such as unemployment and income inequality may add to the costs of adjustment in response to energy transition if relevant policy measures are not adopted. Dynamic and flexible policies are needed for the transition to a renewable energy-oriented portfolio and higher energy efficiency. These policies should take into account social effects, as well as economic and environmental impacts. Intergovernmental Panel of Climate Change (IPCC) Special Report “Global Warming of 1.5°C” demonstrate robust evidence that, in order to mitigate the possible social and economic costs of transition, transfers compensating the unintended distributional effects at cross-sectoral and cross-national level along with consistent policy packages are necessary.

Several general trends are observable in the energy sector. The first is the regular increase in renewable energy investments and the rapid cost reductions of wind and solar photovoltaic (PV) technologies. Another trend is that global energy consumption increases continuously with population growth, despite efforts to limit this growth with increased energy efficiency. Thus, the share of renewables in the total global energy mix remains at around 18% since more than two decades with the rest being supplied largely from fossil fuels. This ongoing dependency on fossil fuels brings environmental burdens, including biodiversity losses and global warming.

According to REN21 (2020), while modern renewable energy sources (excluding the traditional use of biomass) met 11% of the total final energy consumption in 2018, the installed capacity in renewables increased by more than 200 gigawatts (GW). Besides, global energy intensity has continued to decline in recent years, which is an indication of improved energy efficiency. Final energy intensity improved by 14% between 2007 and 2017 in the Organisation for Economic Co-operation and Development (OECD), whereas this improvement corresponds to a rate of 25% in the non-OECD countries (REN21, 2020: 24).

On the other hand, the energy transition creates many risks in the fossil fuel sector. Companies engaged in fossil fuel-related activities will have to abandon some of their investments leading to the so-called problems of stranded assets (Saygin et al., 2019). Petroleum companies may have to leave some oil in ground and thermal power plants may remain idle. Since investment costs in these fields are very high and assets have a long lifetime, the risk of loss is expected to be high.

While incentives, subsidies, and government support played an important part in the increase in renewable energy investments during the first decade of the 21st century, with rapid cost declines over the past ten years, power generation from renewable resources can now compete with fossil fuel plants at the utility scale. IRENA estimates that renewable energy accounted for 80% of total power capacity additions in 2020 (IRENA, 2021). The penetration of renewable energy in developed countries is expected to further accelerate with the investments that homeowners and companies will make for their own use. Developing countries, especially Brazil, China, India, and South Africa, have also become important markets in renewable energy production and capacity increases.

Digitalization and decentralization are driving a new industrial paradigm in the energy sector. Increased decentralization in the power sector (e.g., increased deployment of power generators at the distribution level) as well as electrification (e.g., the emergence of electric vehicles (EVs), heat pumps and electric boilers) has added to the mounting importance of digitalization, forming the new facets of energy transition as an enabler. With the increase in individual- and corporate-level electricity generation and production that is connected or not connected to the electricity network, the energy sector is eventually reshaped towards having a more local structure.

Yet, there are various implications of transforming the global energy system. These implications come into prominence at economic, social and environmental spheres. This report at hand deals with the socio-economic and environmental impacts of the energy transition in Turkey over the coming two decades. Impacts have been quantified in economic terms in real 2018 US dollars.

While several previous studies have shown that new jobs and net-positive employment can be created by renewable energy, fewer studies have examined in depth the structural employment impact caused by the transition from fossil-fuels to renewables.

The evaluation and measurement of the impacts of the energy transition can be carried out based on a selection of socio-economic and environmental indicators. Economic indicators to trace are, in fact, quite straightforward. GDP, GDP per capita, exports, imports, current account balance, employment, private consumption, public deficit, etc. are among the usual indicators which are potentially influenced by the transformation of the energy sector. In what follows, the report mainly concentrates on the average wage levels, functional income distribution, regional income distribution, health, access to energy, etc. as the technical indicators of social impacts. For instance, externalities on human health from the use of fossil fuels for electricity generation can be mitigated by their substitution with renewables. The energy transition can also help enhance the development of communities in rural areas and make them more resilient.

Employment is widely considered as one of the critical social impacts of energy transition and receives particular focus in this study. Globally in the energy sector, directly and indirectly 58 million people are employed (IRENA, 2020). Nearly one fifth of this total is represented by the renewable energy industry, a sector that is growing in total employment by about half a million each year (IRENA, 2020). In Turkey, of the 117 thousand people employed in the electricity, gas, steam, and air conditioning supply sectors, about 38 thousand are employed in the renewable energy sector. The success of Turkey's renewable energy deployment implies this share could grow in the future. While several previous studies have shown that new jobs and net-positive employment can be created by renewable energy (REN21, 2015; 2020; Borbonus, 2017), fewer studies have examined in depth the structural employment impact caused by the transition from fossil-fuels to renewables. Implementing policies such as early retirement or retraining in sectors that either produce fossil fuels or use them as inputs, can mitigate some of the negative employment impacts of the transition. The real wage gap across jobs lost and potential new jobs to be created by transition will determine the rate at which an employment shift will be realized towards renewable energy sectors.

Finally, environmental implications of energy transition can be addressed via indicators such as per capita or total greenhouse gas (GHG) emissions; air, water, and soil pollution; natural resource use, waste, and so on. In the current study analysing the socio-economic impacts of energy transition in Turkey, we employ an assessment of most of these indicators to the extent that existing and available data allows for. According to a recent report, externalities associated with the use of fossil fuels for electricity generation, heating and transport reached about US$ 10 billion per year in 2018, the value representing a low end of a wide range. This is equivalent to about 1.4% of Turkey's GDP and covers around 32% of the pre-CoVid period health sector expenditures in the same year. Thus, health and climate change impacts, known as external costs, are quantified and incorporated into the study.

Nevertheless, welfare implications of energy transition are multi-layered and can go far beyond the selected indicators in this study. To begin with, the economic indicators mentioned above may fail to capture various aspects of economic well-being. Alternative welfare indicators such as green gross national product, energy intensity of well-being, and environmentally adjusted human development index[1] could bring the economic, social and environmental dimensions together in a more holistic and comprehensive manner. Besides, an ongoing energy transition may not lead to continuous welfare gains as the transition will also require vast amounts of material use (considering the build-up and installation of power plants, production of energy equipment, etc.). Hence, the pressure on nature and the environment might take on different faces and rebound effects could be significant.

1.2 Energy transition in a post-COVID-19 world

Calls for low-carbon transitions based on the SDGs and the European Green Deal for transition to a green and digital, job-based, and inclusive recovery from the COVID-19 pandemic are on the rise.

The pandemic has not only been a tragedy for health and human life but also a great threat to national economies as well as individuals who struggle to make a living and social resilience. A number of reports have been published in order to discuss how a low-carbon transition could make the recovery from the pandemic possible at micro (individual and firm) and macro levels. Calls for low-carbon transitions based on the SDGs and the European Green Deal for transition to a green and digital, job-based, and inclusive recovery from the COVID-19 pandemic are on the rise.

An analysis conducted by Cambridge Econometrics (2020) finds that the green recovery plan consisting of, e.g., public investment in energy efficiency, subsidies for wind and solar power, and public investment in upgrading electricity grids in the EU, would lead to 2 million more jobs by 2024. The key message of the analysis is that green recovery has a more positive impact on income, employment, GDP, and GHG emissions than other types of recovery programs.

[1] The standard Human Development Index (HDI) defined by the UNDP is "a summary measure of average achievement in key dimensions of human development: a long and healthy life, being knowledgeable and have a decent standard of living. The health dimension is assessed by life expectancy at birth, while the education dimension is measured by mean of years of schooling for adults aged 25 years and more and expected years of schooling for children of school entering age. The standard of living dimension is measured by gross national income per capita" (UNDP, 2020). Although the analysis in the current report addresses per capita income changes as a result of the energy transition, the failure to address the other two dimensions of the HDI, namely health and education, is among the methodological limitations of the current analysis.

McKinsey (2020) reports that targeted low-carbon programs, such as expanding energy storage, accelerating wind and solar power installations, improving industrial energy efficiency, creating bus rapid transit and urban rail schemes and so on, could revive economic growth and employment creation while leading the drive for a more environmentally sustainable "next normal". In a European context, a direct government spending of around 75-150 billion Euros could create 1-3 million job-years of employment excluding knock-on effects, 180-350 billion Euros of gross value-added, and 15%–30% reduction in CO_2 emissions by 2030 relative to current emissions and based on potential. The gross value-added multiplier of several stimulus measures (such as accelerating build-out of wind and solar power and expanding energy storage) are much stronger than others such as installing smart-building systems and expanding electric-vehicle charging networks. Moreover, it is argued that stimulus measures can be even more effective if a balanced combination of mechanisms is used. For instance, energy efficiency measures in buildings (i.e., retrofit houses for energy efficiency) could be executed as a joint effort by regulation and funding, where it could be made obligatory for residential properties (during the rent-out or sale of the property) to have a certain minimum energy rating as a push factor and direct funding to retrofit residential properties could be provided as a pull factor. The report warns that low-carbon stimulus measures and specifically an energy transition via government spending on renewable energy and energy efficiency should be urgently adopted in order to mitigate the negative impacts of the COVID-19 pandemic.

A recent International Energy Agency report on energy efficiency highlights the role of energy efficiency in governments' stimulus packages in recovering from the COVID-19 pandemic throughout the world by creating jobs and stimulating spending while reducing greenhouse gas emissions.

A recent International Energy Agency (IEA) (2020) report on energy efficiency highlights the role of energy efficiency in governments' stimulus packages in recovering from the COVID-19 pandemic throughout the world by creating jobs and stimulating spending while reducing greenhouse gas emissions. The IEA has observed that 66 billion US$ of funding for energy efficiency-related measures was announced as part of the stimulus packages until the end of October 2020. 39% of it has been allocated to the buildings sector, which is estimated to create around 15 jobs for every 1 million US$ spent. The report further evidences that the efficiency-related stimulus spending announced (until October 2020) could generate the equivalent of 1.8 million full-time jobs between 2021 and 2023, "nearly two-thirds of which would be in the buildings sector, 16% in industry and 20% in transport" and over 80% of which would be generated in Europe. However, the IEA Sustainable Recovery Plan released in June 2020 reveals that there is even a higher potential of energy efficiency investments to create around 4 million additional jobs globally through public and private sector investment in buildings, transport, and industry, which would accelerate suggests further economic recovery from the pandemic.

Similarly, International Renewable Energy Agency (IRENA) (2020) envisages a global transformation of the energy sector, coupled with a deep decarbonization perspective as a panacea to the COVID-19 pandemic-related economic, social, and humanitarian crises. The report concludes that there could be a 70% decline in the world's energy-related CO_2 emissions by 2050, owing to a transition to renewables and energy efficiency measures. Employment, environmental and health benefits of such a transition are expected to be broad and globally widespread. For instance, 100 million jobs would be achieved by 2050 in the energy sector, and economy-wide jobs would increase by 7 million compared to current policies. The low-carbon transition scenario would lead to a 2.4% higher global GDP by 2050 than what the current plans would end up with. Yet, the energy transition together with climate policies implemented within the context of the pandemic may give rise to negative effects on some groups or sectors. Sustainable Development Solutions Network (SDSN) (2021) argue that dealing with the negative social impacts of climate policies is of utmost importance to create wide support for energy transition. According to the report, regressive effects of greening policies can be fully counterbalanced with policies targeted at employment and other socio-economic outcomes.

1.3 An energy transition vision for Turkey

As a developing upper-middle-income country, Turkey is in a transition with respect to its increasing use of electricity and primary energy sources. It is also grappling with the challenges of ensuring cost-competitive energy supply for its citizens and industrial sectors, while also realizing its emissions reduction targets. Faced with increasing energy demand and limited indigenous resources, Turkey is at cross-roads regarding its future energy mix (Saygin et al., 2018). This study comes at a time when crucial decisions are being made in Turkey's energy sector and the country's long-term climate change mitigation and adaptation plans.

Turkey's current progress in the energy transition has focused mainly on increasing the share of renewable energy in electricity generation while progress in non-power sectors has been limited.

Turkey's current progress in the energy transition has focused mainly on increasing the share of renewable energy in electricity generation while progress in non-power sectors has been limited. Since 2000, the share of renewable energy in total electricity generation has increased from 24% to 42% while the increase in power demand is 2.5-fold. On the energy efficiency side, energy intensity has been declining at an annual rate of more than 1%; however, the rate of decline needs to accelerate to realize the vast efficiency potential and to achieve the national sector-wide targets set by the government. Despite a rapid shift in electricity generation towards renewables, their share in total primary energy supply has remained just above 10% due to sustained subsidies through legislative and regulatory measures and the lack of any effective policy in end-use sectors such as transport and heating.

The government perspective on the energy transition is manifested in several policy documents, including the National Renewable Energy Action Plan (2014-2023), National Energy Efficiency Action Plan (2017-2023), National Climate Change Strategy (2010-2020) and National Climate Change Action Plan (2011-2023). According to President Erdoğan's announcement in April 2021, Turkey is currently working to update its climate change strategy and adaptation plan to 2030 and 2050 (Gazete Vatan, 2021). Some of the common objectives of these plans include:

- Securing energy supply, by giving priority to domestic resources; increasing the share of renewable energy resources within the energy supply; increasing energy efficiency, enabling the free-market conditions operate fully and providing for the improvement of the investment environment and providing the diversity of resources in the field of oil and natural gas.
- Enhancing Turkey's influence in the field of regional and global energy, by turning the country into an energy hub and terminal by using the geo-strategic position effectively within the framework of regional cooperation processes.
- Minimizing the negative environmental impacts of energy and natural resource related activities.
- Increasing the contribution of natural resources into the national economy and increasing the production of industrial raw materials, metal and non-metal mineral reserves and providing for their utilization on a national scale.

- Increasing the effectiveness in the management of energy and natural resources and being the pioneer and supporter of innovation in the field of energy and natural resources.

Turkey has also signed the Paris Agreement, it has yet to ratify it and the 2015-dated INDC remains as the main climate plan to 2030. The INDC stipulates that under a business-as-usual (BAU) scenario that Turkey's greenhouse gas emissions would reach 929 megatons CO_2 equivalent (CO_2e) and proposes a 21% reduction from this level (UNFCCC, 2015). Turkey's current baseline path shows that current policies, as assumed in the baseline scenario in this study, will result in a significantly lower level of CO_2e emissions than stipulated in the INDC BAU path. While national targets for renewable energy to 2023 have been largely surpassed, the government announced in 2018 an annual target for addition of 1000 megawatts (MW) of solar and 1000 MW of wind energy until 2027 (Daily Sabah, 2021). There have also been numerous new legislations for improving energy efficiency. At the start of 2020, a vision for the passenger electric vehicle segment has been defined with the aim to achieve at least 1 million electric vehicles and 1 million charging points by 2030 (AA Energy, 2020). Government-enabled efforts are ongoing for blending 5% clean hydrogen to the gas grid (ICIS, 2021).

Over the next ten years, the Turkish energy transition is expected to concentrate on promoting the penetration of renewable energy in power generation, continuing energy intensity improvements in end use sectors and accelerating the electrification in transport sector.

Over the next ten years, the Turkish energy transition is expected to concentrate on promoting the penetration of renewable energy in power generation, continuing energy intensity improvements in end use sectors (industry, buildings, transport), along the lines of the National Energy Efficiency Action Plan, and accelerating the electrification in transport sector. Crosscutting these three areas is grid development, which includes technologies for system flexibility, smart grid applications, as well as industrial development in related areas, such as domestic production of renewable energy and energy efficiency equipment, batteries for electric mobility and power storage, and electric vehicles.

Since 2017, SHURA's various scenario analyses have provided a new pathway to accelerate this trend to 2030. This study explores the socioeconomic impact of the SHURA vision versus the baseline that is developed based on the existing government targets. SHURA scenario intends to explore the possibilities for a realistic transition within the context of Turkey, achieving by 2030 major structural changes on the demand and supply side of the power sector. The power system transition envisaged by SHURA for 2030 shows that at least 50% renewable's share in total generation is technically and economically viable with wind and solar energy comprising about 30% as well as a 10% reduction in total power demand by 2030 compared to the government current policies baseline.

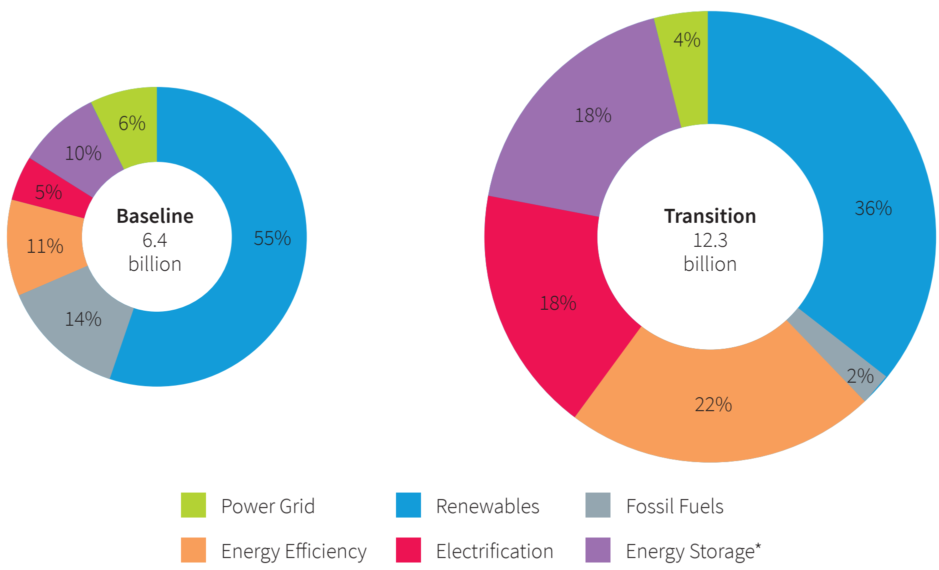
Figure 1: *SHURA's 2030 Vision for Power System Transition*

Electrification of end-use	Efficiency gains of 10% compared to the baseline	50% renewable energy share in total output
2.5 million EVs & 1 million charging points + 2 million heat pumps & smart homes = **7-9 TWh of additional electricity demand**	17.3 TWh savings in industry + 19.3 TWh savings in buildings + 6.0 TWh savings in the distribution system = **42 TWh of net demand reduction**	Improved market design + 2000 MW energy storage + Demand-side response reduction of peak demand by up to 10 GW + System-friendly wind & solar location + Flexible power plant fleet = Flexible grid for integration of 30% share in wind & solar

The main challenge for realizing scenario targets will be securing financing for the necessary investments which require doubling the current and baseline levels.

The total average annual investment level required to achieve the SHURA transition vision for 2030 has been calculated at 12.3 billion US$ while current annual investment levels in the power sector and the Baseline scenario are in the order of 6-7 billion US$ with the main difference coming from energy efficiency, electrification and technologies that can enable flexibility such as battery storage. The main challenge for realizing scenario targets will be securing financing for the necessary investments which require doubling the current and baseline levels. Nevertheless, electrification and renewables grid integration come with negligible additional costs and energy efficiency generates 1.2-1.5 in financial benefits for every dollar invested.

Figure 2: *Annual average investments, Baseline and Transition scenarios.*



* Note: Energy Storage includes both electric vehicles and power grid energy storage.

Considering the potential in renewables and energy efficiency, Turkey is well positioned to join the global trend toward reducing overall GHG emissions, as well as reducing the emissions intensity of its production. In the upcoming period, a green transformation is required for all sectors of the economy. Energy transition will play a major role in reaching this target. To this end, renewable resources ought to become more prominent in the primary energy mix, and rapid increases in energy efficiency as well as improved electrification have to be experienced.

The scenario labelled "Transition scenario" in this report carries important elements of a transition from a carbon intensive energy sector to one based on low carbon resources: increase of renewables investment to lift its share in power generation to above 50% by 2030; no investment in new coal-fired generation, increase in energy efficiency, investment in battery storage, electric vehicles and heat pumps. Increasingly, policy makers globally are becoming aware of the fact that a more fundamental and rapid transformation will be needed to comply with the targets of the Paris Agreement, leading to zero carbon emissions by 2050. Such a global transformation to "net zero" has been, most recently, developed also by the International Energy Agency. SHURA is in the process of developing such transformative net zero pathways in more detail for Turkey's energy system in the near future.

1.4 The aim and approach of the study

"The Socioeconomic Impact of Energy Transition in Turkey" is a unique study that shows the benefits of transitioning to a more efficient and renewable power system based on the vision SHURA has charted for Turkey by 2030. It is the first study in Turkey that explores the social and economic impacts of power system transformation.

Looking from energy sector perspective, the study answers major questions Turkey's economy confronts today, such as what would the value-added look like if more renewable energy capacity is in place instead of more fossil fuels?

Looking from energy sector perspective, the study answers major questions Turkey's economy confronts today, such as what would the value-added look like if more renewable energy capacity is in place instead of more fossil fuels? How would Turkey's power system transformation impact the country's manufacturing industry? In which sectors new jobs will be created and will there be losses? How will the wages and income distribution be impacted? Does power system transformation improve human welfare? What is the economic benefit of better human health and environmental quality?

The approach taken in the report to answering these questions is based on a pair of electricity and macroeconomic models that are soft linked, combined with desktop research. The results provide recommendations for how Turkey can reap the benefits of a more affordable and cleaner energy system for its growing population and economy in the coming decade.

To this end, the study uses two models:

- An economy-wide macroeconomic model with an explicit and detailed energy subsector to study the two levels of interactions between production sectors and aggregate demand components. First, by utilizing the flows of input-output intermediate input demand embedded in macroeconomic accounting framework, we follow the up-stream and down-stream production requirements of the energy sector. Second, after solving the current policies baseline scenario, we accommodate various alternatives towards more intensive use of energy efficiency as well as transition towards a renewable resource-driven pathway to enable low carbon production.

- A multi-period linear Generation Expansion Planning (GEP) model with an hourly temporal resolution for the Turkish power generation sector complements the macroeconomic framework of the first model. The co-integration of the GEP and the Computable General Equilibrium (CGE) models enable us to address issues of electricity generation driven by renewables and increased efficiency, especially in transport and buildings sectors under the macro economy wide general equilibrium balances.

The modelling framework uses official national income statistics, Input-Output (I/O) tables of TurkStat, as well as the hourly load data by each technology (through YTBS of TEIAS) and hourly market clearing prices (through transparency platform by EXIST). TurkStat data on GHG emissions by sector are disaggregated to allow further detail at the energy sub-sectoral level.

Box 1: The 2020 COVID-19 Shock; Impacts on the Turkish Economy

The COVID-19 pandemic is being experienced as a multidimensional systemic crisis based on the simultaneous manifestations of the supply, demand, and financial shocks. These effects have already been realized in the exacerbation of deep inequalities in income distribution, in functional, regional, and gender terms; in access to public services that are commercialized; and therefore, in an environment where poverty is experienced with social exclusion due to severe inequalities of income.

The crisis has hit the Turkish economy under a conjuncture where the adverse effects of the 2018 financial turbulence have not yet been alleviated, and the macroeconomic balances have not been resolved in a sustained fashion. Turkey has displayed already high rates of unemployment (at the rate of 13.6%) and inflation (11%) by the end of 2019.

Against the pandemic many countries introduced a wide arsenal of fiscal policy instruments together with monetary accommodation. Turkey's response, on the other hand, had almost exclusively relied on credit expansion and loan guarantees, while minimizing the role of fiscal policy. Coupled with compulsory Presidential decrees on setting a minimum ratio for banks' credit obligations (known as the so-called active credit ratio) and a zealous expansion of monetary supply, Turkish economic team hoped for the alleviation of the crisis conditions via short run financial expansion, ignoring any real intervention on the part of incomes policy.

With this strategic policy preference, Turkey has diverged away from many of her emerging market and developing economy counterparts, with excessive reliance on short term monetary expansion. In what follows, performance of Turkey's economy over the course of the first year of the pandemic has been erratic and severely biased against wage earners and low-income groups. Furthermore, pursued in the midst of an already inflated asset markets, it proved destabilizing and inflationary along with significant currency depreciation.

Official statistics by Turkstat reveal a modest positive rate of growth for GDP at 1.9% for 2020. As indicated above, this was mainly achieved by the short run expansion of credit which increased at a rate of 150% reaching to a ratio of 80% to the GDP (from an average of 30%), and by vigorous monetization that expanded the M1 supply of money by almost 200% over the first nine months of 2020. In contrast, level of employment fell by 1 million 268 thousand, with the rate of open unemployment jumping to 15.6% by the end of the year. Independent research based on the ILO's methodology of "full time job equivalent losses of hours worked", as conducted by the DISK Research Department reports that Turkey suffered from a loss of 2 million 829 thousand of equivalent full time job loss; and that the ratio of open plus disguised unemployment (including those jobless who are actively looking for a job, as well as those who quitted their job search and yet report themselves available for work within one week if they are offered a job) reached to 27.4%.

IMF's Staff Report of November 2020 has put Turkey's loss of employment over its potential at 10.1%. All these had severe repercussions on wage incomes as well as on the rural and urban poor, with an increase in poverty rate.

Throughout our analysis, we have chosen to extend the adverse effects of the Covid pandemic over a long horizon as a decline in the trend value of the potential rate of growth for the Turkish economy. Rather than to attempt to track the short-term fluctuations in the business cycle, it is our contention that the pandemic will have longer lasting effects on the trend value of growth. It should also be noted that quantitative models of this genre are not well-equipped to handle short term projections of swings along the business cycle and such a projection is an entirely separate line of research beyond the scope of this study. Thus, under this modus vivendi we chose to operate with a lower rate of average growth under the base path and the scenario analyses. In what follows, rate of growth of GDP was calibrated to a path of 3.25% in real terms. This contrasts with an average historical potential rate of growth of 4.5%-5.0% typically envisaged for Turkey.

2. Literature Review

The findings indicate that the net impact of the transition on economic growth and employment tends to be small and mostly positive unless the transition studied involves a large uncompensated cost.

Studies on the macroeconomic impacts of the energy transition is a burgeoning field of research that encompasses both developed and developing countries. Table 1 shows a summary of international and Turkish studies, mostly using a CGE model similar to the one used in this study to explore the macroeconomic impacts of a low carbon energy transition. The findings in the table indicate that the net impact of the transition on economic growth and employment tends to be small and mostly positive unless the transition studied involves a large uncompensated cost as in Bachner et.al. (2020).

Social impacts of energy transition cover, for example, distributional effects in terms of both functional income distribution and income distribution at individual or household levels.[2] Alternatively, distributional impacts may arise from potential price changes due to a switch towards higher shares of renewable energy in the energy mix. For instance, investigations into the effects of the German Energiewende on different income groups (i.e., on income inequality) found that the financial burden falls primarily on end users. Proposed solutions to compensate for the additional burden arising from renewable surcharges include increasing social transfers, improving energy efficiency, reducing electricity taxes, and increasing renewables finance via the public budget or specific funds (Lutz and Breitschopf, 2016; Diekmann et al., 2016).

In addition to the economic benefits in terms of output and employment, Garcia-Casals et al. (2019) also investigated welfare gains due to a global energy transition and highlighted a 62% reduction in health impacts from local air pollution in 2050. Besides, education expenditures and other dimensions of social welfare accompany the positive impacts. However, they argue that the benefits of the transition are not distributed evenly among all countries and propose a just transition which can distinguish between countries, regions, and communities in order to minimize the risks and adjustment costs of energy transition. In their elaboration of the existing evidence on social impacts of energy transition and climate change mitigation policies, Markkanen and Anger-Kraavi (2019) demonstrate that carefully designed policies might lead to desirable social outcomes in addressing poverty, gender, health, and economic inequalities. Yet, the authors argue that, even in that case, benefits will not be exclusively positive nor equally distributed. A pro-poor approach as well as the consideration of potential inequalities at all stages starting from policymaking to implementation could mitigate existing inequalities.

[2] See section 5.2 for employment impacts.

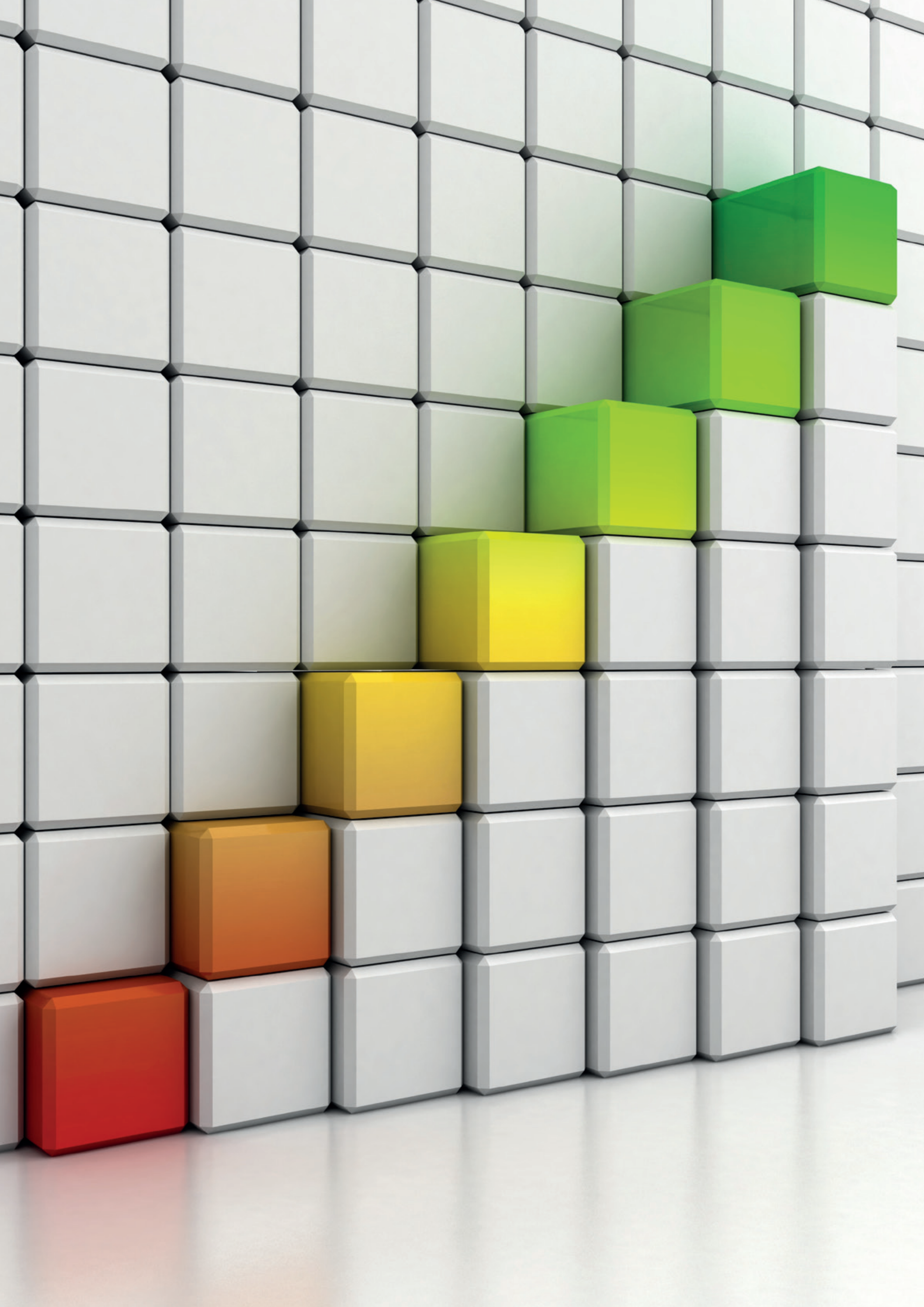
Previous CGE modelling studies for Turkey found that comprehensive transition policies are needed to maintain production and employment growth together with emissions reduction.

Previous CGE modelling studies for Turkey have concentrated mainly on measuring the economic impact of policies, particularly carbon taxes, to meet Turkey's INDC targets. These studies found that comprehensive transition policies are needed to maintain production and employment growth together with emissions reduction. Studies concentrating on the industrial development and employment impacts of energy transition in Turkey, such as IPM/IPC-IASS (2019) Co-benefits Study, emphasize the potential for raising the technology level of production and creating new jobs at medium and high skill levels. In addition, Kayahan-Karakul (2016) emphasize the importance of educational policies for creating a "green collar" work force for a low-carbon economy.

The current study measuring the socioeconomic impact of SHURA's power system transition scenario draws upon the previous CGE modelling studies in certain aspects, such as employing renewable energy subsidies as needed and carbon pricing together with a "neutral tax" and sensitivity analyses (see Section 4.2), but otherwise relies mainly on market mechanisms.

Table 1: *Studies on Macroeconomic Impacts of the energy and low-carbon transition*

	Geographic Coverage	Transition Coverage	Target Year/Period	Indicators	Net Impact	Key Finding
Lehr, et. al. (2012)	Germany	Renewable Energy	2030	Employment	**Positive:** 150 thousand additional	Positive impact dependent on RE equipment export volume. Can turn negative if exports are minimal.
Blazejczak et. al. (2014)	Germany	Renewable Energy	2030	GDP	**Small Positive**	Investment growth leads to manufacturing growtn
				Employment	**Net Neutral**	Gains in business services; Losses in public and private sector.
O'Sullivan and Edler (2020)	Germany	Renewable Energy by Technology	2000-2018	Employment	**Positive:** bell-shaped with gains peaking in 2011, declining to 2018 and stabilizing thereafter.	Manufacturing and installation major winners. Biogenic fuels has highest potential for O&M.
Thalman (2015)	Germany	Energy Transition		GDP by sector	**Positive for export oriented sectors, neutral** or negative for others.	Power prices increased due to renewable energy taxes; had a negative impact on sectors that did not have exemptions.
Garrett-Peltier (2017)	USA	Energy Efficiency, Renewable Energy	-	Employment	**Positive** in comparison to fossil fuels	Switching from fossil fuels to industrial energy efficiency and renewable energy will create 5 more new jobs per 1 million US$ investment.
Swartenbroekx (2018)	EU-28	Energy Transition	2000-2015	Employment	**Small Positive**	Relies highly on worker mobility and skill adjustment; targeted support and guidance needed.
				External Trade Balance	**Small Negative** with considerable country-level variation	Despite doubling of exports, increase in PV equipment imports results in overall small negative trade balance.
Garcia Casals et. al. (2019)	Global	IRENA Energy Transition Sceario	2050	GDP	**Net Positive**	Europe, US, net oil importers gain while net oil exporters, India and Southeast Asia lose.
				Employment	**Net Neutral**	All regions gain except China and sub-Saharan Africa (only South Africa gains.)
Bachner et. al. (2020)	EU-28	Decarbonisation of European Steel Industry	2050	GDP	**Moderately Negative** at 1.6% lower.	High cost technology causes increase in costs and decline in productivity.
Laitner and McKinney (2008)	USA	Energy Efficiency	2030	Employment	**Positive,** 0.5-1.5 million net employment gain.	Employment gain as a result of 20%-30% overall efficiency gain in the economy.
Füllemann et. al. (2020)	Switzerland	Energy Transition	2050	Employment	**Positive**	Distributed renewable energy and energy efficiency create more jobs over fossil fuels in comparison to utility scale renewables.
Bouzaher, Şahin and Yeldan (2015)	Turkey	Carbon Tax	2030	GDP	**Small Positive**	If carbon taxes are channeled to green investments, a 2% increase in GDP is observed over BAU scenario.
				Employment	**Net Neutral**	No significant impact on employment levels due to carbon tax.
Voyvoda, et. al. (2015)	Turkey	Energy Transition	2030	GDP	**Small Negative**	By 2025, GDP under climate policies grows by 3.3% instead of 4% under BAU. This gap disappears by 2030.
				Employment	**Small Negative**	In the absence of social policy packages, employment levels grow at a marginally slower rate than in the BAU.
Yeldan et. al. (2016)	Turkey	Carbon Tax	2030	GDP	**Net Negative**	Compared to BAU, a neutral tax leads to increased GDP in the short run, but slightly lower 3.7% GDP by 2030.
				Employment	**Neutral**	Employment impacts vary according to labor-intensiveness. Neutral carbon tax means employment taxes are cut, so job losses are recuperated over long term.
Acar, Voyvoda and Yeldan (2018)	Turkey	Energy Transition	2040	GDP	**Net Positive**	Deployment of a green policy package results in 7% higher GDP over baseline.
				Employment	**Net Positive**	Green policy package results in lower unemployment rates, reduced unregistered employment and closing of the wage gap between poorer and richer regions.



3. Methodology

To assess the socioeconomic impacts of the accelerated power transition, this study couples a bottom-up power system model, TR-Power (Kat, 2021), with a detailed top-down macroeconomic model (similar to Acar, Voyvoda & Yeldan, 2018; Acar & Yeldan, 2016; Yeldan & Voyvoda, 2015). The bottom-up power system model exhibits an engineering view and represents, in detail, how the power system develops. The top-down model, in return, allows for a full representation of the macroeconomic transactions and policy interventions within a dynamic general equilibrium framework. In short, the bottom-up model simulates the structural transition in the power system and provides input to the top-down model, in which capital, labour, intermediates, and fuel use values as well as precise emission projections and tax revenues from emission taxation are assessed.

The two models are coupled in a soft fashion to span the 2018-2040 horizon in a dynamic manner, i.e., the two models are iteratively synchronized through electricity generation, inputs to the power sector, and emissions. The main findings and discussions will be presented for the target year 2030. However, the models are run until 2040 to reduce end-of horizon effects and to illustrate the long-term effects of the transition.

This section continues with summary overviews of the top-down and bottom-up models, followed by an explanation of how the models are integrated. Further details of each model, including mathematical formulations can be found in Appendices I and II.

3.1 Top-down CGE Model

The analytical approach is based on the methodology of applied general equilibrium distinguished as the paradigm of CGE. The methodological rationale for this choice is the urgent need to improve our understanding of the complex trade-offs between attaining objectives of sustainable development, mitigating climate change, and improving social welfare.

The CGE modelling methodology presents itself as the most conducive analytical apparatus to capture these diverse objectives and policy trade-offs within the discipline of general equilibrium theory. Embedded in the theoretical realm of what is known as “Walrasian” or “Structuralist” equilibrium, the CGE framework provides a coherent system of data management and scenario analyses addressing issues of sustainability and mitigation simultaneously.

The top down CGE model enables a macroeconomic analysis of the impacts of the energy transition on indicators such as value-added, employment, wages, external trade flows, the current account balance, consumption, investment, fiscal balances, domestic and foreign debt formation and industrial transformation as well as carbon emissions.

The top down CGE model enables a macroeconomic analysis of the impacts of the energy transition on indicators such as value-added, employment, wage remunerations by sectors, external trade flows, the current account balance, consumption, investment, government’s fiscal balances, domestic and foreign debt formation, industrial transformation as well as environmental indicators such as total greenhouse gas emissions by sector. The purpose here is to examine the sectoral outcomes of energy transition on the overall economy, including, but not limited to: green jobs, green investments, and fiscal reorientation apart from fossil fuels towards renewables. Although the integrated framework allows for approximating the total emissions of the entire economy, the models will focus predominately on the greenhouse gas emissions originating from fossil fuel combustion.

CGE modelling is an applied approach to the Walrasian economic system. It is Walrasian in the sense that it brings behavioural assumptions, production technologies and market institutions together within the discipline of general equilibrium. Along with this equilibrium, production processes bring factors of production, for example capital, labour, and in this study, an energy aggregate input, within a dynamically adjusting technological pathway.

Commensurate with the production activities, incomes are generated through the disposition of wages, profits, and other factor payments. Income remunerations are channelled to the households whose role in the system is to dispose of the generated factor income as (private) consumption expenditures on goods and services or (private) savings. Saving funds, in turn, are disposed of as investment expenditures on fixed capital to accentuate the potential output in the next production cycle.

Following the identities of national income accounting, any gap in the balance between domestic savings and investments is met by foreign savings; that is, the balance on the current account of the balance of payments. Adjustment on a flexible (real) exchange rate (conversion factor of the price indexes of the domestically produced versus foreign goods) or quantity adjustments on foreign exchange flows are possible modes of adjustment to bring forth the warranted equilibrium. Government, in turn, is institutionalized at every aspect of economic activity considered thus far. Through various administrative capacities of taxation and subsidization, the government acts as both an economic agent fulfilling public expenditure and saving accounts and also as an administrative unit in designing alternative policy scenarios and implementing instruments of abatement. It is the capability of the CGE framework to provide an economic evaluation of the "what if?" policy interventions under various abatement scenarios.

The CGE framework provides an economic evaluation of the "what if?" policy interventions under various abatement scenarios.

The version of the CGE model used here addresses the characteristic features of peripheral development and the dual objectives of development and environmental protection in various ways. A distinguishing feature of the model is that it deliberately takes account of the rigidities in the labour and capital markets by introducing explicit gaps against the equalization of the wage and profit rates across sectors. This feature underlines the structuralist tradition of the model. These structuralist 'distortions' are defined via existing data on wage rates (and rates of profit) across sectors and are maintained as rigid divergences from equalization of the 'average' wage rate. Migration is a further behavioural rule, governing the movement of labour from the poor wage sectors towards the high wage sectors.

Environmental damage is modelled mainly in the form of gaseous pollution. Measured in terms of CO_2 equivalents, the greenhouse gaseous emissions are the end-result of four sets of economic activities: (1) combustion of fossil fuels to supply aggregate energy; (2) industrial processes mainly for iron and steel and cement production; (3) agricultural processes mainly as methane; and (4) household consumption and waste. Sub-modelling of the emissions in the CGE apparatus recognizes these sources by way of technological parameters derived from the greenhouse gas emissions inventory published by Turkstat.

The model is built on the augmented input-output (I/O) data structure provided by TurkStat. The most recent official I/O data is dated 2012. Starting from this data set the I/O structure was updated to reflect the 2018 macroeconomic balance of the Turkish economy. See Box 2 for further detail on how I/O Tables are used in CGE models, Appendix II for details of the CGE model formulation, and Appendix V for more information on I/O analysis.

Box 2: I/O Tables and CGE Models – What they can and cannot tell

Input – Output representation of an economy is a standard method in collecting and categorizing micro and macro level data. The essence of the data stream is the input output flows, wherein across any particular row intermediate input flows are followed as they originate from the yielding sector (represented in the row) to the recipient sector (the columns). The row sum of any column then collects input costs and add this the value-added components –factor remunerations such as wages, operational surplus, as well as indirect taxes paid. Over on the other side, along the row, additions of columns yield total demand from any sector. The final demand components of Private and Public Consumption, Investment expenditures and net exports determine the aggregate demand for the sector. By identity, the row sum (aggregate costs of supply) must be equal to this column sum (aggregate revenues from demand).

The computable general equilibrium modelling framework utilize this data to generate economic actions based on optimization behaviour sustained by economic theory. It can be argued that the I/O level data is a static photographic representation of the economy, while the CGE modelling enables behavioural action given policy shocks, and otherwise perturbations to the system.

The CGE modelling methodology presents itself as the most conducive analytical apparatus to capture these diverse objectives and policy trade-offs within the discipline of general equilibrium theory. Embedded in the theoretical realm of –what is known as—the Walrasian / Structuralist equilibrium, the CGE framework provides a coherent system of data management and scenario analyses addressing issues of sustainability and income equality simultaneously.

Thus, CGE modelling is an applied approach to the Walrasian economic system. It is Walrasian in the sense that it brings behavioural assumptions, production technologies and market institutions together within the discipline of general equilibrium. Yet, as such, it also suffers from the many limitations and drawbacks of applied quantitative models that social scientists have to confront. First and foremost is the fact that within these class of models, economic behaviour is embedded mostly within an optimizing framework, given smooth and well-behaved functional forms, operating under well-functioning markets. Yet, the real economic life offers many bottlenecks, shortages, and costs of adjustment. Government's tools of intervention, likewise, are mostly motivated with political rationalities superseding the "economic rationalities". Hence, public policy instruments may be delayed, be subject to frictions and conflicts that the algebraic structure of the model could poorly address. Instruments of abatement, in particular, are vulnerable to such frictions in policy making. Furthermore, these types of models typically adopt technological and institutional change in an exogenous fashion. Failure to endogenize sources of technological productivity gains within an economic system results in almost costless improvements in total output and may lead to excessively optimistic outcomes.

Nevertheless, being aware of the limitations and shortcomings, applied general equilibrium presents itself as a valuable tool to study policy alternatives under the discipline of economic theory and provides an important step in our quest for socially relevant instruments of abatement and mitigation.

A useful summary of the structure of the CGE framework in contrast to I/O and other quantitative modelling paradigms is provided in Robinson, S. (1989) "Multisectoral Models" chp 18 in Chenery & Srinavasan (eds) Handbook of Development Economics, Elsevier.

3.2 Bottom-up power sector model

The bottom-up TR-Power model is a GEP model used to analyse the long-term evolution of the power sector based on factors such as changes in the total demand, load curve patterns, cost of capital, and fuel prices (Kat, 2021). The bottom-up model is run under exogenous demand projections, i.e., the model focuses on generation and capacity dynamics and does not model energy demand. In this study, the power model is used to replicate SHURA's vision of energy transition (see Section 1.3). As the TR-Power model is soft-linked to the CGE model, this allows for macroeconomic impacts to be investigated as the power system develops incrementally over time.

TR-Power is a large-scale linear programming model in which the objective is to minimize the total discounted cost of the power system, where capacity expansion, operation planning and power dispatch decisions are combined within a single integrated framework. Annualized investment costs, operational costs, fuel costs and the cost of non-served electricity are also taken into account. Moreover, the model allows for a precise accounting of GHG emissions and can calculate the implicit costs of emissions using shadow prices of the associated emission constraints, or through introducing exogenous taxes.

The aim of the GEP model is to determine the technology, capacity level, time of commissioning, and spatial distribution of power plants over a long-term planning horizon.

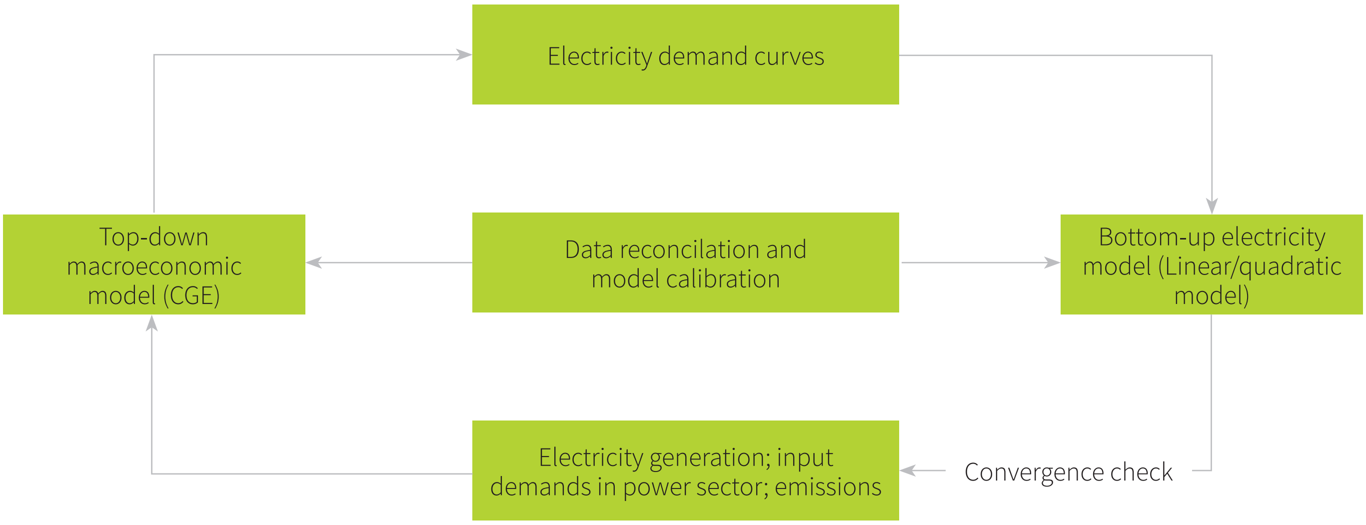
The aim of the GEP model is to determine the technology, capacity level, time of commissioning, and spatial distribution of power plants over a long-term planning horizon. GEP models also include technical, regional, economic, environmental, and policy constraints as well as operational restrictions. They are mostly linear programming models with a wide range of variants in which non-linear, integer, or dynamic programming are employed. The usual objective function in GEP models is the minimum cumulative discounted total cost (Kagiannas, Askounis, & Psarras, 2004; Koltsaklis & Dagoumas, 2018). Multi-objective GEP models also exist and have included additional objectives such as minimizing emissions, outages or maximizing reliability in the power grid (Antunes & Henriques, 2016; Antunes, Martins, & Brito, 2004; Meza, Yildirim, & Masud, 2007; Tekiner-Mogulkoc, Coit, & Felder, 2012; Tekiner, Coit, & Felder, 2010). The TR-Power model used in this study solves a single objective, however; in addition to the economic dimension, it handles environmental dimensions via a precise representation of emissions that enables the introduction of an emissions tax pathway.

The primary data input are hourly generation and availability values of the power system as well as installed capacities, including a break-down by generating technologies provided by Turkish Electricity Transmission Corporation (TEİAŞ) and energy Exhange Istanbul (EXIST). Hourly data from 2017, 2018, and 2019 are used to approximate some key parameters such as capacity factors, renewable resources availability at an hourly or seasonal scale. While cost and technical parameters have been gathered from national and international publications & databases (e.g., TEİAŞ, MENR, NREL, IEA, EIA, IRENA), the predominant source of data is SHURA's Optimum Capacity Mix study (SHURA, July 2020). See this study for detailed techno-economic inputs, including capacity and operational costs, fuel prices, infrastructure costs, etc.

3.3 Soft-linking the macroeconomic and power system models

It is widely recognized in the energy modelling literature that both the top-down and bottom-up approaches originated from different fields with different purposes and the key differences between the two modelling approaches may in fact lead to inconsistent (or at the least non-comparable) outcomes (Grubb et al., 1993; Wilson & Swisher, 1993). The two approaches substantially complement each other rather than opposing each other. Thus, given the shortcomings of both paradigms, there have been considerable attempts to propose a model that combines the bottom-up and top-down approaches, since a complete analysis of policies related to energy supply and use needs to incorporate each model's strengths. A review of linked top-down and bottom-up models and their solution approaches can be found in Kat (2019).

Figure 3: *The link between the BU and TD models*



The state-of-the-art approach that integrates the top-down and bottom-up models is the block-decomposition algorithm proposed by Böhringer and Rutherford (2009). This approach takes its roots from the earlier studies of these authors in which they introduced the theory of the proposed methodology (Böhringer, 1998; Böhringer & Rutherford, 2005, 2008). The algorithm has been implemented in various studies to integrate existing models of bottom-up power system models and top-down CGE models (Hwang & Lee, 2015; Labandeira, Linares, & Rodríguez, 2009; Lanz & Rausch, 2011a, 2011b; Octaviano, 2015; Rausch & Mowers, 2014; Ross, 2014a; Tapia-Ahumada et al., 2014, 2015; Tuladhar, Yuan, Bernstein, Montgomery, & Smith, 2009). Figure 1 outlines the iterative scheme between the two models used in this study.

In this study, since the electricity demand forecasts are exogenously determined, a one-way link from the bottom-up model to the top-down model is used. The input shares (e.g., capital, labour, and fuel) of the power sector are transferred to the macroeconomic model. These shares are determined based on GTAP data (Augiar, Narayanan, & McDougall, 2016) and the methodology introduced in Ram et al. (2020). The models are further calibrated by aligning common outputs such as emissions, investments, and carbon taxes.

Thus, the methodology follows an iterative structure: first the CGE model takes the pathways of production and emissions of the power system from the BU TR-Power model over our scenario horizon 2019-2030, with an extension to 2040 mainly for displaying "long" term effects of the transition. This input is given in Terawatt-hours (TWh) of electricity. Using the price index of the sector as solved (endogenously) from the bottom-up model we convert this input-data into denominations of the value of output measured in constant 2018 Turkish Liras. In doing so, we replace the production function for the electricity sector in CGE system with fixed values of electricity production. Employment along the sector, on the other hand, is determined by cost minimization given the relative price structure and wage costs and is resolved endogenously within the overall macroeconomic system.

4. Scenarios

The Transition scenario describes an accelerated power system transition focused on improving efficiency gains and increasing renewable energy deployment, and the decarbonisation of energy end-use sectors, such as in transport, heating and industry that goes beyond the current official plans.

The socioeconomic impacts of energy transition are investigated using two scenarios, the Baseline scenario and SHURA's Power System Transition, or Transition scenario, for short. While the Baseline scenario reflects current economic trends and government expectations of the development of the economy and the energy sector, the Transition scenario describes an accelerated power system transition focused on improving efficiency gains and increasing renewable energy deployment, and the decarbonisation of energy end-use sectors, such as in transport, heating and industry that goes beyond the current official plans. It is important to note, however, that the Transition scenario focuses predominately on the power sector and does not aim for a net-zero target, nor a deep transformation of end-use sectors, which are outside the scope of this report. Yet, if the accelerated transition were to continue, especially in end-use sectors, this could put the power sector well on a pathway to reach net-zero emissions by mid-century. Technology deployment in these sectors and their transformation have also not been modelled in the context of this report. Based on earlier SHURA analyses, the main distinguishing factors of the two scenarios include the following for the Transition scenario:

- Implementation of a carbon tax that increases from no use today to 25 US$ per tonne CO_2 by 2030 (SHURA July 2020);
- Amended subsidy schemes, removing support for fossil-fuels and adding additional support for renewables in the power sector which contribute to increasing the share of renewable energy in total electricity output to 55% by 2030, including a share of wind and solar energy of 30% (SHURA, July 2020)
- Increased electrification and energy efficiency improvement rates that extend beyond the 2023 of the National Energy Efficiency Action Plan (SHURA, October 2020; SHURA, December 2019) and,
- Addition of electricity storage technologies to the power system along with better market design to increase the system flexibility needed for grid integration of variable renewable energy technologies. (SHURA, April 2019; SHURA, November 2019).

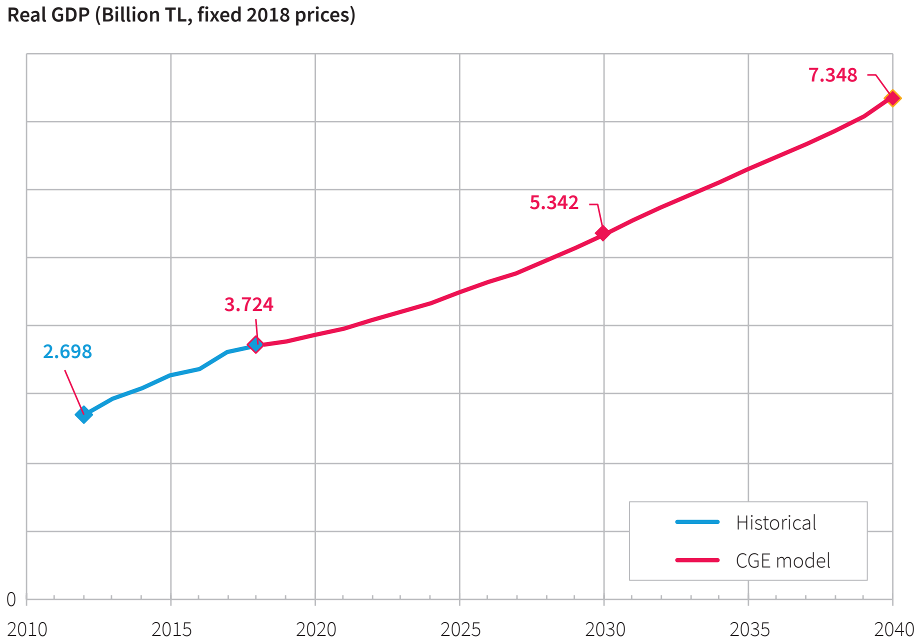
4.1 Baseline scenario

For the CGE model, the Baseline scenario requires exogenous information on labour force growth, capital depreciation rates, technical efficiency changes, and exogenous flows of fiscal as well as foreign assets. The model then solves the savings rate and investment shares endogenously, along with relative prices, the wage rate (the model works with homogenous labour), profit rates and the (real) exchange rate to close the markets for goods, labour, capital, and foreign exchange, respectively.

Adopting historical trends from TurkStat, the Baseline scenario assumes labour force supply to increase at a rate of 0.45% per year, bringing total labour supply from 28.7 million in 2018 to 35.7 million in 2040. Capital stock physical depreciation rate and technical efficiencies are annually adjusted to give a smooth pathway that results in an annual real growth rate of 3.1% from 2019 to 2040. The scenario also assumes autonomous energy efficiency improvements of average 0.1% per year, while also adopting the officially projected additions of non-fossil fuel energy sources. However, no changes are envisaged over instruments of fiscal policy or abatement by the government sector. Foreign flows of workers' remittances, enterprise foreign borrowing and net foreign transfers, are assumed to remain as a ratio to the endogenously solved gross domestic product.

For the Baseline scenario, the model estimates GDP to grow at an annualized rate of 3.1% to reach 1,136 billion US$ in 2030, and to 1,556.8 billion US$ in 2040 (in fixed 2018 prices).

Figure 4: *Development of real GDP (billion TL in fixed 2018 prices) in the Baseline Scenario*



The Baseline scenario describes a development pathway that is driven by the historically determined attributes of the Turkish economy.

Thus, the Baseline scenario describes a development pathway that is driven by the historically determined attributes of the Turkish economy, namely cost minimization of wage labour with limited capacity for employment growth due to reliance on imported intermediate goods in a capital-driven industry. In 2018, wage remunerations accounted for 32% of aggregate value added. Textiles and clothing industries are key labour-intensive sectors with a wage share of 36%. Automotive and Machinery sectors display higher wage shares mostly driven by their larger characterization of formal labour and technical personnel. The food industry, in turn, displays a significantly low share for wage labour remunerations at a rate of 18%.

The Baseline scenario builds upon this fragmented structure. The overall capital intensity of the domestic economy is driven by the fact that the ratio of installed physical capital per worker employed averages 80 thousand Turkish Lira (TL) per worker in 2019 prices. Textiles display a lower capital per worker ratio at 65,000TL and narrates that over the long run, labour efficiency will be low. This holds true in the Baseline scenario, as textiles sector is observed to expand basically on wage suppression. In fact, much of the gains in production and export competition is due to wage cost minimization in the historically determined Baseline scenario.

4.2 Transition scenario

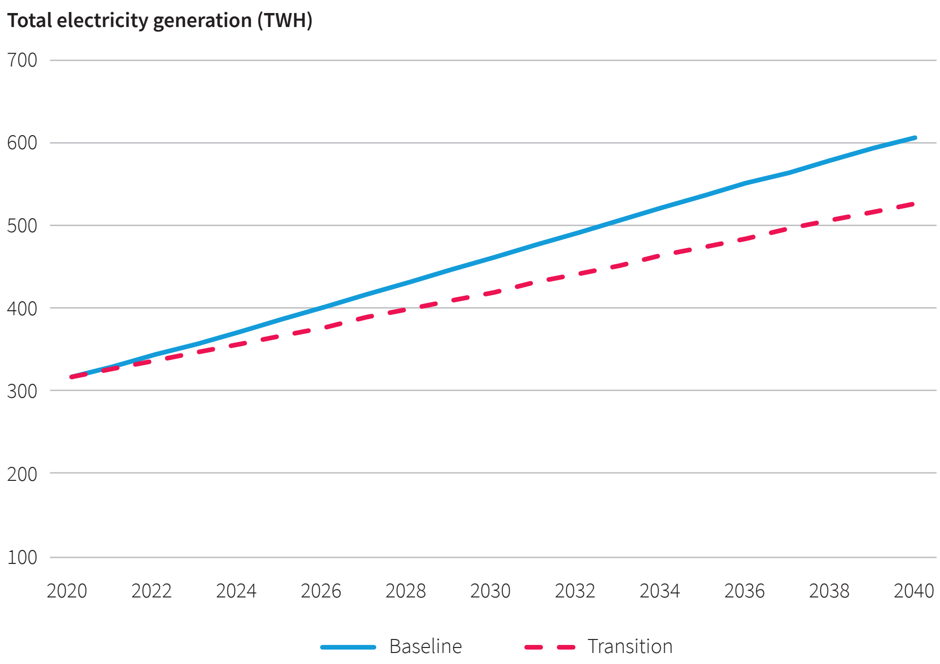
While the Baseline scenario represents a continuation of historical trends, the Transition scenario, on the other hand, is driven by the expansion of the renewables sector as well as gains in energy efficiency. The Transition scenario results in a renewable share of 55% (30 % of which is wind+solar) in comparison to 43% in the Baseline scenario. All technical and cost assumptions related to power plants have been adopted from SHURA's Optimum Capacity Mix study (SHURA, July 2020) and Kat (2021). In addition, the discount rate starts at 14% in 2020 and gradually decreases to 9% by 2030. The rate beyond 2030 is fixed at 9% as in the same study.

From a power generation perspective, the Transition scenario differs from the Baseline mainly in the reduction of power demand through energy efficiency and the introduction of a carbon tax to promote a shift from fossil fuels to renewables.

The main difference between Baseline and Transition scenarios is the total electricity demand, with the Transition scenario having 9% lower energy demand than the Baseline in 2030 and widening to 13% by 2040 (see Table 4). Baseline takes its assumptions from official projections and Shura's Optimum Capacity Mix study (SHURA, July 2020). Transition scenario is mainly shaped by Shura's energy efficiency and business models (SHURA, October 2020) in which some of the efficiency gains in 2030 (48.9 TWh) are offset by the increased power demand due to electrification of end-use sectors, mainly in transport and buildings (6.6 TWh).

A second major difference between the scenarios is the introduction of a carbon tax in the Transition scenario. The carbon tax scheme gradually increases to US$ 25 per ton by 2030 as is implemented in SHURA, July 2020. This assumed tax rate is relatively small, especially when compared to the International Monetary Fund's (IMF) call for a global average carbon tax to reach US$ 75 per ton by 2030 in order to meet Paris Targets (IMF, 2019)

Figure 5: *Development of total electricity generation 2020-2030 in the Baseline and Transition scenarios.*



The subsidy schemes in the scenarios are assigned in a way that they reflect current implementations and also future policy aspects. In the Baseline scenario all the current subsidies are removed, except for solar, while the Transition scenario also adds subsidies for biomass and geothermal in addition to solar (see Table 2). In the Transition scenario, a feasible and realistic path that can carry as much intermittent and renewable generation as possible by 2030 is investigated. In contrast, in the Baseline, subsidy rates are introduced at the minimum levels that would satisfy demand projections while in line with official targets and short-term plans. It is important to note that the bottom-up power system model handles subsidy rates as percent reduction in the cost of generation since the methodology proposes a minimum-cost long-term generation expansion plan rather than implementing a merit-order for a single year. The values for the base year 2018, are assigned in a way that the model replicates the actual generation amounts in that year.

Table 2: *The subsidy schemes in the Baseline and Transition scenarios.*

Baseline							Transition						
2018	**2020**	**2023**	**2026**	**2030**	**2035**	**2040**	**2018**	**2020**	**2023**	**2026**	**2030**	**2035**	**2040**
10%							10%						
50%							50%	75%	75%	60%	60%	60%	60%
40%							40%	50%	50%	25%	25%	25%	25%
10%							10%						
25%							25%						
25%							25%						
10%							10%						
50%	35%	35%	35%	35%	35%	35%	50%	50%	50%	25%	25%	25%	25%
25%							25%						

Note: subsidy rates are implemented in the model as a percent reduction in the cost of generation.

Due to promising developments and projections of continued cost declines and improved performance of power storage technologies, the Transition scenario assumes storage technologies are available to balance the high shares of variable solar and wind in the system. Running the model without storage technologies (as a sensitivity exercise) has shown that significant fossil-fired capacity would be needed to satisfy the operating reserve and reserve margins which are defined to handle uncertainty in the intermittent technologies. The utilized capacities can be as seen in Table 3.

Table 3: *Storage capacities (batteries and pumped hydropower storage) in the Transition Scenario*

Year	Installed Capacity (GW)
2026	1.00
2030	2.10
2035	3.35
2040	4.77

The Transition scenario assumes an increase in productivity gains in the industrial sectors at a rate of 0.2% per annum[3]. These gains are envisaged to reflect efficiency gains in return to switching to new green technologies and increased investments along the sector. These gains are further to be realized as returns to the strategy of switching towards electricity-saving technologies. The enhanced availability of intermediate resources released from electricity sector enhance gains in sectors such as machinery, automotive, and petrochemicals competing for these resources.

To induce the transition to the renewables at the sectoral level, as well as to create an investable fund for the productivity enhancing technology adaptation, production taxes in fossil fuel sectors (coal and petroleum products) are increased gradually by 0.1%, per year. The additional tax revenues are disbursed in a lumpsum fashion to the enterprise sector. Thus, the tax revenues do not create any fiscal incidence for the government sector.

A significant increase in renewable shares in electricity generation occurs once the carbon tax is in place.

Additional sensitivity analyses further investigate the impacts of carbon tax, assumed discount rates, and subsidy schemes in the power sector model. A significant increase in renewable shares in electricity generation occurs once the carbon tax is in place, while higher tax rates rising to 40 US$/tonne in 2030 results only in a marginal increase. A low price on carbon is already enough to accelerate renewables deployment over fossil fuels. Moreover, the overall economic impacts of higher carbon tax are also investigated in the macroeconomic model by advancing the collected tax as additional public sector income to be used as an investment fund for environmental abatement. It also has to be underlined here that; the so-called "Neutral Tax" would be the case where the energy tax is "balanced" with reductions in existing taxes on other matters. See Appendix III for further results and discussion.

As indicated above, the comparison of the power generation in the Baseline scenario is solved from the bottom-up power system model and implemented to the top-down macroeconomic model as the Transition scenario. This path also adapts the emissions from the power system model and, via iteration on the sectoral emission coefficients, endogenously solves for the aggregate energy-induced emissions. This brings the emissions intensity down under the given power system model solution.

[3] The scenario runs follow quite modest expected gains in efficiency. Official data released by the Turkstat reveal, for instance, that over 1990-2019, carbon intensity (CO_2) fell from 0.300 kg/TL GDP to 0.240 kg/TL GDP. This reveals a fall of carbon intensity by 1.01% per year over this period. Likewise, The Shura Study on Energy Efficiency Under Transition shows that Turkey's primary energy intensity has fallen at a rate of 1.52% per annum over 2000 to 2018. Similarly, final energy intensity has also receded at a rate of 1.63% (SHURA, October 2020). The report also finds that over the same period, power stations had enjoyed a cumulative sum of efficiency gains on the order of 5 percentage points.

World Bank data underscores that Turkey's Energy use (kg of oil equivalent) per US$1,000 GDP (in constant 2011 PPP values) had been reduced from 91.5 kg in 1990 to 87.4 kg in 2012 (World Bank Millenium Goals, and EU Commission EDGAR data base). Finally, the Shura 2020 study projected that consumption of electricity in the industry in 2030 could be reduced from 138.3 TWh in the baseline to 133.9 TWh in the SHURA Efficiency Scenario, providing a gain of 1.02% per annum.

The CGE modelling assumptions over the baseline take these developments and projections and implement an efficiency gain of 0.1% per annum in value terms (in constant 2018 TRY prices). Carbon intensity of the energy sector falls from 0.500 kg/US$GDP in 2018 to 0.447kg447 kg/US$GDP by 2030. This amounts to an annual fall of 0.88% per annum over this period under the baseline and is comparable to the data and projections cited above.

5. Results and Discussion

5.1 Structural transition of the power system

Turkey's power system has undergone a remarkable period of growth over the last two decades, nearly tripling the installed capacity over that period. Thanks to a combination of low-cost renewables and government support including feed-in tariffs, renewable energy resources received over half of total investments into the power sector, with a large proportion of that investment occurring in the past decade. As a result, Turkey added 32.3 GW of renewable energy between 2010 and 2020, with nascent wind and solar industries accounting for over 40% of new renewable energy installed capacity. In 2020, renewables accounted for 42.5% of total power generation, including a 15.5% contribution from wind and solar.

The policies enacted in the Transition scenario result in a displacement of fossil-fuel capacity by a suite of renewable energy technologies, led by new wind and solar installations. Small increases in bioenergy, geothermal and some planned run-of-river hydropower also occur (See Figure 5). By 2030 wind and solar account alone account for 30% of total power generation, with all renewables accounting for 55. Although natural gas installed capacity decreases by one-third in the Transition scenario compared to the Baseline, the decrease in the share of natural gas in total generation is only marginal. This is in part due to reduced overall demand, but also due to increased utilisation rates of gas plants.

The policies enacted in the Transition scenario result in a displacement of fossil-fuel capacity by a suite of renewable energy technologies, led by new wind and solar installations.

Figure 6: *Installed capacities (left) and generation (right) by technology in 2020 and in 2030 for the Baseline and Transition scenarios. Source: TEIAS, 2020 and EMRA, 2020*

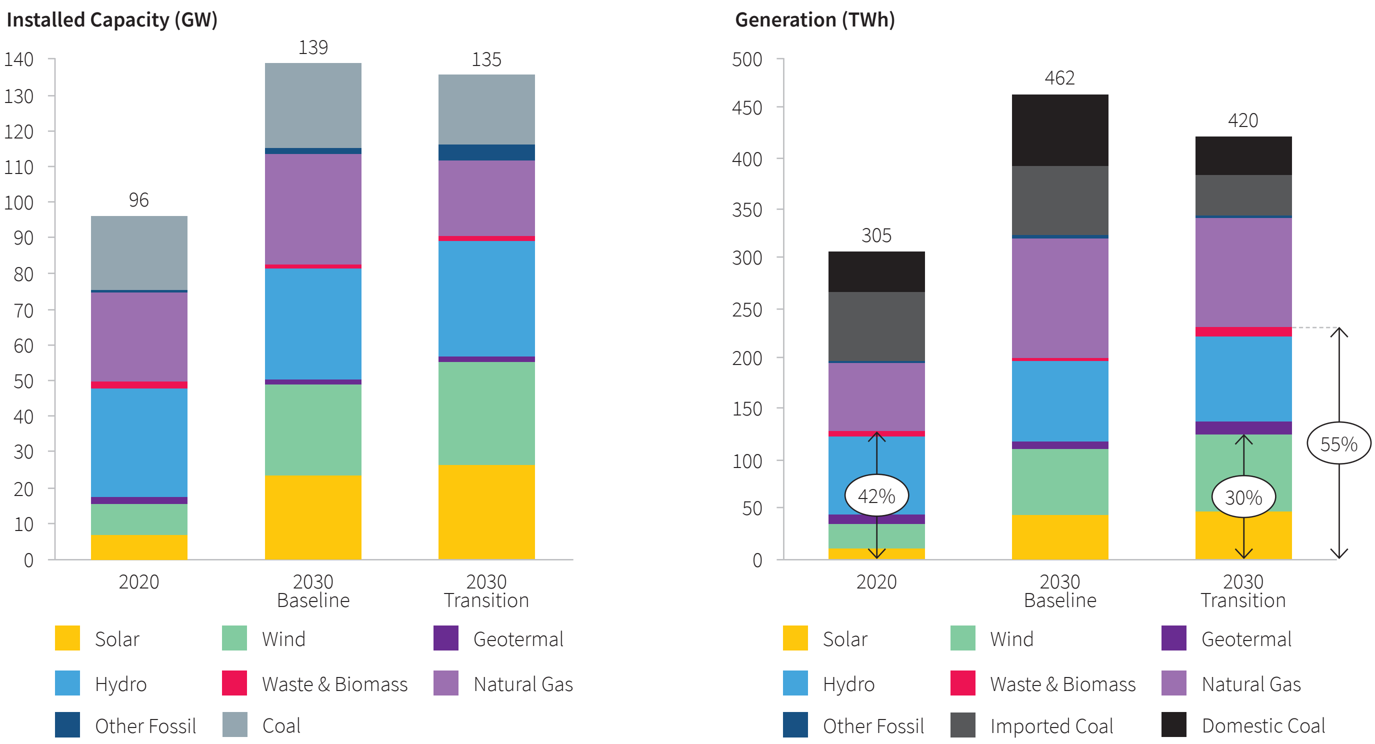


Table 4 summarises the main indicators in 2020 and for each scenario in 2030. Total installed capacity in the Transition scenario is lower than in the Baseline despite the significant increase in renewables with lower capacity factors mainly because of the nearly 10% decrease in total energy demand. While both scenarios result in similar levels of required investments, it is important to note that this does not mean that they are even in terms of cost effectiveness; the Transition assumes that additional investments will have been used to increase the rate of energy efficiency improvements in order to reduce total demand. The high penetration of variable renewables drives a 12 US$/Megawatt hour (MWh) increase in the market clearing price. Further detailed results of the power system model as well as sensitivity analyses are summarised in Appendix III.

Table 4: *Main indicators: Baseline and Transition*

			2020	Baseline 2030	Transition 2030
generation	total	TWh	304.9	461.8	419.7
installed capacity	total	GW	95.9	138.9	133
renewable generation	percent	%	42.5	43.5	55.1
solar & wind	total	GW	15.5	49.07	54.7
solar & wind generation	percent	%	11.7	24.0	29.98
natural gas	total	GW	25.7	30.8	21.9
natural gas generation	percent	%	22.7	26.0	25.4
coal	total	GW	20.3	23.6	18.9
market clearing price		US$/MWh	39.0	56.7	69.3
emissions intensity		gCO_2e/kWh	484*	440	343.3
Investment requirement	average	Billion US$		4.34	4.37

**As of 2019, latest available year*

5.2 Social and economic impacts of Turkey's power system transformation

The macroeconomic and social impacts of the Transition Scenario in comparison to the baseline are detailed in Sections 5.3 and 5.4. This section summarises the general findings and the overall net impacts.

Albeit small, the net gains in GDP and employment over the base path are significant and indicate that the transition will have an overall positive impact on the economy.

Two of the main indicators of economic development, GDP and employment, display small, but net positive gains in the transition scenario in comparison to the baseline scenario. Total growth in employment over 2018-2030 is about one-tenth the rate for total GDP. The slower rate of increase in employment in comparison to value added is a result, partly of the capital-intensive nature of the power system transition, but also of efficiency gains. Albeit small, the net gains in GDP and employment over the base path are significant and indicate that the transition will have an overall positive impact on the economy. Turkey's gross domestic product (GDP) in the Transition Scenario reaches US$ 1,143 billion (real, in fixed 2018 prices), an increase of 1% over the baseline in 2030. Total net employment gain in 2030 over the baseline is projected to be 43 thousand people, or 0.1%. The positive impact of the transition scenario will be mainly on industrial employment which is 1.5% higher than the baseline in 2030.

The main drivers behind higher GDP growth in the transition scenario are gains in efficiency and real wage income, both of which result in higher disposable income. By 2030, the rise in disposable income is projected to trigger savings and investment limiting growth of private consumption. The cumulative effect of efficiency gains and investments in the transition scenario trigger further GDP growth beyond 2030, increasing the gains of the transition compared to the baseline.

Socioeconomic benefits of the transition could exceed overall impact on GDP by 10%.

A summary of the overall net impacts measured in real 2018 values is shown in Table 5. The impact of the transition is defined as the difference between transition scenario value and the baseline scenario value of each indicator, where GDP is shown as the main indicator for the impact on national income and wage income for social welfare. Other socioeconomic welfare impacts included are the impact on trade balance of power generation imports and health and environment impacts. Power generation imports are included as an indicator of energy security. Socioeconomic benefits of the transition could exceed overall impact on GDP by 10%. By comparison, the benefit on overall trade balance is nearly as large as the impact on GDP. In addition, industrial transformation as measured by industrial value added is a significant contribution of the power system transformation. These benefits exclude potential gains from the phase-out of ineffective fossil fuel subsidies that currently account for about 1% of the total GDP and benefits that can be attained in non-power sectors representing 80% of Turkey's total final energy consumption.

Table 5: *Target Year Annual Transition Impact Summary (billion US$)*

	Baseline (2030)	Transition (2030)	Transition Impact (Transition-Baseline)
National Income Impact			
Real GDP	1131.6	1142.6	11.0
As percentage of Baseline GDP			***1.0%***
Overall Trade Balance Impact			
*Trade Balance**	-7.8	2.4	10.2
As percentage of Baseline GDP			***0.9%***
*Net Energy Trade Balance for Power Generation**	-6.2	-5.2	1.0
As percentage of Baseline GDP			***0.1%***
Industrial Transformation			
Industrial Value Added	730.1	770.8	40.7
As percentage of Baseline GDP			***3.6%***
Socioeconomic Welfare Impact			
Wage Income	332.8	341.5	8.7
*Net Energy External Trade Balance for Power Generation**	-6.2	-5.2	1.0
*Net Investment Goods External Trade Balance for Power Generation**	-2.9	-2.5	0.4
*Health Impact (Air Pollution)***	-2.5	-1.1	1.4
*Climate Change Impact (CO_2 Emissions)***	-5.1	-3.8	1.3
TOTAL Socioeconomic Welfare Impact			12.8
As percentage of Baseline GDP			***1.1%***

*Negative sign indicates that the trade balance is negative, meaning that imports exceed exports.
**Negative sign indicates that the value is a cost.

GDP in 2030 is 1% higher in the Transition Scenario compared to the Baseline.

5.3 Macroeconomic Results

The overall macroeconomic model results are summarised in Table 6, where results are shown as an index compared to 2018 values (in constant US dollars). Turkey's GDP in the Transition Scenario reaches US$ 1143 billion (real, in fixed 2018 prices), an increase of 1% over the baseline in 2030; in the long term to 2040, the transition impact raises the GDP by 3.4% over the Baseline.

Table 6: *Main macroeconomic results.*

Macroeconomic Results (Billions US$, 2018 Fixed Prices and Indexes 2018=100)					
	2018	2030		2040	
	Base Year	Baseline	Transition	Baseline	Transition
GDP	789.1	143.4	144.8	197.3	204.0
Private Disposable Income	669.1	138.2	140.4	190.0	200.9
Fixed Investment Expenditures	233.4	140.1	142.3	188.7	199.2
Private Consumption Expenditures	447.3	141.1	140.5	195.8	197.7
Public Sector Revenues / GDP (%)	15.5	15.6	16.4	15.8	17.0
Public Sector Budget Deficit / GDP (%)	2.0	0.6	0.6	0.5	0.5
Public Sector Domestic debt / GDP (%)	30.4	31.2	30.2	27.5	25.3
Trade Balance / GDP (%)	-2.95	-0.69	0.21	0.73	2.45
Share of Industrial Labor Employment in Total (%)	14.3	14.8	15.0	15.0	15.4
Index of Real Wages (2018=100)	100.0	126.3	129.7	159.9	164.3

Private disposable income increases in Transition scenario by 0.5% in 2030 and by 1.4% by 2040. The main mechanism in bringing out additional gains in private disposable income is the acceleration of real wages. Supported by improved real wages, private disposable income increases. Given the general rise in incomes, private savings also grow, which supports an increase in fixed investments of around 2 index points over the Baseline scenario in 2030 and reaches 10 index points by 2040. This indicates that the short- to medium term impact of the energy transition may be relatively small or even negative in terms of private consumption. In the long term, however, efficiency gains take hold and promote further gains in investable resources. The impacts of the energy transition compared to the baseline with respect to GDP (in Billion US$), and real wages are shown in Figures 7 and 8, respectively.

Figure 7: *Development of real GDP across Baseline and Transition scenarios*

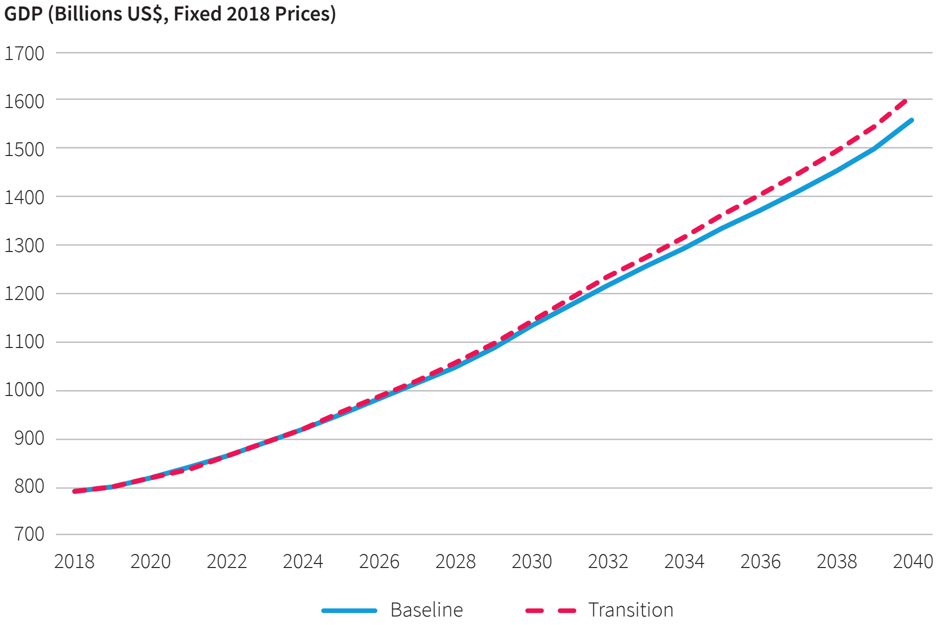
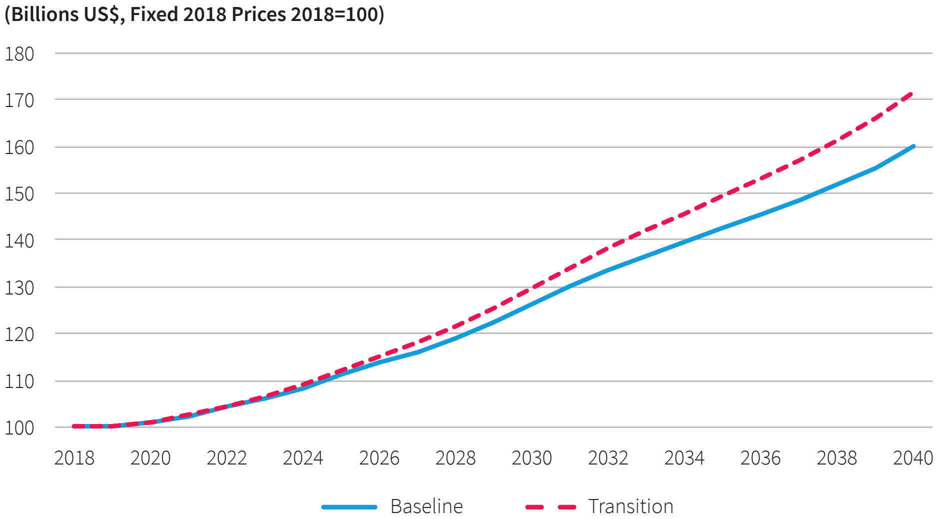


Figure 8: *Real wage Indexes across Baseline and Transition scenarios*



Industrial exports rise by 9% over the Baseline by 2030, causing the trade deficit to narrow.

The increase in savings, and the closing of the domestic savings-investment gap alleviates pressures of the foreign gap, in particular the trade deficit.[4] Industrial exports rise by 9% over the Baseline by 2030, causing the trade deficit to narrow. This is due in part to efficiency gains leading to higher exports which also drives the appreciation of the Turkish Lira. This, in turn, alleviates import costs. Accordingly, the real exchange rate, measured as the ratio of domestic good prices to that of imports, appreciates 12% by 2030. This appreciation translates the foreign costs of imports, especially of imported fuel oil and natural gas, into lower domestic costs denominated in local Turkish Lira and thereby increases the profitability of export-oriented industries, mainly in the machinery, automotive, and to a lesser extent in the iron and steel sectors.

[4] Given national income accounts, any (domestic) gap in the savings–investment balance manifests itself as a compatible gap in the foreign account, i.e., the current account balance.

The invigorated private incomes also allow for improved fiscal gains. Consequently, the public deficit narrows as budgetary revenues reach 17% of GDP by 2040. It is important to note that these impacts are non-linear, and the improvements to public fiscal balances occur only after 2030 once the gains due to energy efficiency improvements are realized. These external effects which spill over to the public sector go together with improvements in the foreign balance.

Box 3: Treatment of Real Exchange Rate in CGE Modelling

CGE models are basically driven by the Walrasian structure where optimizing decisions of producers and consumers are ultimately driven by relative prices. Over the decision of demand decision denominated in foreign currency, the model has to operate with a conversion variable, r. For most countries, and especially for the developing, it is reasonable to assume that the country is 'small' on world markets and cannot affect its international terms of trade. However, it is also reasonable to assume that world prices in the tradable sectors do not dominate the domestic price system. Based on this observation, the essence of the external-sector specification of most recent single-country CGE trade models can be captured with symmetric product differentiation for imports and exports.

Accordingly, an independent import demand function is generated given the hypothesis of imperfect substitutability of foreign traded goods relative to the domestically produced goods. This imperfection avoids the classic dichotomy of goods along a traded versus non-traded classification and offers, rather a continuum of substitutability between foreign and domestic demand given the relative prices. This relative price is what these models use as the real exchange rate. Note that this is an endogenously solved variable obtained from the general equilibrium system of the CGE, rather than the financial spot variable –the so-called r above. These issues are introduced and discussed further in de Melo and Robinson, 1989.

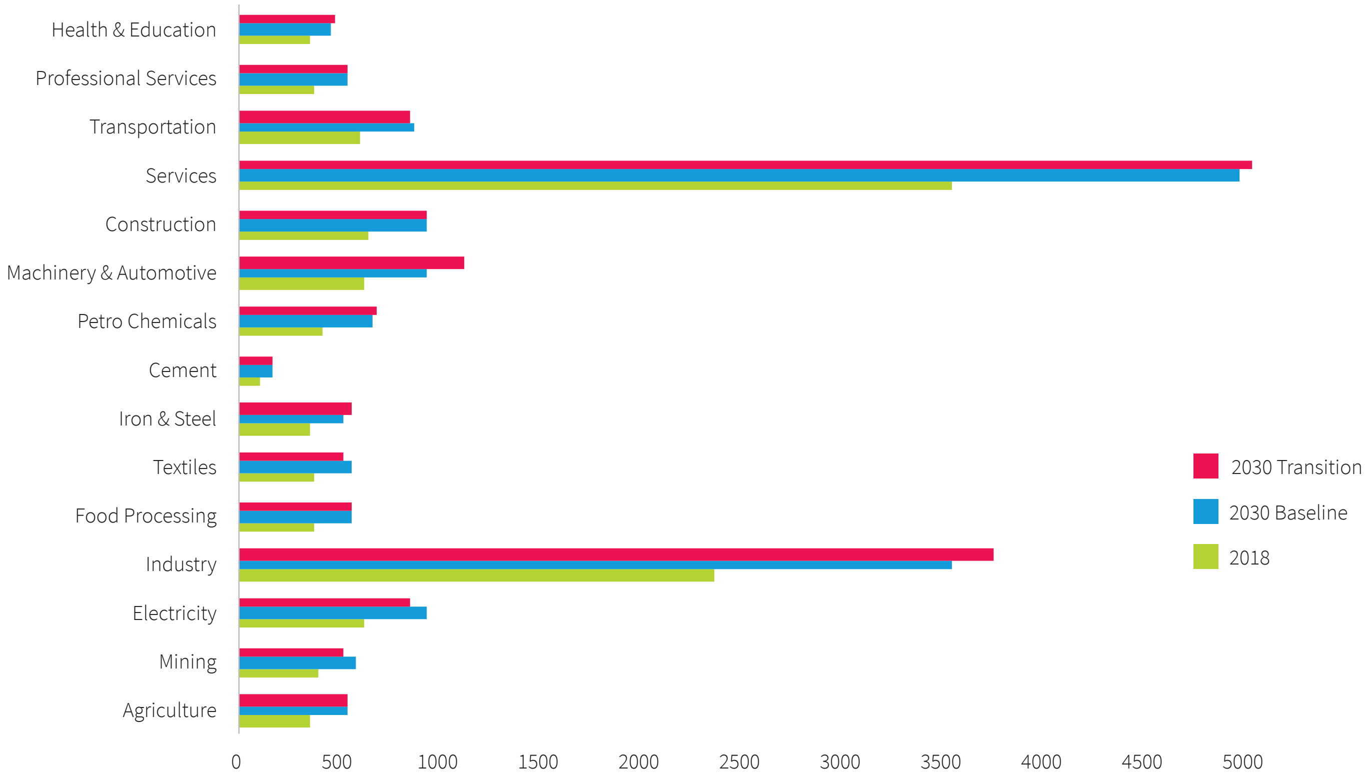
5.3.1 Sectoral Production

The sectoral production implications of these favourable macroeconomic results follow the conditions of cost minimization, implying that improvements in electricity efficiency will lead to a relocation of labour and capital towards industry. As the total value of electricity production in the Transition scenario falls by 13% compared to the Baseline in 2030, the electricity sector releases labour and capital to find employment for in the industrial sectors. The relative price of industry aggregates thus rises by 4.8% against the price of the energy aggregate, enabling industrial sectors to expand with the largest gains occurring in machinery, automotive, iron and steel and petrochemicals sectors.

In general, sectors which are more energy dependent and compete with the energy sector in using intermediates, gain from the transition due to the availability of energy with more favorable conditions.

In general, sectors which are more energy dependent and compete with the energy sector in using intermediates, gain from the transition due to the availability of energy with more favorable conditions. Export orientation also enhances the gains in production. In contrast, traditional sectors such as food processing and textiles remain weak, as these sectors experience lower rates of efficiency gains due to their relatively high reliance on labour intensity in production. As observed, one of the key results of the transition is the rise in the overall wage rate due to productivity gains emanating from expansionary investment growth in the Transition Scenario. Textiles and Apparel, a predominantly labour-intensive sector, faces a disproportional rise in wage costs relative to the high technology-driven industrial sectors, and fails to capture employment gains at the same scale as had been possible in those industries namely, Machinery, Automotive, Iron and Steel, and high technology driven services. The sectoral output results for 2030 are summarised in Figure 9 and shown in more detail in Appendix VII.

Figure 9: *Real Output by Sector (billion US$)*



The macroeconomic model suggests that the main mechanism for the sectoral shif is the transition from historically determined conditions of production traditionally based on capital-intensive manufacturing and wage cost minimization, to one of strategically driven production technologies that are less dependent on energy inputs.

The macroeconomic model suggests that the main mechanism for this sectoral shift is the transition from historically determined conditions of production traditionally based on capital-intensive manufacturing and wage cost minimization, to one of strategically driven production technologies that are less dependent on energy inputs. The sectoral shifts within industry that move away from traditional wage-competition to efficiency-led expansion act as the main driver of this adjustment. This path intrinsically saves on scarce foreign exchange and thereby reduces domestic industry's reliance on imports. Due to the higher productivity of the energy sector, intermediate demand for energy falls relatively in those industrial sectors that are the most energy-intensive, and consequently they enjoy cost savings that enable a greater expansion relative to traditional sectors.

The construction sector is expected to benefit from the expansion in fixed investments in the Transition scenario. Consequently, construction output increases over the Baseline by about 0.8% in 2030 and continues to grow to 2040. Despite the technical limitations of the macroeconomic model which obscure the detailed impacts of the energy transition on the construction sector, results show that energy efficiency improvements in the building sector will be based on very different dynamics than the traditional rent-seeking and will drive increased production in the construction sector based around the design and implementation of more energy efficiency building stock.

It is important to note that these structural shifts are non-linear and results from both models indicate that the impacts of energy efficiency improvements will take time and that the gains will not translate into higher production and employment overnight. Most of the benefits due to energy efficiency improvements will only be realized after 2030, with the greatest benefits occurring closer to 2040.

Box 4: Local Manufacturing of Renewable Energy Equipment

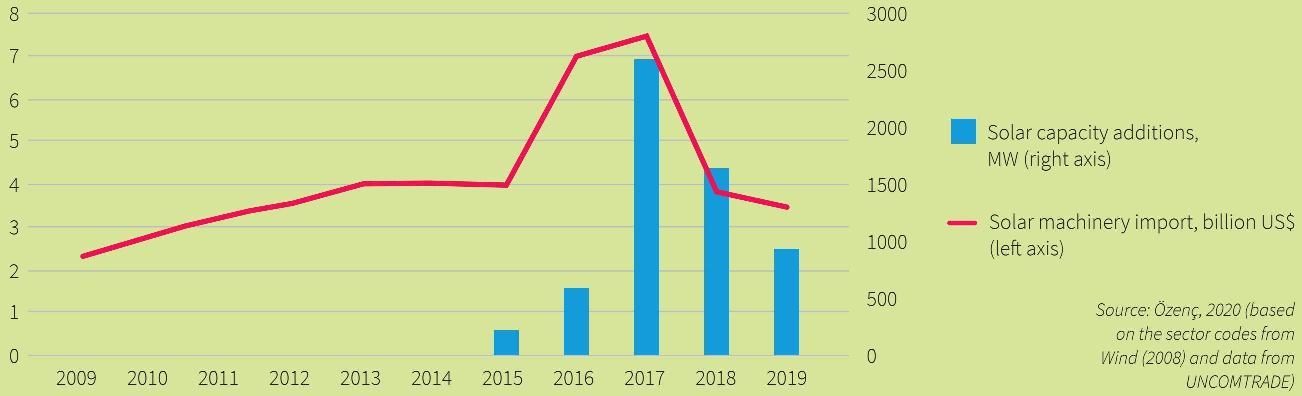
Turkey has been making strides in production of renewable energy equipment and the energy transition is likely to facilitate more local production, especially of equipment for wind and solar plants. The country already has a well-developed iron and steel and mechanical equipment manufacturing industry. Wind turbine blades and towers, as well as some mechanical parts of hydroelectric plants, are typically produced locally. Since 2019, the range of wind equipment produced in Turkey has expanded to include generators as well as turbine parts (TUREK, 2019). Wind equipment produced in Turkey is also exported and Turkey's wind equipment producers are positioned among the major players in Europe (Wind Europe, 2020). In 2016, a leading international producer of geothermal equipment started operations in Turkey and has been producing most of the equipment used in geothermal plants locally (Ormat, 2021).

Turkey opened its first integrated PV solar cell and panel manufacturing facility in 2020. The plant having an annual production capacity of 500 MW, is the only integrated facility in Europe and the Middle East. The factory was designed as part of the YEKA-1 auction held in 2017. The auction required the successful bidder to build and operate an integrated solar cell factory and research centre in exchange for land, grid allocation and 15-year power purchase guarantee for a 1000 MW solar plant. In addition to the recently established solar cell and panel factory, there are 15 PV panel plants with a combined annual capacity of 5.6 GW (STANTEC, 2020).

The development of renewable energy equipment manufacturing has been supported by government incentives; mainly local content requirements in the YEKA auctions and the premium provided for local content in the YEKDEM (feed-in-tariff scheme) . The current YEKDEM, which is effective for plants becoming operational till mid-2021, has a premium for locally sourced components differing by renewable technologies and type of component. In 2021, of the 927 plants with a combined capacity of 23.1 GW benefitting from the scheme, 25% used some locally manufactured components and benefitted from the premium tariff. The YEKDEM list shows that locally manufactured equipment is currently used mostly in geothermal and wind plants. Two out of three geothermal plants and about one third of wind plants in operation contain locally produced components; however, this holds for less than 10% of hydroelectric and biomass plants. The YEKDEM list also reveals that, based on the amount of premium obtained in power plants using locally produced components, the ratio of local content in total equipment is as high as 70% in geothermal plants and about 55% in wind plants.

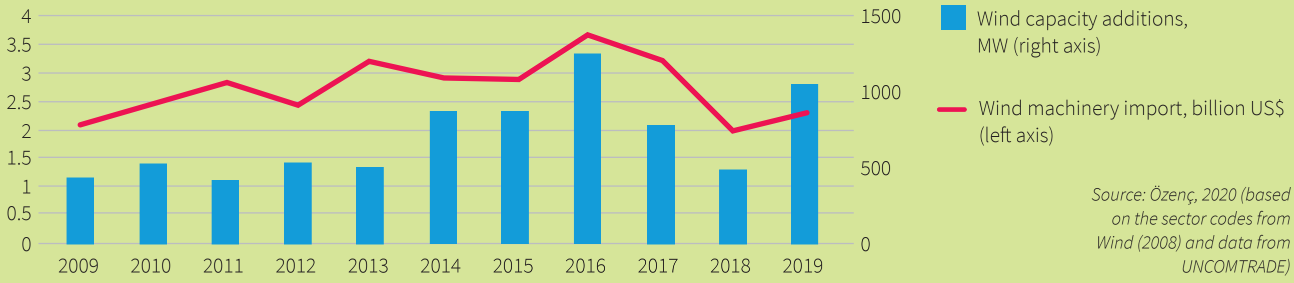
While there has been significant progress in local production of renewable energy equipment, the question of reliance on imported equipment for renewable energy investments remains. Previous trends in the imports of machinery and equipment mostly used in solar power production and those used in wind power production to a limited extent are correlated with the solar and wind capacity additions respectively, as displayed in Figure 14 and Figure 15. The figures reveal that imports of solar and wind equipment demonstrate a declining trend in recent years, accompanied by increased or steady exports in the machinery manufacturing industries, specifically when solar equipment are considered (Özenç, 2020).

Figure 10: *Import dependency of solar power equipment in relation to solar capacity additions*



Source: Özenç, 2020 (based on the sector codes from Wind (2008) and data from UNCOMTRADE)

Figure 11: *Import dependency of wind power equipment in relation to wind capacity additions*



Source: Özenç, 2020 (based on the sector codes from Wind (2008) and data from UNCOMTRADE)

Yet, decreasing the import dependency in solar equipment and machinery will require more effort. According to UNCOMTRADE statistics, during the period 2018-2019, solar machinery exports remained at a steady level (at around US$2 billion) while solar equipment imports have fluctuated highly reaching US$7.5 billion US$ in 2017. Turkey's trade deficit for this equipment increased to 5.6 billion US$ in 2017, more than twice the 2013-2015 values, dropping to an average of US$1.3 billion during 2018-2019 (Özenç, 2020).

Through increased local production of energy equipment, net imports of investment goods for energy investments, particularly renewable energy equipment, is expected to be lower in the Transition scenario. The share of net imports is expected to decline from 55% to 45% in wind investments and from 65% to 55% in solar investments in the Transition scenario compared to the Baseline.

Exports increase rapidly due to the efficiency gains enabled by the transition.

5.3.2 Sectoral Exports and Imports

Both imports and exports are higher in the Transition scenario compared to the Baseline. Sectoral exports increase rapidly due to the efficiency gains enabled by the transition. Given the structural parameters of export-orientation displayed in the relative price of exports to domestic costs and energy intensity, machinery and automotive expand. This sets the stage for increased share of these sectors in generating employment demand as well. The increased production and exportation will also eventually increase import demand. This is due to the import-dependence of Turkey's domestic industry. Nevertheless, the difference in industrial exports between the Transition and Baseline scenarios is nearly twice as large as that in industrial imports. In 2030 it is estimated that industrial exports will be 24 billion US$ higher than the baseline whereas industrial imports will be 14 billion US$ higher than the baseline. The sectoral export and import results for 2030 are summarised in Figure 10 and Figure 11 and shown in more detail in Appendix VII.

Figure 12: *Exports by Sector (billion US$)*

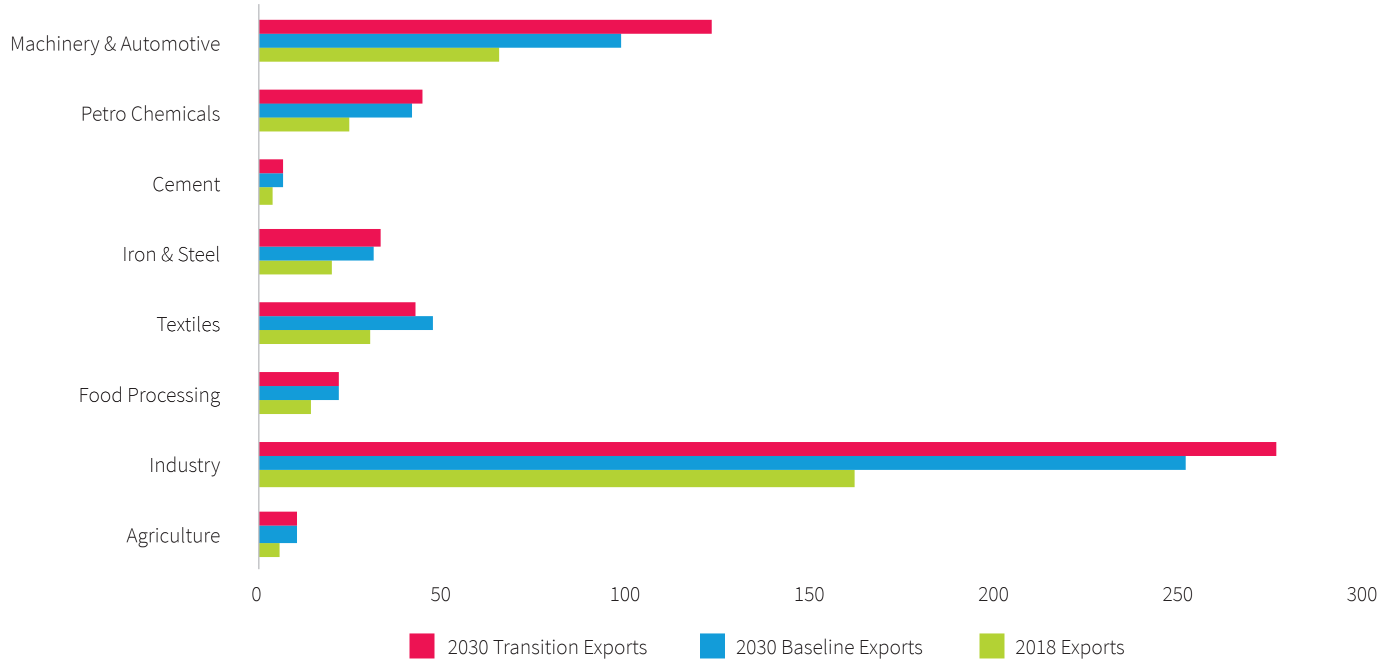
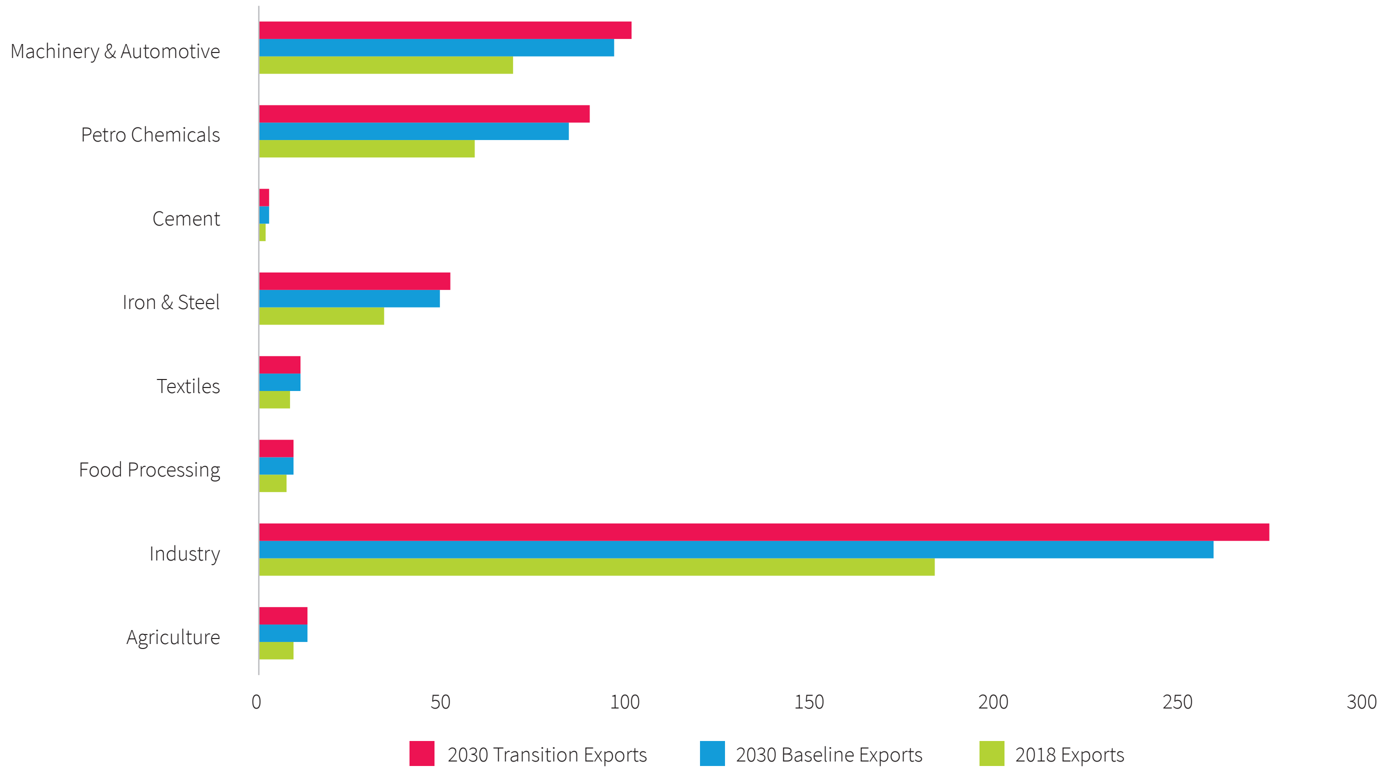


Figure 13: *Imports by Sector (billion US$)*



The gain in exports, the utililization of domestic intermediates and domestically produced renewable resources lead to higher domestic value added.

The energy efficiency improvements engendered in the Transition scenario will, however, lead to reduced overall energy import costs and allow for industrial sectors to have greater access to foreign currency savings for expanded investments and capital accumulation. As energy imports, especially oil and gas, typically account for two-thirds of Turkey's current account deficit, energy efficiency improvements reduce total energy demand and mitigate the need for expensive energy imports, which ultimately improve Turkey's trade balance (see Table 6). This is evident in the Baseline scenario, where autonomous efficiency improvements help to turn the trade balance on commodity imports to a marginally positive figure by 2040. This shift is accelerated in the Transition scenario due to increased domestic renewable power generation and additional electricity efficiency improvements which cause an additional decline in total power demand. Thus, the gain in exports results in the utilization of domestic intermediates and domestically produced sources of renewables, leading to higher domestic value added. It is this structural characteristic of the energy transition that allows for a more labour-intensive expansion of industry to pulls real wage incomes upward.

5.3.2.1 Avoided costs of imported fuels

As renewable energies begin to displace the use of fossil-fuels in the Transition scenario, both in power generation but also in transport and heating, this also has a significant impact on reducing costs of imported fuels into the Turkish energy system. In 2019, Turkey spent a total of 41.1 billion US$ on imported fuels, contributing significantly to Turkey's 29.5 billion US$ current account deficit that year. Reducing this deficit has become a top economic policy priority for the Turkish government. The use of renewables in the power sector alone allows for cumulative savings of around 11 billion US$ between (2020-2030), or annual savings of 1 billion US$, in the Transition scenario compared to the Baseline.

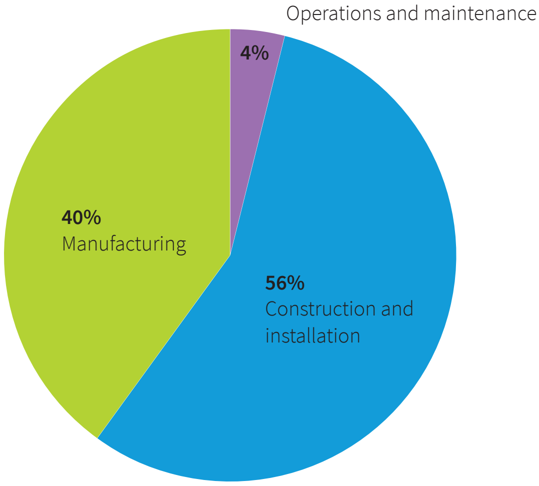
5.4 Social Impacts

5.4.1 Employment

New investments in renewable energy have the potential to generate 590 thousand jobs between 2018 and 2030, which corresponds to 68 thousand more jobs compared to the Baseline.

Baseline scenario results in 32.9 million jobs by 2030, corresponding to an increase of 4.2 million jobs over 2018. Transition scenario results in 32.96 million jobs, indicating a small, but net positive impact overall. New investments in renewable energy have the potential to generate 590 thousand jobs between 2018 and 2030, which corresponds to 68 thousand more jobs compared to the Baseline. Most of the jobs created by renewable energy are in the investment stage, especially in equipment manufacturing. Distributed energy, especially rooftop solar, is expected to create jobs in construction & installation as well as operation and maintenance. Energy efficiency, while reducing employment in power generation, is expected to create 36 thousand additional employments, compared to the Baseline scenario, in different sectors.

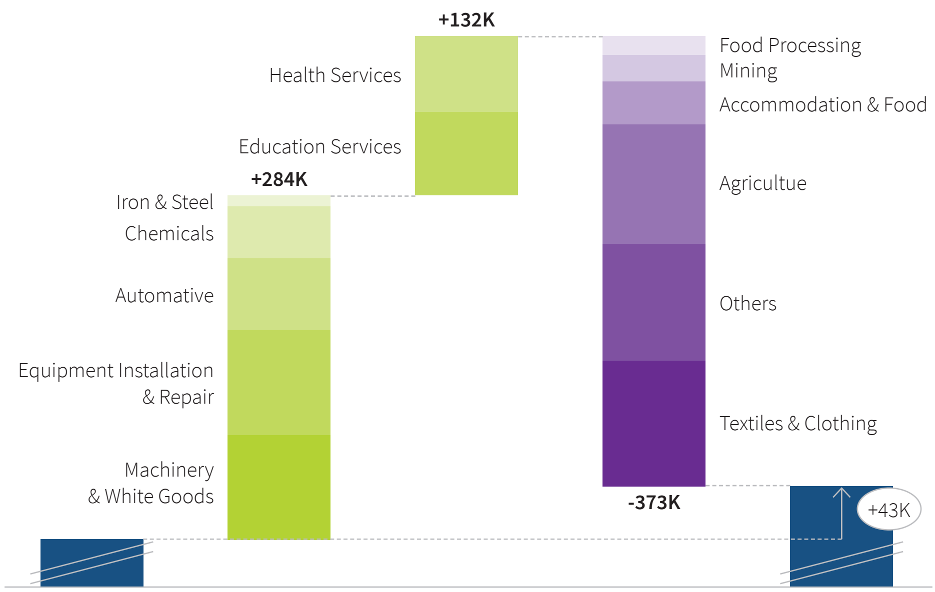
Figure 14: Types of new jobs related to wind and solar in Turkey



Overall, transition has a small, net positive impact on employment, creating 43 thousand cumulative additional jobs compared to the baseline in 2030, equivalent to a net increase of 0.1% over the Baseline.

Overall, Transition has a small, net positive impact on employment, creating 43 thousand cumulative additional jobs compared to the baseline in 2030, equivalent to a net increase of 0.1% over the Baseline. While the increase with respect to Baseline is marginal, new employment areas in sectors such as information and communication technologies that emerge with energy transition and digitalisation sectors are excluded from this analysis. When these and other sectors are accounted for, the impact will likely be higher. The total net employment gain over the period 2018-2030 is 4.2 million, representing a growth in employment of 14.6%. Growth in employment over the targeted period is significantly lower than GDP growth. While the ratio of value-added increase to the level of growth in employment is an indication of significant productivity growth overtime, the effect on social welfare needs to be considered. Nevertheless, from the point of view of energy transition, the overall employment impact is deemed neutral while there is considerable variation in individual sectors.

***Figure 15:** Cumulative change in jobs by economic sectors in 2030, Transition scenario in comparison to the Baseline*



With energy transition, the largest employment gains occur in high growth sectors such as machinery and white goods (85 thousand additional jobs over the Baseline), installation & repair (85 thousand additional jobs over the Baseline), automotive (63 thousand additional jobs over the Baseline) and chemicals (42 thousand additional jobs over the Baseline). Some of these high growth sectors, such as machinery & equipment and installation & repair also provide intermediate goods for the energy transition. Also, iron and steel, expected to provide 8-9 thousand additional jobs over the Baseline, is both an important intermediate goods provider and beneficiary of efficiency gains.

Employment gains are also expected in services sectors, such as education and care services (132 thousand additional jobs over the baseline). Gains in the services sector are associated with skills development required by the transition as well as upgrading in social services with improved quality of life afforded by health and environment benefits.

Employment in mining sector is 21 thousand lower than the Baseline scenario, though still 2-3 thousand higher than in 2018. Reduced electricity generation compared to the baseline due to energy efficiency results in two thousand fewer jobs in the electricity sector compared to the baseline, though employment in the sector will have grown by 38 thousand since 2018. Nevertheless, additional jobs in the energy sector which may be created due to digitalization and energy management, triggered by electrification, distributed generation and energy efficiency, are not captured entirely in the current study.

5.4.1.1 General Employment Results

Table 7 describes the change in total employment levels across the Baseline and Transition scenarios in 2030 and 2040, where employment changes can be considered as the employment impacts of the energy transition as a whole, i.e., the combined impacts of increased renewable energy, energy efficiency improvements and end-use sector electrification.

As the CGE model uses macroeconomic sectoral aggregates, Electricity (EL: Electricity) is a combination of the employment numbers from the electricity, gas, steam and air conditioning, supply and water supply; sewerage, waste management and remediation activities (D.35 and E36-E39 according to NACE Rev.2). According to TurkStat's Annual Industry and Service Statistics (2020), total employment of 288 thousand in the electricity sector includes both registered formal (207 thousand) and non-registered informal (81 thousand) employment.

According to Turkstat, in 2018, 114 thousand people were employed in the D.35 sector (D35 - Electricity, gas, steam and air conditioning supply), of which 49.8 thousand (~44%) worked in electricity generation (D.3511). According to the calculations based on governmental reports, SHURA analysis suggests around 8 thousand people work in coal-fired power generation, 4 thousand in gas-fired power plants, and the remaining more than 35 thousand people in renewable power generation.

*Table 7: Total employment impacts in 2030, Baseline and Transition scenarios**

(in 1000)	Total Employment	Total Employment Baseline	Total Employment Transition	Change in employment Transition	Change in employment Transition - Baseline
	2018	2030	2030	2030-2018	2030
AF: Accommodation & Food	1,611	1,794	1,759	148	-2.0%
AG: Agriculture	4,739	5,562	5,465	726	-1.8%
AT: Air Transport	295	332	298	3	-10.3%
AU: Automotive	215	255	318	103	24.8%
CE: Cement	305	353	351	46	-0.4%
CH: Chemicals	410	528	570	161	8.0%
CN: Construction	1,972	2,222	2,202	230	-0.9%
EL: Electricity	288	328	326	38	-0.6%
ES: Education Services	1,682	1,908	1,977	295	3.6%
FO: Food Processing	610	698	685	74	-1.9%
FS: Financial and Real Estate Services	1,044	1,180	1,175	131	-0.4%
HE: Health Services	1,383	1,570	1,632	249	4.0%
IS: Iron and Steel	172	205	214	42	4.3%
MI: Mining	150	173	153	3	-11.9%
MW: Machinery, White Goods	990	1,159	1,244	253	7.3%
OE: Other Economy	4,677	5,297	5,381	705	1.6%
PA: Paper Products	144	169	168	23	-0.8%
PE: Petroleum Products	10	12	10	-1	-19.2%
PR: Professional Services	1,337	1,513	1,508	171	-0.3%
PS: Postal and Courier Services	93	105	104	11	-0.5%
RT: Retail trade	3,960	4,448	4,435	475	-0.3%
TE: Textiles, Clothing	1,242	1,477	1,373	131	-7.0%
TR: Transportation	1,175	1,343	1,338	163	-0.4%
TS: Tourism	233	254	243	9	-4.2%
Total employment	28,738	32,883	32,926	4,188	0.1%

**see Appendix VII for long-term effects to 2040*

Those sectors that potentially provide inputs to the aggregated electricity sector, or provide intermediate goods, experience positive employment impacts. This includes sectors such as Machinery and Automotive (85 thousand additional jobs compared to Baseline in 2030), Iron and Steel (9 thousand additional) and subsectors contained within Other Economy, in particular those subsectors that focus on the repair and installation of machinery and equipment or other manufacturing.

The Education and Health Service sectors also see higher levels of employment due to Transition.

The Education and Health Service sectors also see higher levels of employment due to transition. In this context, Education sector comprises pre-primary to post-secondary education as well as cultural education and educational support activities. The growth in Education Services (62 thousand more than the Baseline in 2030) is driven in part by the need for better educated and trained workers that will fill new positions related to renewable energy and electrification. Education services will need to pivot in order to provide this new workforce with the skills and knowledge required by the renewable energy industry along the supply chain. Health Services include the Nace categories Q86-Q88-Human health and social work activities, which cover Human health activities, Residential care activities, and Social work activities without accommodation. It is likely that the additional jobs in this sector arise mainly due to increased investments into energy efficiency improvements. These findings are corroborated by a recent IEA report on energy efficiency suggesting that governments can pave the way to boost energy efficiency investments "by channelling them into public buildings, such as social housing, schools, healthcare facilities and government offices". Employment benefits could be accentuated if additional funding is channelled into building new or upgrading existing schools, hospitals, or homes to be more energy efficient. This presents a window of opportunity for economic stimulus programs seeking to kick-start economies after COVID-19 driven recessions and 'build-back-better'. For example, over 200 thousand jobs were created due to stimulus programmes that aimed to rebound from the 2008 global financial crisis.

Employment in sectors directly related to power generation from fossil fuels or those that do not benefit from efficiency gains will be lower in the Transition compared to the Baseline.

Certain sectors will experience negative employment impacts because of the power system transition. Mining sector stands out due to the possible closing of lignite mines. Mining sector will employ 21 thousand fewer people under Transition compared to Baseline, corresponding to 14% of total mining employment in 2018. As discussed in the analysis of sectoral impacts, those economic sectors whose growth is slower in the Transition due to efficiency gains, e.g., textiles and food processing, also experience job losses. These negative impacts could be mitigated through complimentary social policies incorporating just transition principles such as employment, infrastructure, and rural development programs.

Focusing on the aggregated electricity sector in 2030, model results show the sector employs 2 thousand less people in 2030 compared to the baseline. This can be partly attributed to declining production in the mining, petroleum, and gas sectors (see Table 7), and some employment shifting from traditional fossil-based energy supply sectors to modern renewables. In general, the installation of renewable energy capacity and operation are more labour- and skill-intensive than fossil fuel sectors (Mathews and Tan, 2014). However, it has been argued that different stages of the energy transition will require different skill levels; highly skilled labour is favoured during the early stages due to technological innovation and increased research and development, whereas demand for lower-skilled labour will only grow as the transition progresses (Czako, 2020). Thus, one of the generalised employment impacts of the energy transition in Turkey is higher wages in related sectors such as renewable energy generation, machinery, and installation of machinery and equipment.

However, there will be new and emerging sectors in which employment impacts of transition are obscured due to the aggregated structure of the CGE sectors investigated here, notably energy service companies that deliver new business models and the IT and digital service sectors that will be crucial for enabling and managing this transition. As the global energy transition is being realised in "parallel to and in the

Usually, innovating firms attract jobs from non-innovating firms and there is a reallocation of labour from the more traditional industries towards modern industries.

context of digitalisation" (Czako, 2020), this will drive an associated transition in the required education and skills in sectors seeking to capitalise on these opportunities. "Demand towards medium- and high-skill sets will increase in the renewable energy sector as well, in connection with automation and remote operation increasing demand for information and communication technology (ICT) skills. A simultaneous shift in demand towards more multidisciplinary knowledge is also likely in the context of new business models and societal initiatives, including social enterprises" (Czako, 2020: 37). These dynamics reflect Josef Schumpeter's theory of innovation and technological change as 'creative destruction', i.e., a process of destruction of old technologies. Whether this destruction results in a higher or lower number of jobs depends on whether the innovation is either process- or product-oriented (Greenan and Guellec, 2000). Usually, innovating firms attract jobs from non-innovating firms and there is a reallocation of labour from the more traditional industries towards modern industries, as exemplified by the labour decline in agriculture, mining, textiles and clothing sectors above.

The results are consistent with findings of the IEA (2020) and OECD (2020), revealing that the majority of job creation over the next two decades are expected to take place in renewable power generation and services (mainly education and health among others), while several manufacturing sectors, agriculture, food production and fossil-fuel based power are expected to record job losses.

5.4.1.2 Employment impacts due to increased shares of renewable energy in total generation

The employment impacts due to the increased build out of renewable energy was estimated using two methods. The employment factors approach uses regional multipliers per megawatt installed across three categories: manufacturing, construction and installation (C&I), and operations and maintenance (O&M) as derived in Ram et al. (2020). Decomposition analysis, on the other hand, uses the CGE model results on average wages to estimate employment generated using coefficients of renewable labour input share (see Appendix IV for more detail).

Table 8 summarises the results for the Transition scenario using the employment factors approach for wind and solar PV. In 2030 the 36.4 GW solar PV and 38 GW wind generate 62,694 O&M jobs by 2030.

Table 8: *Jobs to be created in the Turkish wind and solar sectors by 2030 assuming only onshore wind and utility-scale solar PV are deployed.*

	2030		
Technologies	Manufacturing [000 Job-yrs]	C&I [000 job-yrs]	O&M [000 job-yrs]
Wind onshore	304	207	19
PV Utility-scale	414	804	43

Source: authors' calculations
**see Appendix VII for long-term effects to 2040*

Initially, manufacturing, construction and installation generate the bulk of the jobs, however over time, ongoing operations and maintenance services employ more people. In Turkey, the accelerated expansion of wind and solar PV cause a total of 718 thousand job-years in manufacturing and 1,7 million job-years for C&I stage by 2030. Manufacturing jobs are expected to occur mainly in the metals (iron and steel, copper, etc.), machinery and electrical equipment sectors.

Calculations based on decomposition analysis shows that in 2030 total employment in wind and solar energy will be 63.8 thousand in the Baseline scenario and 71.3 thousand in the Transition. The results obtained through decomposition analysis are consistent with the estimated O&M employment calculated through the employment factors approach (see Table 8). Based on the decomposition analysis, the transition scenario will create 7.5 thousand net employments stemming from increased share of renewable energy[5].

A net positive impact on employment attributable to energy efficiency and electrification under the Transition scenario can be perceived as a favourable inclination.

5.4.1.3 Employment impacts due to efficiency gains and electrification

The Transition scenario envisaged by SHURA encompasses energy efficiency and electrification in addition to increase in the share of renewable energy. The analytical tools used in this study do not provide direct information on the impact of energy efficiency and electrification on employment. However, it can be assumed that the total net impact of the Transition is the sum of the net impacts of renewable energy, energy efficiency and electrification. In 2030, the total net employment gain in Transition compared to Baseline is 0.1% or 43 thousand people, as shown in Table 7. Decomposition analysis shows that employment gain due to increased share of renewable energy in 2030 is 7.5 thousand people (see Section 5.4.1.2) in Transition compared to Baseline. It can therefore be inferred that the remaining 35.5 thousand net gain is due to the combined impact of energy efficiency and electrification. Nevertheless, due to limitations of the CGE model methodology, the employment impacts of electrification versus energy efficiency cannot be disaggregated as they do not represent single sectors but show inter-sectoral relationships in relation to energy and electricity. While a detailed analysis has not been possible, a net positive impact on employment attributable to energy efficiency and electrification under the Transition scenario can be perceived as a favourable inclination. On the other hand, as the CGE model and I/O analysis treats energy efficiency simply as a reduction in power demand, most of the resulting employment impacts emerging from the model are negative.

The energy transition will create direct and indirect employment impacts on all sectors that use electricity as an intermediate input in their production. It implies that the reduction in electricity demand due to improved energy efficiency will impact all sectors, including the electricity sector itself. The impacts impinging on the EL sector itself are called direct employment effects, whereas those on other sectors are indirect effects. Table 9 summarises direct and indirect employment effects created by energy efficiency improvements leading to reduced electricity demand. Positive employment effects compared to 2018 occur in the EL: Electricity, CN: Construction, RT: Retail trade, FS: Financial and Real Estate Services, and HE: Health Services sectors, triggered by lower EL final demand. In all other sectors, energy efficiency is estimated to imply job losses by 2030 compared to 2018.

[5] Decomposition analysis was only applied to wind and solar energy since the difference in installed capacity for hydroelectric and other renewables between the baseline

When compared to the Baseline, energy transition creates negative direct employment effects in the aggregated electricity sector, as the sector needs to employ less labour due to reduced energy demand. Indirect employment effects in the other sectors due to lower electricity demand are negative in comparison to the Baseline scenario as well, as the sectors will need to employ less labour owing to energy efficiency.

Table 9: *Employment generated by electricity demand*[6]

	2018	Baseline 2030	Transition 2030	Transition 2030-2018	Transition Baseline
AG: Agriculture	5,687	4,296	4,082	-1,605	-214
MI: Mining	40,847	41,473	38,128	-2,719	-3,345
FO: Food Processing	542	458	443	-99	-15
TE: Textiles, Clothing	1,747	1,279	1,214	-533	-65
OE: Other Economy	42,735	36,321	35,196	-7,539	-1,125
PA: Paper Products	1,883	1,318	1,285	-598	-33
PE: Petroleum Products	309	201	167	-142	-34
CH: Chemicals	5,869	2,366	2,340	-3,529	-26
CE: Cement	3,650	3,425	3,335	-315	-90
IS: Iron and Steel	1,426	705	688	-738	-17
MW: Machinery, White Goods	9,930	6,074	6,086	-3,844	12
AU: Automotive	189	104	107	-82	3
EL: Electricity	166,930	185,198	183,010	16,080	-2,188
CN: Construction	7,516	7,918	7,783	267	-135
RT: Retail trade	18,969	18,479	17,954	-1,015	-525
TR: Transportation	13,133	11,916	11,435	-1,698	-481
AT: Air Transport	1,585	1,266	1,190	-395	-76
PS: Postal and Courier Services	958	913	891	-67	-22
AF: Accommodation and Food	2,899	2,615	2,537	-362	-78
PR: Professional Services	17,747	15,962	15,530	-2,217	-432
FS: Financial and Real Estate Services	23,984	24,919	24,488	504	-431
TS: Tourism	300	254	245	-55	-9
ES: Education Services	1,137	1,084	1,055	-82	-29
HE: Health Services	22	22	21	-1	-1
TOTAL	369,994	368,566	359,210	-10,784	-9,356

Note: Employment loss in the electricity sector due to lower electricity demand is the direct effect of energy efficiency, whereas losses in all the remaining sectors are indirect sectoral employment effects of energy efficiency improvements. The effects displayed here are those that are not stemming from renewable energy or electrification, but only from energy efficiency resulting in lower energy demand in most of the sectors.
**see Appendix VII for long-term effects to 2040*

[6] The total employment in the electricity sector in 2018 due final electricity demand is not equal to total employment in the electricity sector, because other components of final demand such as heating and cooling also exhibit an employment effect on the sector. So, the cumulative impact of energy efficiency improvements on the electricity sector are 288 thousand total jobs (see Table 7), compared to 167 thousand due to only electricity final demand in 2018 (see Appendix V for detailed explanation of how I/O methodology calculates employment impacts).

As the CGE model treats energy efficiency as a reduction in power generation, it cannot capture the effect of increased investment in energy efficiency and electrification. Generally, the number of jobs created at construction, installation, and manufacturing stages may be more relevant for an energy efficiency investment program, which is not examined here. We would expect that such investments would trigger employment at C&I and manufacturing stages more quickly than employment at O&M stages (Juchau and Solan, 2013). The decomposition analysis combined with the CGE results, presented at the beginning of this section, may have captured some of these impacts though it is still not possible to separate the effect of energy efficiency from electrification.

5.4.1.4 Employment Impacts of Digitalisation, Storage and Distributed Generation

The CGE modelling and I/O Tables used in this study is unable to provide a clear indication of how new technologies, such as battery storage and increased digitalisation will impact employment in the Transition scenario.

Much of the employment will be in new business areas like energy efficiency, demand response, distributed energy and peer-to-peer trading that did not exist before.

Digitalisation will be part of both investments and operations relating to both renewable energy and energy efficiency. New employment and highly skilled employment will need to be created to design and integrate digital systems for renewable energy plants at both the utility and distributed scales and for their successful integration into the grid system. Digitalisation is also an integral part of operating an efficient and flexible transmission and distribution grid integrated with renewable energy, storage, and consumer demand response. While digitalisation will create many relatively high skilled and high paying jobs, especially in the initial stages of the power system transition, there may be concern over digital systems replacing workers in certain areas. Nevertheless, much of the employment will be in new business areas like energy efficiency, demand response, distributed energy and peer-to-peer trading that did not exist before. Therefore, the overall impact needs to be explored in more detail.

Another area whose impact needs to be explored is storage and the production of batteries for electric vehicles and grid storage. Investment is currently underway for a large-scale production facility for nickel-cobalt batteries and the factory plans to employ 2.5 thousand people upon completion (Dünya, 2018, Ekonomist, 2021). The planned new employment is in similar magnitude as the loss in employment in the electricity sector due to energy efficiency.

One other impact that is not included in the current study is that of distributed renewable energy, especially rooftop solar, which has twice as much employment potential as utility scale solar at the construction and installation and operation and maintenance stages (Ram et.al., 2020).

On the whole, the impacts of digitalisation, storage and distributed energy, which are not completely accounted for and quantified in this study, represent a substantial upside to the employment impacts of the Transition scenario.

Box 5: Comparison with Other Energy Transition Experiences in the World

In this section we briefly compare the above employment results with countries similar to Turkey in terms of unemployment or energy import bills, as well as global trends.

In 2018, around 11 million people were employed in the Renewable Energy (RE) sector, up from 7.3 million in 2012 (IRENA, 2019), with the greatest expansion experienced by solar PV, reaching over 3.6 million in 2018. By 2050, total employment in RE is expected to reach 42 million globally (as shown below).

A similar study modelled the employment impacts due investments in energy efficiency and renewable energy in Germany, Spain, and Greece, also using national input-output analysis. Each of Germany, Spain and Greece are net fossil fuel importing countries, like Turkey. The fossil fuel production activities in these countries are small in comparison with a clean energy investment project at 2.5 percent of GDP or greater. As a consequence of power system transition, these economies will be able to reduce their energy import bills as their domestic clean energy sectors become capable of providing an increasing share of their economy's overall energy supply. Correspondingly, this import substitution effect will become an increasing source of job creation in all three countries, along with all other net fossil fuel importing economies. The cases of Greece and Spain could be good examples for Turkey of how energy transition could create new jobs together with lower energy import bills via import substitution in countries with high unemployment rates.

Although we have not employed an investment perspective in regard to energy efficiency in the current analysis, it is noteworthy that energy efficiency investments might create additional jobs in the world of an economic recession due to the pandemic. Ungar et al. (2020) analyse the employment and income effects of energy efficiency investments in homes and commercial buildings, EVs, transportation infrastructure, manufacturing plants, small businesses, states, and cities. Their results prove that "the proposed investments would result in 660,000 more job-years (that is, people working for a year) through 2023 and 1.3 million added job-years over the lifetime of the investments and savings" (Ungar et al., 2020: iv).

Job Creation in Germany, Spain and Greece throguh Energy Efficiency and Clean Renewable Energy

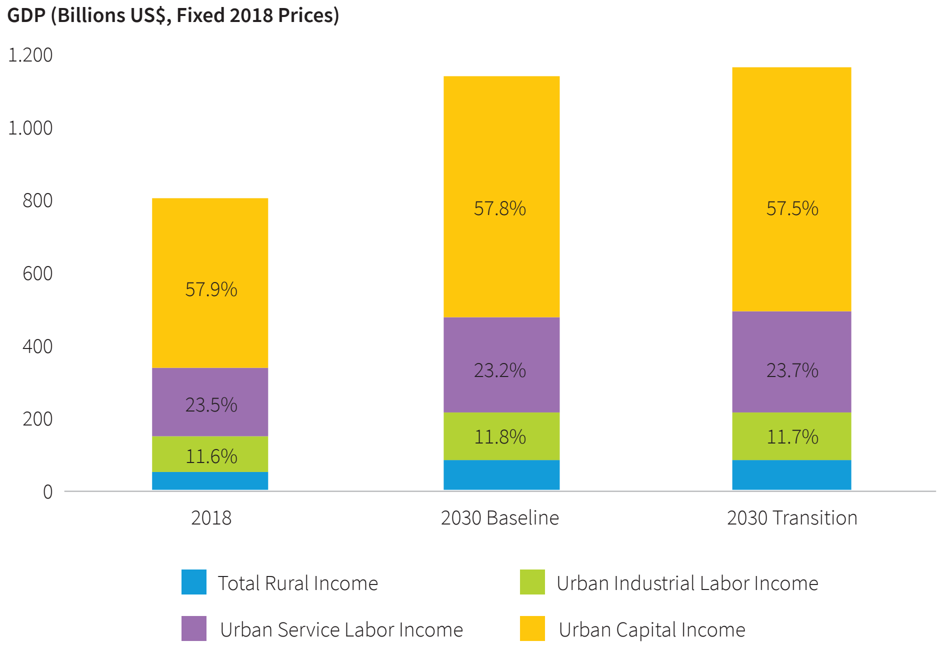
	Germany	Spain	Greece
1. Job creation per €1 billioninvestments (rounded)	11,000	23,000	22,000
2. Job creation at 2.5% of GDP (rounded)	1,400,000	690,000	100,000
3. Job creation as share of 2019 labour force	2.20%	3.00%	2.20%
4. Most recent official unemployment figures	6.30%	16.20%	17.30%

Note: Investments at 2.5% of 2019 GDP; Figures include direct, indirect and induced jobs.
Source: Pollin, 2020.

5.4.2 Income Distribution

With respect to income distribution, energy transition drives a tendency for urban labour incomes to expand relative to urban capital. Even though functional income categories are difficult to change and that structural income shifts are typically delayed, directly comparing baseline and transition scenarios shows an expansion in broad income categories.

Figure 16: *Functional Distribution of Income*



By 2030, the share of urban labour in GDP relative to urban capital is higher in the Transition scenario compared to the Baseline.

Energy transition results in an increase of total value-added by 44.6% in 2030 compared to 2018, and a 1.4% increase over the Baseline scenario. All income categories increase in 2030 due to transition. Comparing how these gains are distributed among income groups reveals that urban service workers experience the highest immediate gains. Over the long run, however, income gains become more evenly distributed by 2040. This delay reflects the time for efficiency improvements to take hold across economic sectors. Only then the productivity gains of early sectoral leaders, e.g., energy, transportation, machinery, and automotive sectors, start to spill over into other economic sectors. This occurs only when the disturbances in relative prices and real exchange rate taper off and the initial policy shocks along the transition path are stabilized.

Initially, urban capital owners capture nearly two-thirds of national income. This skewed income distribution is often highlighted as a significant problem facing Turkey's socio-economic structure. Although the energy transition does reduce the share of urban capital in aggregate value-added, the impact is slow. Thus, the Transition scenario demonstrates that relying only on markets to translate efficiency gains into improved income distribution will not suffice and that addressing income distribution concerns will, in any case, require direct policy interventions, such as tax breaks, direct public transfers, and other social support programs.

Box 6: How Does Renewable Energy Impact Income Distribution?

Previous literature and transition experiences of countries evidence that renewable energy leads to net job gains at different stages of its development. However, employment impacts have not been widely explored from a distributional perspective.

The distribution of new employment could be examined across a number of layers. While jobs could be created in various sectors that are linked to renewable energy, they could also occur differentially across regions or for various socio-economic groups. Besides, new jobs could be unequally distributed among males and females or low-skilled and high-skilled labour.

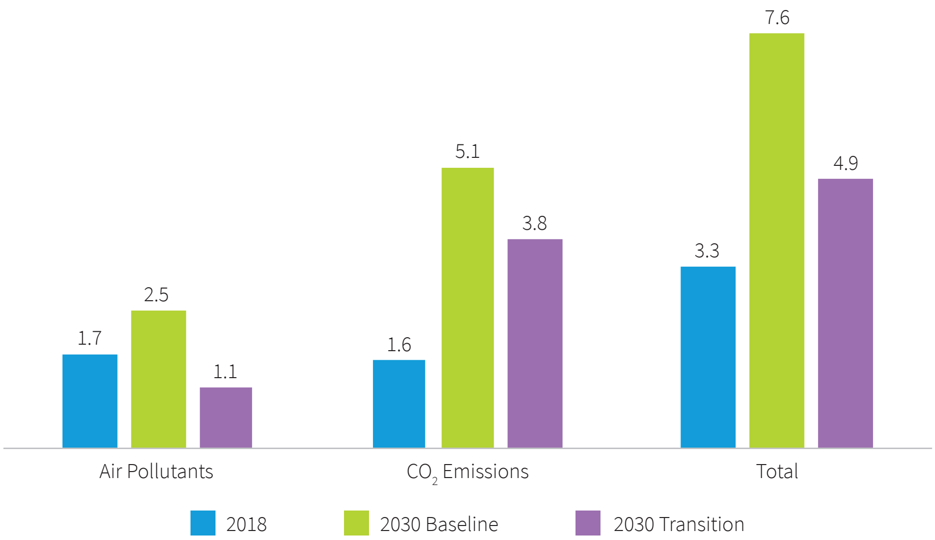
Jobs could be created at construction, installation, operation and maintenance phases of renewable energy development, which would trigger both production and employment in sectors such as the raw material industry and the machine manufacturing. Cai et al. (2014), who investigate the distributional employment impacts of renewable and new energy (RNE) development in China, confirm that new employment driven by RNE arises in those sectors which provide inputs to the power sector. The study further demonstrates that the gender inequality problem is aggravated, which puts women in a less favourable position in the Chinese labour market. Besides, the increased mismatch between the labour demanded and labour supplied leads to structural unemployment problems in the case of China. Region-wise, renewable energy projects could bear advantages for rural areas as renewable sources are more fairly distributed across regions than non-renewable energy resources do. In many cases, the development of wind farms and solar PV are being incentivized in order to enhance employment opportunities and diversify jobs in rural regions. However, although their environmental impacts would remain limited when compared to fossil fuels, renewable energy projects could give harm to other economic activities that are conducted relying on the environment. Examples could include activities based on rural agriculture, ecotourism, or nature-based tourism. Bergmann et al. (2008) investigate urban and rural preferences over environmental and employment impacts arising from renewable energy projects in Scotland and find that rural and urban households face different welfare gains depending on the type of renewable energy technology and on the scale of project. While urban residents were found to attach an insignificant value to the creation of new permanent jobs from renewable energy projects, it was a highly statistically significant factor for rural residents. As another reflection of these diverging preferences over employment, rural residents favoured biomass projects over wind projects due to the higher employment generation capability of biomass power plants. Accordingly, it is highlighted that the employment generation capacities and economic potentials of renewable energy cannot be taken for granted but need to be leveraged by differentiated policy tools for rural areas (Clausen and Rudolph, 2020). For instance, Ejdemo and Söderholm (2015) find that employment opportunities are quite limited and strongly rely on the presence of local manufacturing in rural Sweden in the absence of community benefit schemes.

To conclude, reliable policy options need to be taken into consideration to ensure a fair distribution of new employment throughout sectors, regions, or across different social groups. Training and equal promotion opportunities for women and provision of courses and vocational training in the field of renewable energy development could help mitigate the unemployment problems that might arise due to the penetration of renewable energy (Cai et al., 2014).

5.4.3 Health and Environment Externalities

Externalities due to Turkish fossil fuel use in power generation in 2018 were estimated at 3.5 billion US$ per year, corresponding to 0.42% of Turkey's GDP (SHURA, 2020). Other studies estimated that both emissions and external costs could be more than twice this figure, exceeding 1% of the GDP (HEAL, 2021; Greenpeace, 2020). The external cost estimates of the SHURA study rely on actual power generation of fossil fuel plants in 2018, from a database that comprises more than 262 power plants.[7] The external costs are a direct result of electricity generation from lignite (44.7 TWh), hard coal (66.6 TWh), and natural gas (90.5 TWh). The unit external cost of health and environmental impacts (including air pollutant emissions of CH_4, CO, N_20, NMVOC, NO_x, PM, PM_{10}, $PM_{2.5}$, and SO_X in addition to CO_2[8]) per MWh of electricity produced is 39.9 US$ for lignite plants, 16.1 US$ for hard coal plants and 5.2 US$ for natural gas plants. Average technological conditions for fossil fuel generation and emissions were assumed to be similar through 2030 and therefore the same external costs calculated were adapted to the baseline and transition scenarios in this study to quantify the health and environmental impacts resulting from power generation. However, while adapting the external costs from 2018, estimated changes in real GDP/capita (PPP) in the baseline and transition scenarios relative to estimated changes in real GDP/capita (PPP) in reference countries in the target years were taken into account based on the methodology developed by the IRENA (2016).

Figure 17: *Externalities from Power Generation (billion US$/year)*



In the Baseline scenario, it is estimated that in 2030, lignite fired generation will reach 71.4 TWh, hard coal fired generation 67.1 TWh and natural gas fired generation 120.1 TWh. Therefore, under the same technological conditions, the total external cost of fossil fuel generation in 2030 will be 7.6 billion US$ per year expressed in 2018 values. This number corresponds to 0.7% of the estimated GDP in the Baseline scenario.
In the Transition scenario, it is estimated that in 2030, lignite fired generation is reduced by nearly half to 36 TWh, hard coal fired generation to 43.5 TWh, and natural gas fired generation 106.8 TWh. Therefore, under the same technological conditions,

[7] The study calculates the emissions of each pollutant and CO_2 for each fossil fuel plant for 2018 and estimates the external costs by fuel type, plant type and emission type based on actual generation. The costs are based on those quoted in internationally accepted databases designed for the purpose of quantifying the impacts of pollutants and CO_2 for a selection of countries, mostly EU countries, whose costs were then adapted to Turkey using GDP/capita (PPP) multiplier.
[8] CH_4: Methane, CO: Carbon Monoxide, N_20: Nitrous Oxide, NMVOC: Non-methane Volatile Organic Compounds, NO_x: Nitrogen Oxides, PM: Particulate matter PM_{10}: Inhalable Particles, $PM_{2.5}$: Fine Inhalable Particles SO_X: Sulphur Oxide

the total external cost of fossil fuel generation in 2030 is 4.9 billion US$ per year expressed in 2018 values. This amount corresponds to 0.4% of the estimated GDP in the Transition scenario.

Avoided externalities due to transition will reach 0.2% of GDP in 2030. The main reason for the reduction will be the decline in the share of fossil fuels, especially lignite and hard coal, in power generation in the Transition scenario.

Avoided externalities due to transition will reach 2.7 billion US$, equivalent to 0.2% of GDP in 2030.The main reason for the reduction will be the decline in the share of fossil fuels, especially lignite and hard coal, in power generation in the Transition scenario. The annual value of avoided health and environmental impacts due to air pollutants will be 1.4 billion US$ compared to Baseline, which is equivalent to 4.6% of the annual health expenditure of Turkey in 2018. The annual value of avoided CO_2 emissions, on the other hand, will be 1.3 billion US$ and will comprise 0.1% of GDP. Therefore, the Transition scenario is estimated to have a significant welfare impact from a health and environment perspective.

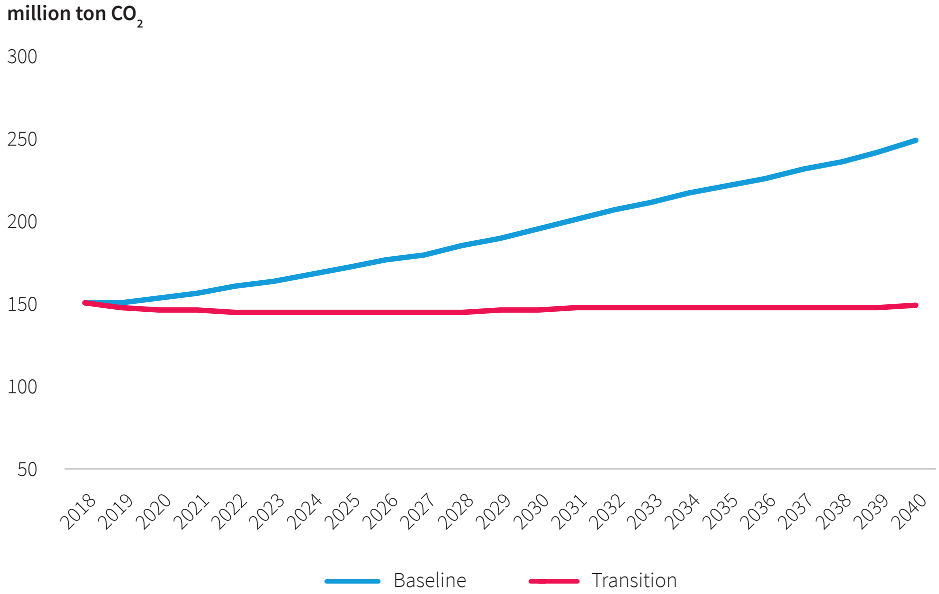
5.5 Impact on Carbon Emissions

The most recent official document specifying Turkey's national emission reduction targets is the INDC submitted to United Nations Framework Convention of Climate Change (UNFCCC) on 30 September 2015, just before the The 21st Conference of the Parties (COP 21) meeting held in Paris. The document summarizes the national criteria to be applied by Turkey, with an emphasis on the special requirements applicable for the country as provided in the resolution no. 1/CP.16 under Annex 1 to UNFCCC and notes how the emission reduction and compliance strategies were established in this context. The document specifies the time frame 2012-2030 as its implementation window, and entails a declaration on part of Turkey, for 21% reduction of its greenhouse gas emissions, from 1,175 million tons of CO_2e as envisaged in the business-as-usual (BAU) scenario, to 929 million tons of CO_2e. It is noted that doing so would constitute a major step towards low-carbon development, so as to achieve the goal of keeping warming under 2^0C at a global scale. The INDC also entails references to certain plans and policies envisaged for emission-intensive industries.

The Transition scenario stops the growth in carbon emissions due to a decline of 22% in emission intensity per KWh compared to Baseline.

SHURA Transition scenario involves a power system transformation whose main impact in reducing emissions is through a reduction in power consumption in end-use sectors and an increase in the share of renewable energy in power generation. Therefore, the impact on carbon emissions is best indicated by the changes in electricity sector emissions. CO_2 emissions are calculated based on the efficiency and power sector assumptions in the Baseline and Transition scenarios outlined in Sections 4.1 and 4.2. The modelling results show that total electricity sector CO_2 emissions grow by 30% during 2018-2030 under the Baseline scenario, resulting in an emission intensity of 0.437 kg CO_2e per kilowatt-hour (kWh) of electricity generated, indicating a decline of 14% from 2018 levels. The Transition scenario, on the other hand, stops the growth in carbon emissions due to a decline of 22% in emission intensity per KWh compared to Baseline (emission intensity in the Transition scenario is 0.343 kg CO_2e).

Figure 18: *Evolution of Electricity Sector CO_2 emissions across Baseline and Transition scenarios*



While power sector emissions stabilize with the actions to 2030 under the SHURA scenario, further action will be needed for an actual peaking and decline. Nevertheless, the Transition scenario demonstrates the realistic potential for significant emissions reductions on top of government baselines. Thus, an accelerated power sector transition could narrow the gap to a net-zero emissions goal, with net-zero emission in the power sector by 2050 emerging as a distinct possibility. This requires, however, a fundamental shift in energy planning that would prioritise the phase-out of inefficient and carbon-intensive fossil-fuels. The socioeconomic impacts of such a net-zero scenario may be quite different than what is explored in this study.

Box 7: European Green Deal and Carbon Border Adjustment

In its Green Deal proposed in December 2019, the European Union strives to become the first carbon-neutral continent by at least 2050. Carbon border adjustment mechanisms (CBAM) have emerged as a key component within the Green Deal strategy. CBAMs propose a tax on imported goods based on their carbon footprints, while aiming to level the playing-field for EU industries to pursue low-carbon production processes and avoid 'carbon leakage'. Carbon leakage refers to the situation that may occur if, for reasons of costs related to climate policies, businesses were to transfer production to other countries with laxer emission constraints (EU, 2021). Up until now, the EU has protected domestic industries by allocating them free emissions rights under its Emissions Trading Scheme or providing subsidised power to Energy-Intensive and Trade-Exposed industries.

In addition to several technical challenges relating to CBAM implementation, a major concern is that the policies could negatively impact developing economies by cutting their export revenues or impeding the development of new export-oriented industries. How an exporting country could be impacted by a CBAM depends on three factors: the fossil-fuel intensity of its industries; the percentage of GDP generated by exports to the EU; and the share of emission-intensive products in its exports. The EU represents Turkey's primary import and export partner and accounts for nearly half of Turkey's exports. The manufacturing industry remains a backbone of the Turkish economy with the sector's value-added accounting for nearly 30% of GDP in 2018. Currently, Turkey's iron and steel, as well as cement production are among the world's top ten and its glass, ceramics and plastics industries rank in the top five of the EU in terms of trade. Despite recent progress in increasing the share of renewables in power supply, the share of renewables in the manufacturing industry remains low, around 2%, and as such are exposed to the any potential CBAM and other international competition. One factor that impacts cost competitiveness is energy costs which could represent a high share of material production costs. As such, a possible CBAM poses a significant risk to the Turkish economy.

Domestic policies that seek to reduce Turkey's reliance on imported fossil-fuels by improving energy efficiency and increasing the share of renewable energies could help reduce Turkish industry's exposure to a CBAM and its impact on the country's current account deficit. At the same time, the CBAM could stimulate new and innovative business models, products, or services and create new market opportunities. While introduction of a CBAM is by no means a certainty, and still needs to address a number of technical design and implementation challenges, CBAM could play a role in shaping the development path of Turkey's economy. Early embarking on an accelerated transition could reduce Turkey's risk of exposure to the CBAM and provide a competitive advantage over other exporters to the EU.

6. Conclusions and Policy Implications

The levelling of carbon emissions with the SHURA transition scenario proposed in this study indicates an opportunity for a net-zero emissions pathway by 2050 in the power sector for Turkey.

A discussion of policy implications starts with taking the necessary steps to make the transition scenario possible and extends to furthering targets beyond 2030. Current trends reveal that Turkey has not yet decoupled its economic growth from rising energy use, a process that has been underway in advanced economies for more than two decades. The SHURA scenario whose effects are explored in this study would result in significant reduction in greenhouse gas emissions; however, a zero-carbon pathway would require further effort. Comparison with international studies on the targets required for a zero-carbon pathway indicate that while share of renewable energy targets for 2030 in the SHURA scenario are in line with the global median of relevant Paris-consistent scenarios, energy intensity and reliance on fossil fuels need to be reduced further in order to approach international zero-carbon benchmarks. Nevertheless, the levelling of carbon emissions with the SHURA transition scenario proposed in this study indicates an opportunity for a net-zero emissions pathway by 2050 in the power sector for Turkey.

Table 10: *Comparison of SHURA Scenario Vision with International Zero-Carbon Benchmarks*

	2019 System	Global Median of Relevant Paris-consistent scenarios	Global Zero-Carbon Benchmarks	SHURA Scenario for Turkey
Power Sector CO_2 intensity	**Global:** 463 grCO_2/kWh **Turkey:** 484 grCO_2/kWh	**2030:** 125 grCO_2/kWh **2050:** -7.5 grCO_2/kWh	**2030:** 87.5 grCO_2/kWh **2050:** -7.5 grCO_2/kWh	**2030:** 343 grCO_2/kWh
Share of renewable or zero-carbon resources in power generation	**Global:** 26% renewables (wind and solar combined 8%) **Turkey*:** 42% (wind and solar 12%)	**2030:** 54% renewables (wind and solar combined 30%) **2050:** 77% renewables (wind and solar combined 51%)	**2030:** 65% renewables **2050:** 100% renewables	**2030:** 55% renewables (wind and solar combined 30%)

Sources: UCL Institute for Sustainable Resources, 2020; TEİAŞ, 2021; SHURA calculations.
**As of 2020.*

Transition scenario has a significant impact on reducing carbon intensity of power generation by 2030 and in the longer run by 2040. Our results underscore the importance of successful implementation of efficiency-driven gains in power generation as well as in industrial production. Thus, we propose that with an integrated strategy that places energy efficiency at its epicentre, supported by a well-focused fiscal policy geared towards supporting renewables while taxing the fossil-based energy generation and consumption, a more conducive macroeconomic environment can be realized with higher employment and enhanced welfare.

Furthering Turkey's energy transition will necessarily involve a long-term vision incorporating all aspects of the transition.

Furthering Turkey's energy transition will necessarily involve a long-term vision incorporating all aspects of the transition. So far Turkey had considerable success in increasing the share of renewable energy in its power generation mix; however, other aspects of the transition, such as accelerating gains in energy efficiency and decarbonising end-use sectors in energy as well as continued penetration of renewable energy, require long-term targets and planning. A new vision along the lines of the emerging "global green deal" is needed, starting with time-bound net zero emissions targets, going down to corresponding interim targets and action plans in all related sectors. Turkey has already expressed an intention for a new climate action plan along the lines of global 2030 and 2050 targets.

6.1 Benefits and Costs of Transition

While transition brings environmental and economic benefits, there will also be additional costs which have to be weighed against the benefits. This study has concentrated mainly on the socioeconomic costs and benefits of transition and found that the net effect will be small and positive. Nevertheless, these benefits have to be weighed against the financial costs to be incurred by the Transition scenario. Previous SHURA studies have explored in detail the financial costs of the Transition.

For renewable energy integration, it was found that investment costs for power generation are only 7% higher and additional investment for grid integration is 10% higher while the cost of grid flexibility is low at 1-5 €/MWh of generation. The main public cost will be the extra power system cost, estimated to be 11% higher than the baseline, as reflected in the rise in the market clearing price of electricity. All in all, the rise in the power system costs due to increased share of renewable energy will require about a 10% increase in the current operational and investment costs.

For energy efficiency and electrification, including batteries for electric vehicles and the grid, an additional annual investment of 4.5-6.5 US$ will be needed. The additional system costs of electrification due to electric vehicle charging, on the other hand, will be negligible. The total investments for energy efficiency and electrification are expected to yield 6.7-8.1 US$/year financial benefits, not including the socioeconomic benefits estimated in this study. In other words, from a financial perspective, by 2030 the amount invested in energy efficiency, distributed renewable energy and electrification is expected to yield 1.2-1.5 dollars of benefit for every dollar invested[9].

The benefits of the transition will far outweigh the costs.

From the foregoing, we can conclude that the net financial cost of the Transition will be at most 10% higher than the financial costs incurred in the baseline scenario, amounting to an annual additional cost of about 4 billion US$/year. By comparison, the socioeconomic welfare impact of the Transition over the baseline, including improved energy and investment goods trade balance, increase in wage income, reduced environmental and health externalities will be 12-13 billion US$/year (see Table 5). Therefore, it can be said that the benefits of the Transition will far outweigh the costs. In other words, transformation of Turkey's power system in the coming decade with more renewables and energy efficiency will open investment opportunities twice as high as the baseline in addition to the environmental and socioeconomic benefits it brings.

SHURA Transition scenario comes with significant benefits to the economy, with socioeconomic welfare impacts over the baseline at 1.1% of GDP in 2030. In addition, an increase of industrial value-added over the baseline at 3.6% of GDP and an improvement in overall trade balance over the baseline at 0.9% of GDP indicate important structural changes. The benefits of this transition would be a significant reduction in the adverse effects of fossil fuel use on human health that is currently valued at a minimum of around 10 billion US$ per year in 2018[10]. In addition to potential health benefits, the transition scenario is expected to contribute to a significant reduction in greenhouse gas emissions, reducing the carbon intensity of power generation by 20-25% compared to the baseline scenario.

[9] https://www.shura.org.tr/executive-summary-the-most-economic-solution-for-turkeys-power-system-energy-efficiency-and-business-models/
[10] https://www.shura.org.tr/turkiyede-elektrik-uretimi-isitma-ve-karayolu-tasimaciliginda-fosil-yakit-kullaniminin-dissal-maliyeti/

6.2 Investment Climate and Challenges for Transition

The total average annual investment level required to achieve the SHURA transition vision for 2030 has been calculated at 12.3 billion US$ while current annual investment levels in the power sector and that in the baseline scenario are in the order of 6-7 billion US$, with the main difference coming from energy efficiency, electrification and technologies that can enable flexibility such as battery storage. In addition to the challenges brought by the partial shift from fossil fuels to renewables, the main challenge for realizing scenario targets will be securing financing for the necessary investments which require doubling the current and baseline levels.

Apart from the additional amount of financial resources required for the transition, the general economic and financial climate in Turkey presents challenges. Turkey has been facing a series of financial difficulties since 2018 with currency depreciation and economic slowdown. The COVID-19 pandemic has hit the Turkish economy under a conjuncture where the adverse effects of the 2018 financial turbulence have not yet been alleviated, and the macroeconomic balances have not been resolved in a sustained fashion. In part because of the pandemic, macroeconomic conditions have become more difficult since 2020 and TL has further depreciated by about 50% against the Euro and about 40% against the US$ since the beginning of 2020. The crisis has exacerbated the already existing inequalities in income distribution and access to public services. The government response for economic relief to alleviate the adverse impact of the pandemic has relied mainly on credit expansion rather than direct fiscal transfers. In comparison, the international response, particularly in developed economies, has been designing comprehensive recovery packages spreading over several years.

Green recovery, encompassing investments in renewable energy, efficiency, and decarbonisation with particular emphasis on green employment, has become the leading concept for post-pandemic economic revival around the world.

Globally, the health impacts of the pandemic and the economic slowdown due to lockdown measures have resulted in heightened awareness of climate change issues. Temporary improvement in emissions due to reduced economic activity served as a motivation for combining economic recovery with a low carbon transition, resulting in global efforts for a “green recovery.” Green recovery, encompassing investments in renewable energy, efficiency, and decarbonisation with particular emphasis on green employment, has become the leading concept for post-pandemic economic revival around the world. The European Green Deal, which aims to shape economic and social policies toward making the continent carbon-neutral by 2050, provides a new paradigm with other large economies such as China, Japan and Korea following suit. In order to achieve a just transition within the context of the Green Deal, The European Union is planning to mobilise financial resources worth 100 billion Euro during 2021-2027. The Green New Deal, together with the concept of “green recovery” to overcome the economic problems caused by the COVID-19 pandemic, will be the mainstay of the habitat for Turkey’s energy transition finance as an estimated one-trillion US$ will be required in the energy sector as part of the International Energy Agency’s Green Recovery Program.

The global context discussed, and the benefits of the low carbon transition implied by the results of this study show that a green recovery needs also be a core element in Turkey’s immediate economic planning agenda. Despite the economic difficulties stemming from the COVID-19 pandemic, in the near term it is important for Turkey to continue in the energy transition path charted by national policy documents in order to reap the benefits afforded by the transition and make use of international

The climate plan will serve not only as a roadmap, but also as a safeguard against the potential risks arising from the process of adaptation to the international climate.

financing opportunities. To enable this, a long-term plan is needed that takes 2030 as the earliest target year to 2050 as a full transformation requires planning for the long-term in line with the climate objectives. Such a plan, which will provide visibility for all the actors involved, will serve the dual objective of climate change mitigation and economic development.

In this context financing, green recovery and the European Green Deal will require particular attention. For instance, as part of its Green Deal transition program, the EU is planning to extend carbon requirements to its trade partners by imposing a carbon border tax on imports whose costs do not include the cost of greenhouse gas emissions in their production cycle. As the EU is Turkey's largest trading partner, the challenges and opportunities arising from the European Green Deal will provide impetus for accelerating efforts for establishing a carbon pricing system within Turkey. The climate plan will serve not only as a roadmap, but also as a safeguard against the potential risks arising from the process of adaptation to the international climate.

As the power system transition will need a doubling of the level of investment, how to secure financing is an impending question. While many uncertainties exist, SHURA's 2019 energy transition financing study (SHURA, October 2019), provides some clues. The report covers the initial transition financing during 2002-2018, when the energy sector had gone through a major transformation and includes recommendations for the public sector, financial institutions and investors in the next period. During this period, investments for energy transition constituted about half of all energy investments with 40 billion US$ for renewable energy, 10 billion US$ for energy efficiency and 7 billion US$ for other investments, including transmission. Financing other than own equity, mostly loans, facilitated financing of about 70% of the investment in renewable energy and about half of the investment in energy efficiency during this period.

With regard to financing conditions for renewables, positive factors pertaining to this period were the access to substantially large, long-term foreign financing, and the roles played by development finance institutions, international export credit institutions and local banks, whose effectiveness in finance has improved as more experience was gained. However, financing was mostly based on renewable energy support policies and imperfections in the operation of energy markets have had a limiting effect. Financing was further limited by the inability to access alternative financing sources and models and by the lack of a policy framework specific to these alternative sources, as well as by the underdevelopment of capital markets. Another shortcoming identified with respect to this period is the lack of development of financing models and policy instruments for creating a distributed generation market. On the other hand, a significant portion of investments that resulted in energy efficiency was either a component of larger projects, or mostly financed by equity, as a result of which they were not reported as energy efficiency financing. The market for energy efficiency in general and for the specific case of energy service companies (ESCOs) are underdeveloped in comparison to the global trends.

Major emphases and recommendations of the study involved the formation of a specific definition, central fund, and coordination mechanism for energy transition, particularly for energy efficiency and the identification of five action areas as follows: reinforcing the energy transition perspective and market mechanism, diversifying financing resources, increasing energy efficiency financing, developing renewable energy and distributed renewable energy resources. The focal point of the prognoses was the need to mobilise climate finance and increase access to financing from development finance institutions (DFIs) and institutional investors. Coordination and cooperation between major stakeholders, namely the public sector (government), international financial institutions, local financial institutions, energy companies and technology providers is a critical component of sustained and sustainable financing.

Even though less than two years have elapsed since the study was released, many of the report's forecasts and recommendations have begun to materialize:

- Small utility-scale YEKA auctions for solar and wind energy have been held and met with substantial investor and financer interest;
- Legislation on net metering has been passed and several investments by commercial and industrial users for self-generation have taken place;
- Certification and trading of renewable energy as a distinct product, facilitating spot and long-term PPAs, will be effective mid-2021;
- Several financial institutions have started offering special financing products for "green" energy production and consumption;
- New resources within the context of climate financing to be provided to Turkey by the government and DFIs are underway ;
- Secondary legislation facilitating the operation of ESCOs for public sector energy efficiency projects has been passed and projects have started.

As green recovery efforts in the short-term are incorporated into long-term action plans, the new YEKDEM and mini-YEKA auction mechanism can provide a sustainable pathway to financing in renewable energy.

While discussions in the public sector to establish a central coordination mechanism for energy efficiency have intensified, an integrated approach with long-term planning that links financing mechanisms with climate action will be needed. As green recovery efforts in the short-term are incorporated into long-term action plans, the new YEKDEM and mini-YEKA auction mechanism can provide a sustainable pathway to financing in renewable energy. Nevertheless, additional tools and approaches will need to be developed to finance the additional investments in energy efficiency and electrification. SHURA will be conducting a study with broad stakeholder engagement to explore the options and tools for financing the Transition together with the implications of green recovery and green deal.

6.3 Policy Implications

6.3.1 Enabling the Transition

Active policies will be needed to realize the potential benefits implied by the modelling study. As emphasized in the foregoing discussion, in order to be effective and predictable, the policies and actions will function best as part of a long-term Climate Action vision to 2030 and 2050. Predictability is particularly important from the perspective of both investors and financers at the national and international level. The policy actions listed below are the main components of an enabling framework for achieving the 2030 vision for shifting from fossil fuels to renewables in power generation:

- **Implementing carbon pricing:** As the results of this study shows, carbon pricing or the implementation of a carbon tax will facilitate attaining higher shares of renewable energy in power generation. It will also provide impetus for energy efficiency and decarbonisation in end use sectors. The study results demonstrate that even a modest carbon price or tax, to be applied at gradually increasing rates and whose burden to the economy is minimal, would support the share of renewable energy in power generation to surpass 50% by 2030. Turkey's current efforts, such as the PMR project[11], for establishing carbon pricing need to be stepped up and carbon pricing should be integrated into the new Climate Action Plan.

- **Together with market-based mechanisms, applying renewable energy subsidies as needed:** As the study results show, with declining costs of renewable energy investments, the need for renewable energy subsidies will be much reduced. However, some subsidies will still be required for increased penetration, especially for distributed generation. Turkey's already existing and well-developed system of subsidization combined with competitive auctions needs to be continued and modified as necessary[12].

- **Eliminating ineffective support and subsidies for fossil fuels:** While this study has not specifically modelled the elimination of fossil fuel subsidies, previous studies show that such subsidies make up nearly 1% of GDP and their elimination would help avoiding substantial amount of emissions (SHURA, 2019; Acar and Yeldan, 2016). The current magnitude of fossil fuel subsidies as a share of GDP in Turkey is comparable to the added social welfare benefits of the Transition scenario. Therefore, an elimination of the ineffective subsidies with the subsequent additional emissions savings would have significant benefits.

- **Long-term planning and market-based policies for energy efficiency:** This study has found that energy efficiency will be the main driver of the socioeconomic benefits that the Transition brings. While major legislative efforts were made to facilitate energy efficiency actions by the private and public sectors, a long-term vision and planning beyond the current plans to 2023 is needed for more effective action. Previous work has shown that most energy efficiency investments are economically viable with market mechanisms and what is most needed for the investments to take off is a legislative and policy framework with well-defined rules and clear market signals (SHURA, October 2020). Energy efficiency obligations for large consumers and utilities, combined with incentives, white certificate schemes and auctions will be the key elements in enabling policies.

6.3.2 Moving Toward a Just Transition

The results of the study show that the overall socioeconomic impact of Transition will be positive with significant benefits for health, environment, and wage income. The investments and enabling policy actions will provide the potential for income and productivity increases to take place. Nevertheless, production and employment in sectors directly related to power generation from fossil fuels and those that do not benefit from overall efficiency gains will be lower in comparison to the baseline scenario. Policies for reorienting production and employment toward sectors that would benefit from the transition, such as work force retraining and compensation programs will be necessary to alleviate losses.

[11] Since 2013 Turkey has been involved in the Partnership for Market Readiness (PMR) launched in 2011 by the World Bank to support developing countries' efforts to reduce greenhouse gas emissions through effective use of market-based instruments. Phase 1 of the PMR program in Turkey comprising analytical studies has been completed in November 2019, and Phase II comprising pilot studies and implementation has begun in January 2020.

[12] In 2021 a new renewable energy feed-in-tariff with reduced prices has been introduced for new plants becoming operational by the end of 2025. Competitive auctions for pre-licensing and licensing under various schemes have been implemented over the past ten years and are scheduled to continue into the future.

While the study indicates that a more skilled and better trained work force will be required by the Transition, active policies will be needed to ensure actual emergence of a "green collar" work force. As a good part of the employment created by renewable energy is in construction and installation rather than operations, the work is more likely to be of a temporary nature. Experiences of other countries have shown that many of workers shifting to other sectors experience a loss of income (O'Connor, 2021). In other words, disparities in regional and functional income distribution may be exacerbated. The overall improvements in wages and income distribution found in the study may obscure some of the devastating impacts specific regions and work areas may experience. Placement of workers previously employed in fossil fuel technologies would require carefully designed regional development programs, as many of these industries are site specific and some, like coal mining, play major roles in the local economy.

While long-term national goals and planning will be essential for furthering the transition, both national and local solutions will be required for ensuring that potential benefits are maximised and shared equitably.

One of the most striking findings of the study is the impact of the transition on industrial transformation in favour of sectors with higher technology level. Though the study does not entirely capture the employment impact of digitalization and energy management triggered by electrification, distributed generation and energy efficiency, the structural shift implies that a new set of skills will be needed. Beyond the technical skills needed for renewable energy and energy efficiency, the greening of surroundings will require a host of skills in education, caregiving, and management services. Increased decentralisation of service provision will also mean integration of transition planning and policy with local and community development. In other words, while long-term national goals and planning will be essential for furthering the transition, both national and local solutions will be required for ensuring that potential benefits are maximised and shared equitably.

Enabling policies and related actions as well as appropriate education and training will be needed for a transition from an economic growth model based on cost minimization, wage suppression and capital injections dependent on imports to one based on increasing total factor productivity with higher value-added domestic production and resources. The Transition scenario coupled with economic policies supporting domestic production of renewable energy and energy efficiency equipment and social policies supporting a just transition will be the main pillars of policy action in the period to 2030. SHURA will be conducting further studies with broad stakeholder engagement to further explore how the policies to enable a just transition can be detailed and implemented.

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Appendix I – Bottom-up Power Model Formulation, Additional Assumptions and Results

Model Formulation

The lists of the sets/indices, parameters, and decision variables can be seen in Table 11, Table 12 and Table 13. The base year of the model is 2018, and time indices go on with 2020, 2023, 2026, 2030, 2035 and 2040.

Table 11: *List of sets and indices.*

symbol	definition
i,j	power technologies {Asphaltite, Biomass, Cogeneration, Diesel, FuelOil, Geothermal, Hard Coal, Hydro_Dam, Hydro_RoR, ImpCoal, Lignite, LigniteLow, LNG, LPG, Naphta, NaturalGas, Nuclear, Solar, Wind}
thr	thermal technologies {Asphaltite, Biomass, Cogeneration, Diesel, FuelOil, HardCoal, ImpCoal, Lignite, LigniteLow, LNG, LPG, Naphta, NaturalGas}
$nthr$	non-thermal technologies {Geothermal, Hydro_Dam, Hydro_RoR, Nuclear, Solar, Wind}
rnw	renewable technologies {Geothermal, Hydro_Dam, Hydro_RoR, Solar, Wind}
h	Hours - 1, ... ,8760
d	Days - 1, . . . ,365
t_0,t,tt	Years - t_0: 2018; t,tt: 2018, 2020, 2023, 2026, 2030, 2035, 2040

Table 12: *List of parameters..*

symbol	definition
pLoad(t,h)	Load demand in year t at hour h in MWh
pLoadProfile(t0,h)	Load demand in year t at hour h - normalized (hourly load over total annual load)
pTotLoad(t)	Total load demand in year t at hour h in MWh
pInsCap0_(t,d,i)	Daily installed capacity in year t by technology i (MW)
pInsCap0(t,i)	Initial installed capacity in the beginning of year t by technology i (MW) - built before the planning horizon
pInsCap0Ret(t,i)	Retired installed capacity in the beginning of year t by technology i (MW) - built before the planning horizon
pRetirementRate(t,i)	Rate of retirement as a ratio of initial installed capacity per technology per year
pAvFac(i)	Availability factor of generators
pLoadFac(i,h)	Generation potential of technology i at hour h . It is 1 for non-renewable resources.
pHeatRate(i)	Heat rate of generators - Mbtu per GWh
pBigGen(t)	Capacity of the biggest generator in year t – (1.5 GW)
pCapCost(i)	Capital cost of technology i - US$ per kW
pFuelCost(i)	Fuel cost of technology i - US$ per btu
pFOMcost(i)	Fixed o&m cost of technology i - US$ per kW
pVOMcost(i)	Variable o&m cost of technology i - US$ per kWh
life(i)	Lifetime of technology i - years
pSUcost(i)	Start-up cost of technology i - US$ per kW
pSDcost(i)	Shut-down cost of technology i - US$ per kW
pMinLoad(i)	Minimum hourly generation amount of technology i - GWh
pMaxNewIC(i,t)	Maximum annual new installed capacity technology i – GW in period t
pMaxTotIC(i)	Maximum total installed capacity technology i - GW
pSbsdy(i)	Decrease in capital cost due to subsidies - percent
pEleGrowth(t)	Electricity growth rate
pPeakLoad	Peak load - the ratio of peak load to the total load in the base year
pOperRes	Operating reserve - the ratio of hourly load (2%)
pFrcstErr	Forecast error for wind and solar (15%)
pResMargin	Reserve margin (15%)
ρ	Social discount rate
pAnnEleGrwth	The annual electricity growth rate
pVOLL	Value of lost load (US$1/kWh)
$\alpha(tt)$	Parameter to handle unequal period length
$pCO_2coef(i)$	kg CO_2 emissions per Mbtu
pEmisTotLim(t)	Upper bound for emissions in year t

The distinction between installed capacity, available capacity, and load generation is important to understand the incurrence of costs and the dynamics of the model. *vICtot(i,t)* represents the installed capacity (or name-plate capacity) of technology i in period t, which is then related to the capital cost and fixed overhead & maintenance (o&m) costs. *vPow(i,t,h),* on the other hand, is the available installed capacity at hour *h* and is related to variable o&m cost. *vGen(i,t,h)* is the actual load generated at hour *t,* thus affects the total variable o&m cost as well as the total cost of fuels used in the plants.

Table 13: *List of decision variables.*

symbol	definition
vGen(i,t,h)	Generated power by technology i in year t at hour h in GWh
vPow(i,t,h)	Available power by technology i in year t at hour h in GW
vPowD(i,t,d)	Available power by technology i in year t on day d in GW
vUp(thr,t,d)	Start-up of technology thr in year t on day d in GW
vDw(thr,t,d)	Shut down of technology thr in year t on day d in GW
vICnew(i,t)	The newly installed capacity of technology i in year t in GW
vICtot(i,t)	The cumulative installed capacity of technology i in year t GW
vFOMc(t)	Fixed cost in year t
vVOMc(t)	Variable cost in year t in 2019 US$
vCAPc(t)	Capital cost in year t in 2019 US$
vNSE(t,h)	Non-served energy in year t at hour h in GWh
vNSEc(t)	Cost of non-served energy in year t in 2019 US$
vEMS(i,t)	Emission from technology i in year t in Mt CO_2e
vUpDwC(t)	Cost of up and down of thermal i on day d of year t in 2019 US$
vAnnCost(t)	Annual total cost in year t in 2019 US$
vTotCost	Total discounted cost in 2019 US$
vEmis(i,t)	CO_2 emissions by technology i in year t in Mton
vEmisTot(t)	Overall CO_2 emissions in the power sector in year t in Mton

Eqn. (1)- (7) demonstrates the accounting of the costs in the model. Annualized cost of capital, fixed o&m and variable costs are represented in equations (1), (2) and (3), respectively. Equations (4) and (5), on the other hand, represent the cost of non-served energy and the start-up costs. Finally, aggregated total costs in each period is given in Eqn. (6) and Eqn. (7) is the total discounted cost of the power system, i.e., the objective function of the model.

$vCAPc(t)= 10^6 \cdot \sum_{i} pCapCost(i) * vICtot(i,t)$	$\forall\ t$	(1)
$vFOMc(t)= 10^6 \cdot \sum_{i} \alpha(t) * pFOMcost(i) * vICtot(i,t)$	$\forall\ t$	(2)
$c(t)= \alpha(t) * \sum_{(i,h)} [10^3 * pVOMcost(i) * vPow(i,t,h) + pHeatRate(i) * pFuelCost(i) * vGen(i,t,h)]$	$\forall\ t$	(3)
$vNSEc(t)= \alpha(t) * \sum_{h} [pVOLL * vNSE(t,h)]$	$\forall\ t$	(4)
$vUpDwC(t)= 10^6 * \alpha(t) * \sum_{(thr,d)} [pSUcost(thr) * vUp(thr,t,d)]$	$\forall\ t$	(5)
$vAnnCost(t) = vFOMc(t) + vVOMc(t) + vNSEc(t) + vUpDwC(t)$	$\forall\ t$	(6)
$vTotCost= \sum_{tt} [vAnnCost(t) \cdot (1/(1+\rho)^{t-t_0}]$		(7)

Total electricity generated plus the non-served amount should be in balance with the demand for each hour as illustrated in Eqn. (8). Note that the (normalized) load profile of the base year is assumed to be constant regarding the patterns of the last three years.

$\sum_{i} [vGen(i,t,h)] + vNSE(t,h) \geq pLoadProfile(t_0,h) * pTotLoad(t)$	$\forall\ t,h$	(8)

Eqn. (9) represents the continuity equality for the installed capacity, i.e., installed capacity of technology i in period t is equal to the sum of the capacity in period t-1 and new capacity in the current period. Moreover, the last two terms represent the retiring capacity either coming from the base year or installed within the planning horizon.

$vICtot(i,t) = vICtot(i,t\text{-}1)+vICnew(i,t) - \sum_{0 \leq tt\text{-}t\text{-}life(i) \leq 3} vICnew(i,tt) - pInsCap0Ret(t,i)$	$\forall\ i,t > t0$	(9)

The intertemporal constraints on available capacity for each thermal option can be seen in Eqn. (10)- Eqn. (13) while the corresponding constraint for the non-thermal units is illustrated in Eqn. (13).

$vPowD(thr,t,d) = vPowD(thr,t,d\text{-}1) + vUp(thr,t,d) - vDw(thr,t,d)$	$\forall\ thr,t,d$	(10)
$vPowD(thr,t,d) \leq pAvFac(thr) \cdot vICtot(thr,t)$	$\forall\ thr,t,d$	(11)
$vPow(thr,t,h) = vPowD(thr,t,d(h))$	$\forall\ thr,t,d$	(12)
$vPow(nthr,t,h) \leq pAvFac(nthr) \cdot vICtot(nthr,t)$	$\forall\ thr,t,d$	(13)

Eqn. (14) indicates that the generation in each hour should lie between the minimum generation and the available power, while Eqn. (15) - (16) introduces limits on the new and total capacity for each period, respectively.

$MinLoad(i) \leq vGen(i,t,h) \leq pLoadFac(i,h) \cdot vPow(i,t,h)$	$\forall\ i,t,h$	(14)
$vICnew(i,t) \leq MaxNewIC(i,t)$	$\forall\ i,t$	(15)
$vICtot(i,t) \leq MaxTotIC(i)$	$\forall\ i,t$	(16)

There should be a reserve margin above the peak load which is represented in Eqn. (17). Eqn. (18), on the other hand, implies that an operational reserve should also be introduced on the difference between the available power and the actual generation. This reserve considers the forecast errors in wind and solar generation as well as the biggest generator in the grid. These reserves are represented in the same way in (Octaviano, 2015).

$\sum_i [\ pAvFac(i) \cdot vICtot(i,t)\ ] \geq (1+pResMargin) \cdot pPeakLoad \cdot pTotLoad(t)$	$\forall\ t$	(17)
$\sum_i [\ pLoadFac(i,h) \cdot vPow(i,t,h) - vGen(i,t,h)] \geq pOperRes \cdot pLoadProfile(t0,h) \cdot pTotLoad(t) + pFrcstErr \cdot [vGen(\text{"Wind"},t,h) + vGen(\text{"Solar"},t,h)] + pBigGen(t)$	$\forall\ t,h$	(18)

The CO_2 emissions originated from the power generation are accounted via Equations (19) and (20), for each technology and as annual total, respectively.

$vEmis(i,t) = 10^{-6} \sum_h [pCO_2coef(i) \cdot pHeatRate(i) \cdot vGen(i,t,h)]$	$\forall\ i,t$	(19)
$vEmisTot(t) = \sum_i vEmis(i,t)$	$\forall\ t$	(20)

Assumptions

Table 14: *Total electricity generation, 2020-2030, TWh.*

Year	Baseline	Transition
2020	316	316
2021	330	326
2022	344	336
2023	358	347
2024	373	357
2025	387	367
2026	402	378
2027	417	389
2028	432	399
2029	447	410
2030	462	421
2031	477	432
2032	492	442
2033	507	453
2034	522	464
2035	537	475
2036	551	485
2037	565	496
2038	579	506
2039	593	517
2040	606	527

Table 15: *Carbon tax path: Transition.*

Year	Carbon Tax
2021	4.42
2022	9.25
2023	19.31
2024	20.13
2025	20.94
2026	21.75
2027	22.56
2028	23.38
2029	24.19
2030	25.00
2035	25.00
2040	25.00

Additional results

Table 16: *Generation amounts and installed capacities under the Baseline Scenario.*

	2023		2030		2040	
	TWh	GW	TWh	GW	TWh	GW
Biomass	0.021	0.646	0.155	0.645	0.140	0.644
Geothermal	9.006	1.260	8.625	1.260	8.183	1.242
Reservoir Hydro	62.449	23.536	62.057	23.536	61.466	23.332
Run-of-River Hydro	19.654	8.155	19.597	8.155	19.407	8.078
Domestic Coal	71.988	10.558	71.386	11.487	103.693	18.121
Imported Coal	64.941	10.249	67.145	12.066	62.985	11.830
Natural Gas	81.925	26.006	120.113	30.824	147.730	38.456
Solar	17.087	9.113	45.348	24.195	74.975	40.000
Wind	30.496	11.351	65.288	24.873	122.505	46.913
Other	0.720	1.004	2.069	1.875	4.726	4.000
Total	358.286	101.878	461.783	138.916	605.810	192.616

Table 17: *Generation amounts and installed capacities under Transition.*

	2023		2030		2040	
	TWh	GW	TWh	GW	TWh	GW
Biomass	6.556	0.987	9.420	1.481	11.742	2.000
Geothermal	9.847	1.432	13.006	1.964	12.269	2.000
Reservoir Hydro	62.266	23.536	62.169	23.536	72.803	27.608
Run-of-River Hydro	19.619	8.155	20.637	8.579	28.855	12.000
Domestic Coal	52.032	9.981	36.026	9.690	48.033	12.571
Imported Coal	62.956	9.723	43.504	9.186	42.000	8.650
Natural Gas	67.609	23.433	106.794	21.931	104.407	21.884
Solar	24.206	12.901	49.698	26.487	75.042	40.000
Wind	40.388	14.836	76.097	28.217	126.139	48.000
Other	1.091	1.131	2.307	1.975	4.275	3.807
Total	346.572	106.114	419.659	133.047	525.565	178.520

Figure 19: *[Transition – Baseline]: Installed capacities, 2020-2040, GW*

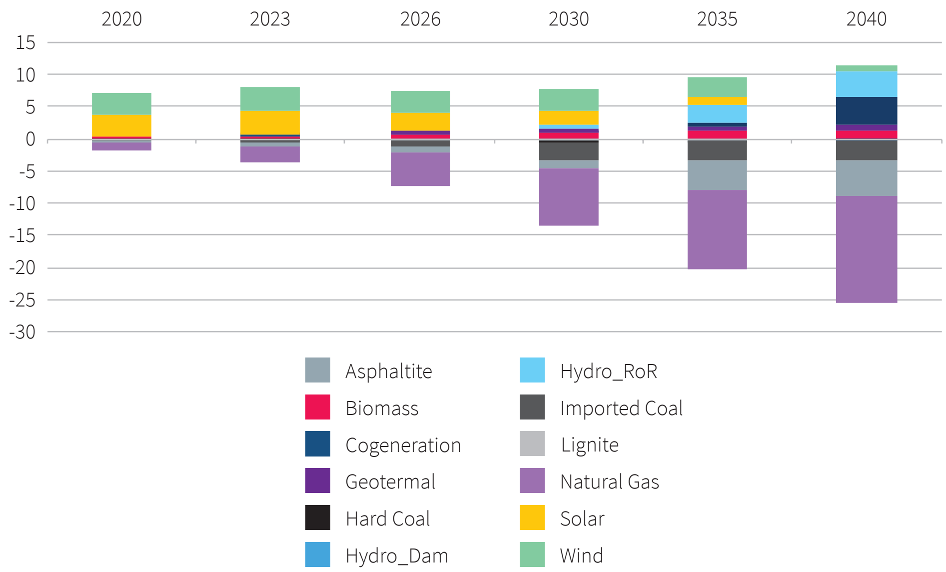
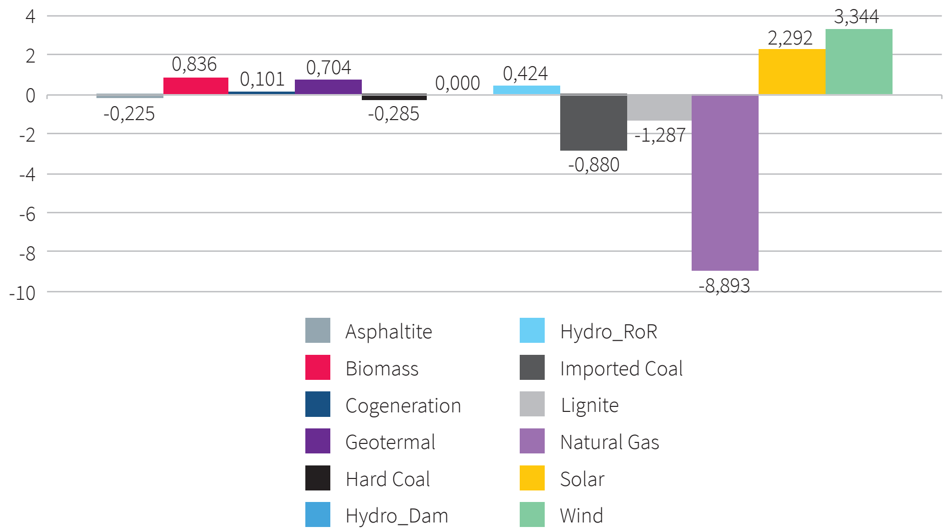


Figure 20: *[Transition – Baseline]: Installed capacities, 2030, GW.*



Appendix II – TD Model Formulation

Building on the augmented I/O data structure, we have total supply (absorption) at the national level as the sum of the value added produced in each region of the economy. The model follows the Armingtonian system of trade where the domestic production (DC), coupled with the import demand (M) makes up the composite commodity at national level. Following (Armington, 1969), we assume that the domestic and imported commodities are imperfect substitutes through a constant elasticity of substitution (CES) function:

$CC_i=(AC)_i\,[\delta_i M_i^{-\rho i}+(1-\delta_i)DC_i^{-\rho i}]^{-1/\rho_i}$	(21)

CC in Equation (21) represents total absorption in terms of the composite commodity; DC is the level of domestic production and M is the level of imports in each sector i. $\sigma=1/(1-\rho)$ is parameter of constant elasticity of substitution between domestic production and imports. Here, we assume that Equation (21) is representing the relationship between domestic production and imports at the national level. Total domestic production, however, is also differentiated by the region of origin, DCr. Therefore, the substitution possibilities represented in the equation above are among the regional domestic production DCY, DCZ, and imports, M which make up total domestic absorption.

The factors of production, capital (K) and labour (L) in each region produce the output X of the region. The profit maximization behaviour of the representative firm in each region determines the regional wages (W) and the regional profit rate (rk). Output in each region is either demanded domestically (DC) or exported (E). Total domestic absorption at the nation-wide level (CC), on the other hand is further decomposed into consumption (C), investment (I), government spending on commodities (G) and regional intermediates (INTr). Under such a setting, the import price in each sector is set at the national level, with no further differentiation at the regional level. Yet, based on the resource availability and differences in factor prices, export price in each sector is allowed to vary at the regional level.

The price of the composite commodity then is a function of the shares domestic commodity and imports in the composite and the prices of domestic commodity and imports in each sector i:

$PC_i=[P_i^D\,(DC_i/CC_i)+P_i^M\,(M_i/CC_i)]\;\;[1+saltax_i]$	(22)
$P_i^M=P_i^{WM}\cdot\varepsilon(1+tm_i)$	(23)
$P_{i,r}^E=P_i^{WE}\cdot\varepsilon(1-tx_{i,r})$	(24)

saltax in Equation (22) represents the sales tax rate. tm and te in Equations (23) and (24) are tariff and export tax/subsidy rates.

Based on the characterization of the production technology at regional level, regional employment rate is driven by marginal productivity of labour inputted, and the wage rates are resolved endogenously by equating aggregate labour demand against its supply. Likewise, total capital supply in each region is equated with total capital demand to clear the capital markets at the regional level:

$\sum_i LD_{i,r} = LSUP_r$	(25)
$\sum_i K_{i,r} = KSUPP_r$	(26)

Net of tax factor incomes, along with transfers from the government, interest income on domestic debt, factor income from the rest of the world net of interest payments on foreign debt are the basic sources of income for the households in each region:

$Yr = \sum_i (W_r\ WFDIST_{ir}\ LD_{ir} + (1\text{-}corptax)\ RK_r\ RKDIST_{ir}\ K_{ir}) + GOVTRANS + r^D\ DomDebtG + NPFI - r^F\ ForDebtP$	(27)

In Equation (27), Wr is the regional nominal average wage rate, WFDISTi,r is the parameter representing the difference between the regional nominal wage rates. Similarly, RKir is the profit rate differentiated at the regional level and RKDISTi,r is the associated difference in the regional profit rates. Kir represents the capital demand of each sector at the regional level. GOVTRANS is total public transfer to the households, DomDebtG is the stock of domestic public debt, ForDebtP is the stock of private foreign debt and NPFI is the net factor income from abroad.

The government collects sales taxes (TOTSALTAX), production taxes (TOTPRODTAX), tariffs (TARIFF), corporate taxes (TOTCORPTAX), income taxes (TOTHHTAX), and export taxes (EXTAX):

$GREV = TOTPRODTAX + TOTSALTAX + TARIFF + TOTSSTAX + TOTCORPTAX + TOTHHTAX + EXTAX$	(28)

On the expenditures side, we assume that the government follows a pre-determined primary surplus target as its fiscal policy rule. Given the public revenues, the amount of public transfers, the stock of domestic and foreign debts, it is the public investment variable that adjusts to the balance of the public sector in the model economy. Accordingly, the public sector borrowing requirement is defined as:

$PSBR = GREV - GCON - GINV - r^F ForDebt^G - r^D DomDebt^G - GOVTRANS$	29

PSBR is either financed by domestic borrowing ΔDomDebtG, or foreign borrowing $\Delta ForDebt^G$.

Private households save a s^p of their disposable income. The rest of the consumption demand is distributed among the products of the sectors of the economy by constant shares, $cles_i$ at the composite price PC_i:

$CD_i = cles_i \cdot PRIVCON/PC_i$	30

Similarly, total government consumption is distributed by constant shares among the sectors of the economy:

$GD_i = gles_i \cdot GOVCON/PC_i$	31

We assume that as part of the fiscal rule, total government consumption, GOVCON in Equation (31) is determined as a constant share of total revenues:

$GOVCON = gcrGREV$	32

The general equilibrium of the macroeconomy is associated with the relative prices in goods and factor markets and the real exchange rate that balances the goods markets, the factor markets, and the current account. In each period, we assume that the formal real wage rate is constant and is the regional unemployment levels that help the regional labour markets clear.

The equilibrium condition of the goods market implies that total demand is equal to total supply in each sector:

$CC_i = CD_i + GD_i + IDP_i + IDG_i + INT_i$	33

The reflection of the goods and factor markets equilibrium at macro-level, implies that total saving and total investments to equate:

$PSAV + GSAV + e\ CAdef = PINV + GINV$	34

CAdef in Equation (14) represents the current account deficit of the national economy in terms of foreign currency (US dollars). Here, CAdef is the difference between the exports and workers' remittances on the revenues side and the import bill, factor income transfers abroad, and interest payments on (private and public) foreign debt on the expenditures side:

$CAdef=\sum_i P_i^W E_i+ROWtrHH+ForBor^E+ForBor^G-[\sum_i P_i^W M_i+(trrow\sum_i(1-t_{Corp})rK_i)/e+r^F ForDebt^E+r^F ForDebt^G]$	35

In the model, we assume that the private and public components of the external capital inflows follow a pre-determined path at a fixed level in foreign exchange terms. Therefore, it is the real exchange rate e that balances the current account each period.

The model updates the annual values of the exogenously specified variables and the policy ratios in an attempt to characterize the 2010 – 2025 growth trajectory of the Turkish economy. Here we first update capital stocks with new investment expenditures net of depreciation; and also increase the available labour supplies by the population growth rates. Similarly, technical factor productivity rates are specified exogenously in a Hicks-neutral manner.

In order to be able to represent the conditions of the labour markets at the regional level in detail, we explicitly model the migration behaviour between the regions of the economy:

$L_Y^S(t+1)=(1+n_Y)\,L_Y^S(t)-MIG(t)$ $L_Z^S(t+1)=(1+n_Z)\,L_Z^S(t)-MIG(t)$	36

Here, MIG represents the labour migrating between regions; based on the value of this variable, we find the total labour supply in regions Y (poor) and Z (rich) respectively. nY and nZ are the population (labour supply accordingly) growth rates in regions Y and Z respectively. We follow the traditional Harris-Todaro (1970) approach to model the behaviour of MIG through successive time periods. Given the elasticity parameter migres to represent the sensitivity of the migration behaviour to the difference between the expected wage rate in the rich region (Z) and the actual wage rate in the poor region (Y), we take on that migration of labour from poor region to rich region is a function of this difference and the labour stock of the poor region:

$MIG(t)=migres\cdot[(E[W_Z]-W_Y)/W_Y]\;L_Y^S(t)$	37

We assume that the public and private sectors differ in terms of their investment behaviour. In the public sector, the distribution of total investments, GINV at the regional and at the sectoral level (investment by destination) is determined exogenously to represent its relevance as a policy tool. On the other hand, the sectoral distribution of private investments in each region is formulated as a function of the profit rates of the production sectors of the economy. Such a formulation is based on the Tobin-q model of investment and helps one to determine the distribution of private investments first at the regional and then, based on the difference between the sectoral and (regional) average profit rates, at the sectoral level. Accordingly, in each region we calculate the sectoral profit rates as the ratio of total value-added net of wage payments to the value of installed capital stock of sector i:

$r_{i,Y}=[PVA_{i,Y}\cdot X^S_{i,Y} - W_Y\cdot L^D_{i,Y} / PC_i K_i]$	38

Once average profit rate (r_{AVG}) in each region is determined, it becomes straightforward to regulate sectoral investment demands through the difference between the profit rate of the specific sector i ($r_{i,R}$) and the average profit rate of the region:

$DK_{i,R}(t+1)=SP_{i,R}+\mu SP_{i,R}$	39

$D_{Ki,R,}$ in Equation (39) is the share of private investment of sector i in region R in total regional private investment, $S_{Pi,R}$ is the share of profits of the same sector in total regional profits. Accordingly, if the profit rate of sector i is higher (lower) than the average profit rate among the sectors of the region, the share that sector gets from the regional total investment increases (decreases) through time.

The sensitivity parameter in Equation (39) is designed to reflect the effect of expectations and future uncertainty on the distribution of total regional investment among the sectors. Even though as mechanical as it may seem, the system designed in Equation (39) emphasizes the "profit drive" as one of the main determinants of the private investments.

Finally, in this stage, we account for the evolution of debt stocks. First note that government's foreign borrowing is taken as a ratio of aggregate PSBR:

$e\ ForBor^G = (gfborrat)PSBR$	40

thus,

$DomBor = (1 - gfborrat)\ PSBR$	41

Consequently, Government Domestic Debt accumulates via:

$DomDebt_{t+1} = DomDebt_t + DomBor_t$	42

Government Foreign Debt, on the other hand, becomes:

$ForDebt^G_{t+1} = ForDebt^G_t + ForBor^G_t$	43

Similarly, Private foreign debt is found as:

$ForDebt^P_{t+1} = ForDebt^P_t + ForBor^E_t$	44

Appendix III – Sensitivity Analysis

The sensitivity analysis on the Transition Scenario has been conducted in the following manner:

Three types of analysis for the power sector model are performed:
- Carbon tax level (no-tax, **low-tax**, high-tax)
- Discount rate (low, **high**)
- Subsidy scheme (none, **low**, high)

Power sector results under the high tax scenario are further coupled with the macroeconomic model.

Note that the low-tax, high discount rate, low subsidy combination characterizes the original Transition scenario for the power sector model. Then, the power sector model was run for an additional five settings. Moreover, one of them (high-tax) is further coupled with the macroeconomic model. In this section, the analysis for the power sector model will be presented first, followed by a summary of the impacts of the high carbon tax on macroeconomic indicators.

Sensitivity Analysis: Power Sector Model

The carbon tax levels used in the Transition scenario (low) and those proposed for the sensitivity analysis (high) are given in Table 18. The carbon tax gradually increases to US$40 in the counterfactual scenario while it increases to US$25 in the original Transition scenario. In addition to these tax rates, a third setting with no tax is also investigated.

Table 18: *Carbon tax levels (US$/ton)*

Year	Carbon Scenario - Low	Carbon Scenario - High
2021	4.42	7.08
2022	9.25	14.80
2023	19.31	30.90
2024	20.13	32.20
2025	20.94	33.50
2026	21.75	34.80
2027	22.56	36.10
2028	23.38	37.40
2029	24.19	38.70
2030	25.00	40.00
2035	25.00	40.00
2040	25.00	40.00

The discount factor paths used in the sensitivity analysis are summarised in Table 19. Note that the Transition scenario uses the higher discount rates. Finally, Table 20 shows the subsidy schemes employed in the sensitivity analysis where the low scheme is the one employed in the Transition scenario. A third setting in which all the subsidies are removed was also analysed.

Table 19: *Discount rate levels*

Year	Discount Rate - Low	Discount Rate - High
2020	12.0%	14.0%
2021	11.5%	13.5%
2022	11.0%	13.0%
2023	10.5%	12.5%
2024	10.0%	12.0%
2025	9.5%	11.5%
2026	9.0%	11.0%
2027	8.5%	10.5%
2028	8.0%	10.0%
2029	7.5%	9.5%
2030	7.0%	9.0%
2035	7.0%	9.0%
2040	7.0%	9.0%

Table 20: *Subsidy schemes*

	Biomass	Geothermal	Solar
High Subsidy	75%	50%	50%
Low Subsidy	60%	25%	25%

In the rest of this section, comparisons will be presented. The comparisons were performed in terms of the following indicators:

- Share of renewable generation
- Share of local generation
- Share of wind+solar generation
- Emission intensity
- Carbon tax collected

Figure 20. Change in renewable share – with respect to the transition scenario. illustrates the comparison of scenarios in terms of renewable share. The figures indicate that the difference between the low and high subsidy schemes is negligible. This result is expected considering that the two schemes are very close to each other. No subsidy case, on the other hand, differs significantly from these two schemes. The share of renewables decreases by more than 3 points under the no subsidy scheme in 2030. The same figure also implies that the impact of the discount rate is marginal (nearly 1.2 points) by 2030. Finally, the last graph in Figure 20.

Change in renewable share – with respect to the transition scenario. presents the comparison under each tax path. It is seen from this graph that there is a significant increase when a tax is levied on emissions, i.e., more than 5 points in renewable percentage. However, it seems that the higher tax rates result in a slight increase. In other words, the low tax path is enough to satisfy most of the potential improvement. The summary of these observations can be seen in Figure 22.

Figure 21: *Renewable share in total generation (%)*

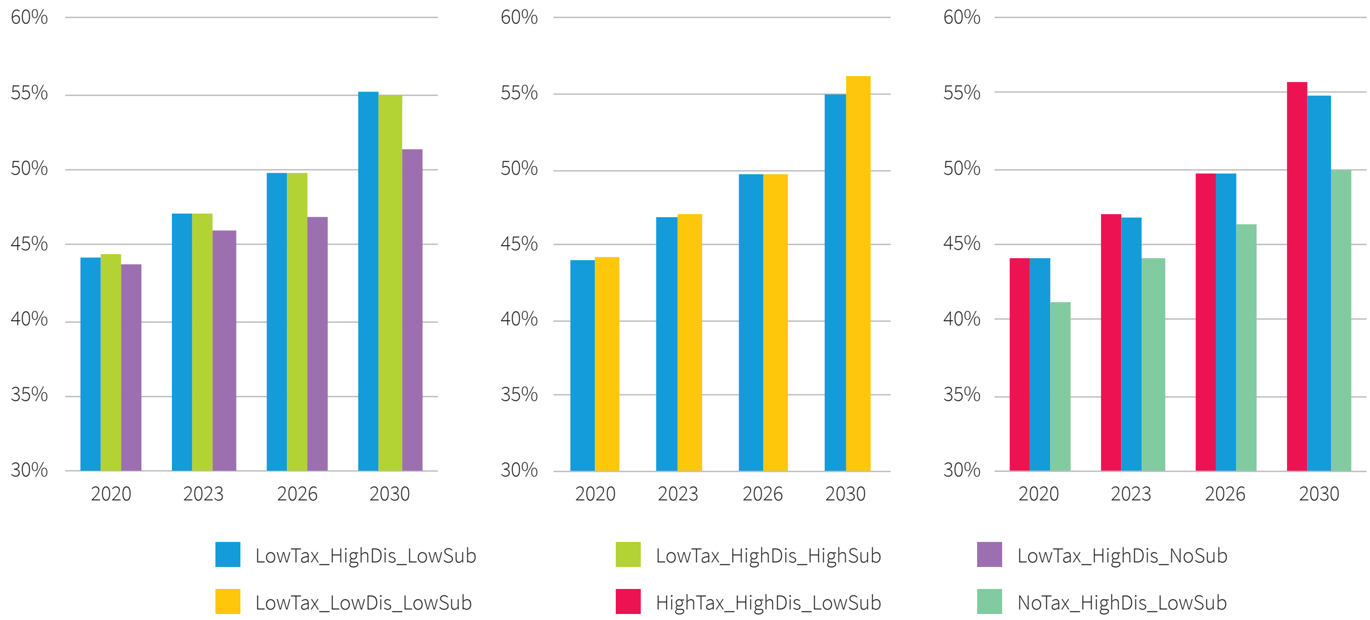
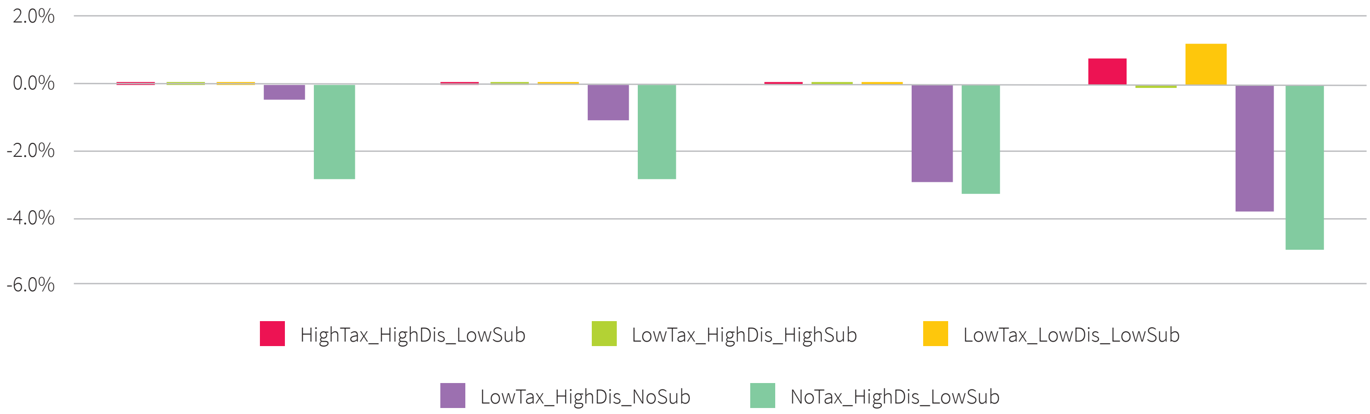


Figure 22: *Change in renewable share – with respect to the transition scenario*



Change in local share – with respect to the transition scenario. and provide similar comparisons in terms of the shares of the local resources in the total generation profile. Again, the scenarios do not differ much under the low and high subsidy schemes while a small but significant decrease occurs when the subsidies are removed. The impact of the discount rate is only a 1.2 points increase by 2030 under the low discount rate. Low and high tax levels result in with the same shares by 2030, i.e., higher domestic coal under lower tax is balanced with the relative decrease in the renewables. No tax case, on the other hand, attains a higher local share mainly due to the higher utilization of lignite plants.

__Figure 23:__ Local share in total generation (%)

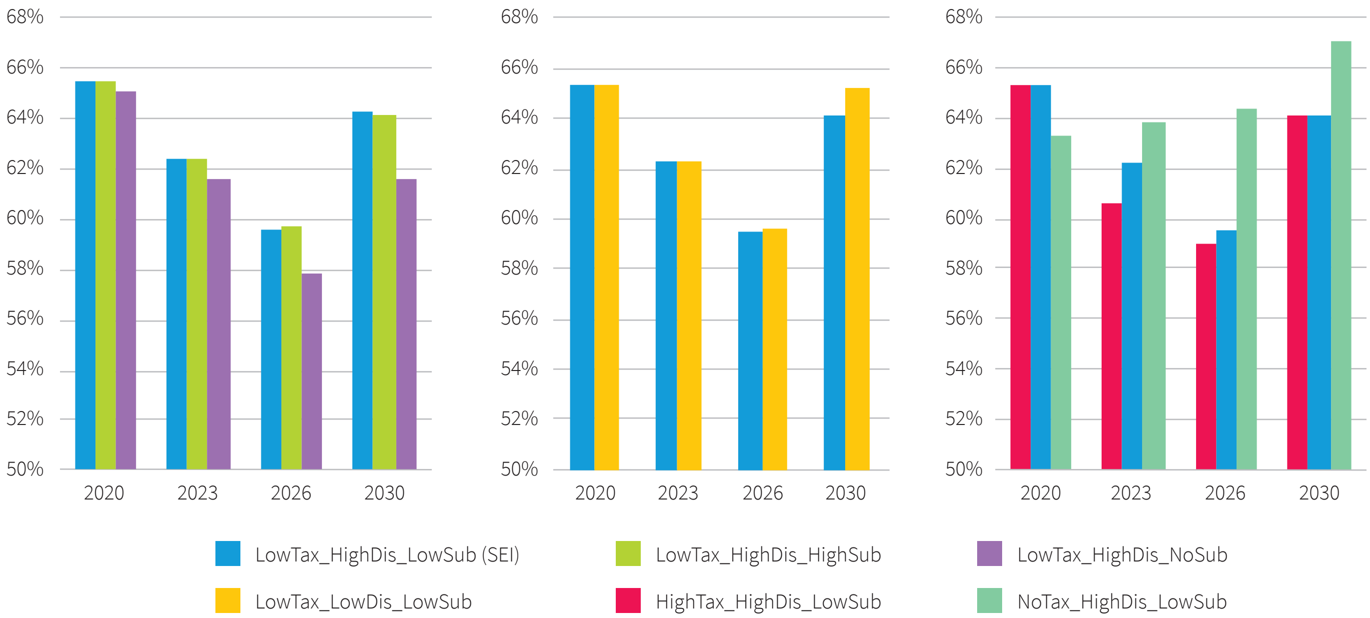
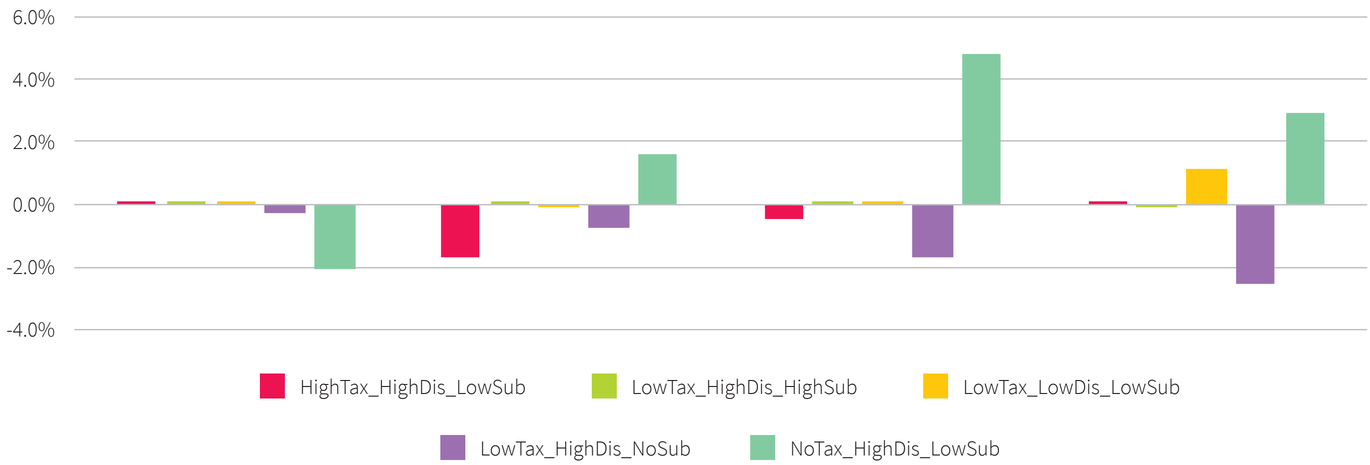


__Figure 24:__ Change in local share – with respect to the transition scenario.



The observations stated for renewable share are also valid for the share of wind plus solar as shown Figure 25. Emission intensity (kg CO_2e/kWh). No subsidy and no tax scenarios significantly differ from the transition scenario while all other options indicate a 30% share by 2030.

Figure 26. Change in emission intensity (kg CO_2e/kWh)– with respect to the Transition. and Figure 27. Total carbon tax (Billion US$). provides the comparison for the emission intensity over the scenarios. The mere observation from this figure is the significant increase under the case of no tax on emissions. The fossil-fired power plants increase the intensity (kg CO_2e/kWh) from 0.344 to 0.456. Error! Reference source not found. illustrates the total emissions as well as the disaggregation in terms of generation technologies where the most notable remark is the dominance of the lignite plants under both of the scenarios.

Figure 25: *Wind+Solar share in total generation (%)*

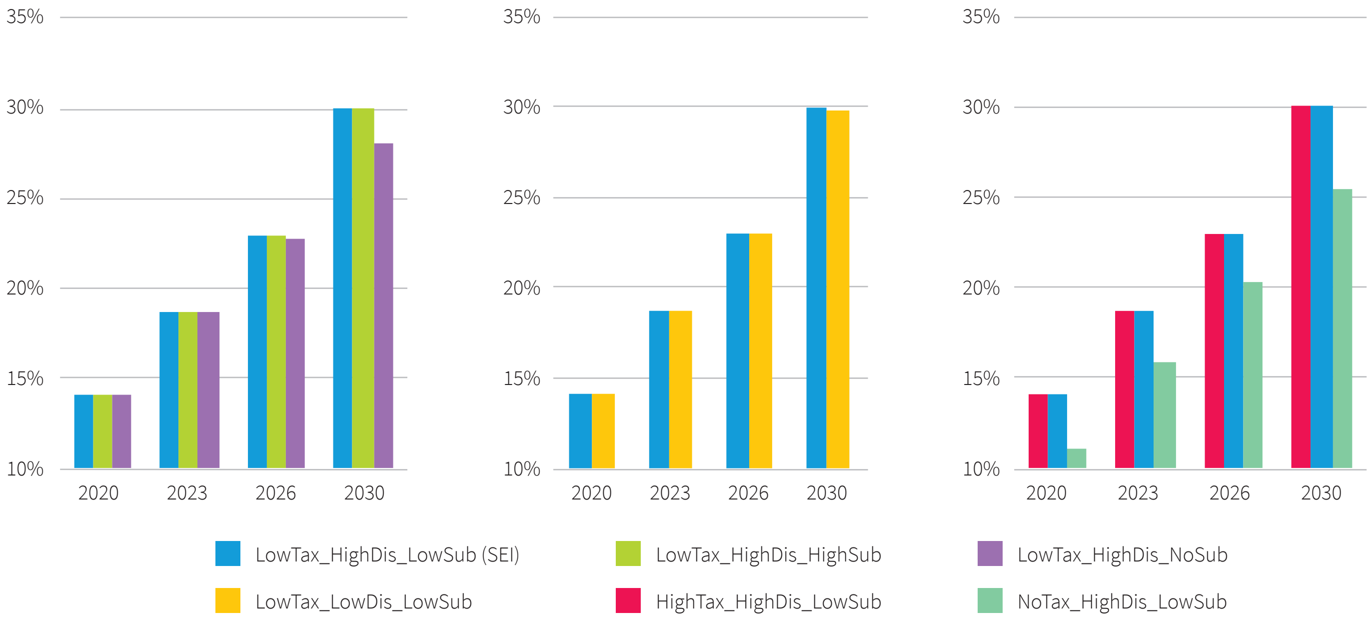


Figure 26: *Change in wind+solar share – with respect to the transition.*

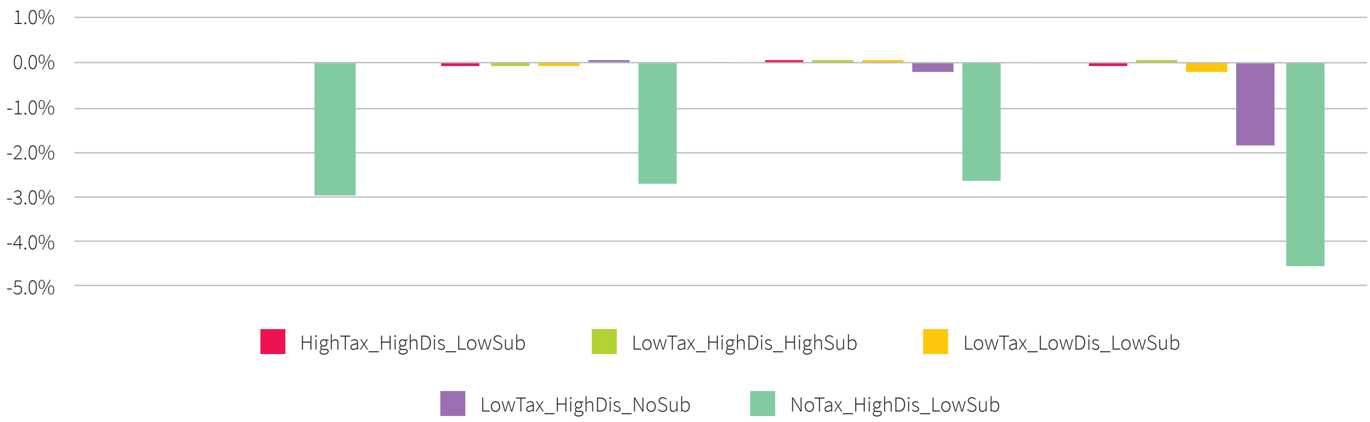


Figure 27: *Local share in total generation (%)*

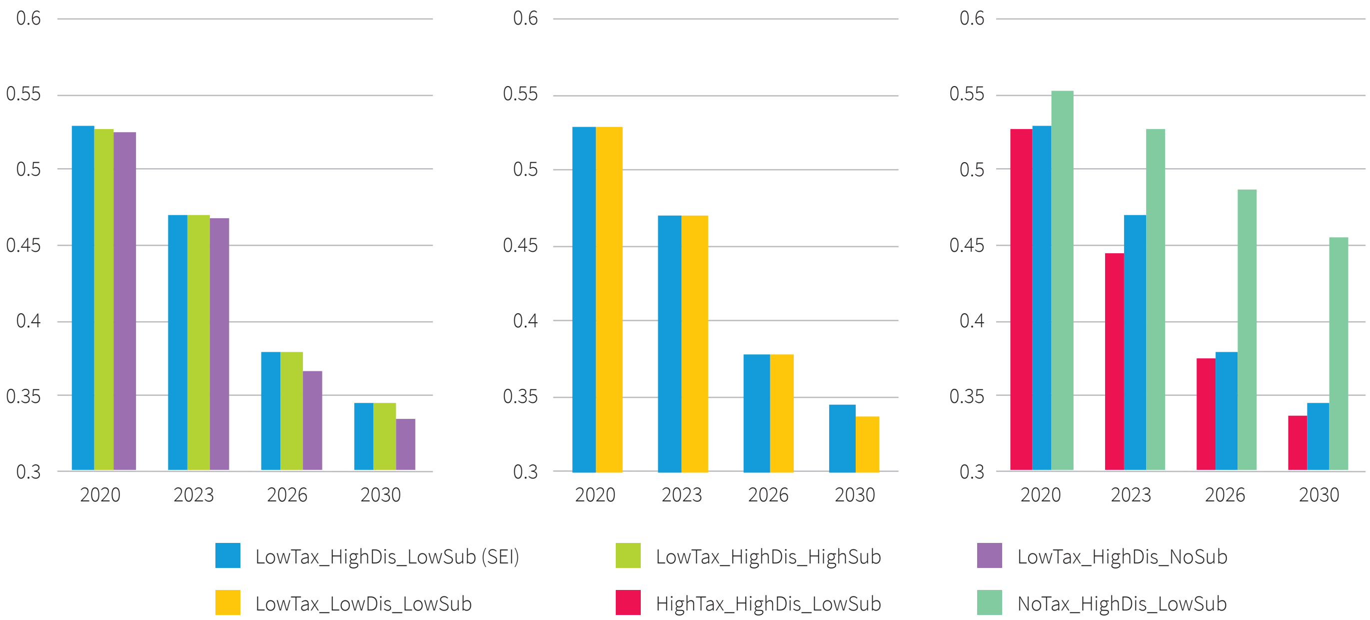


Figure 28: *Change in emission intensity (kg CO_2e/kWh)– with respect to the Transition.*

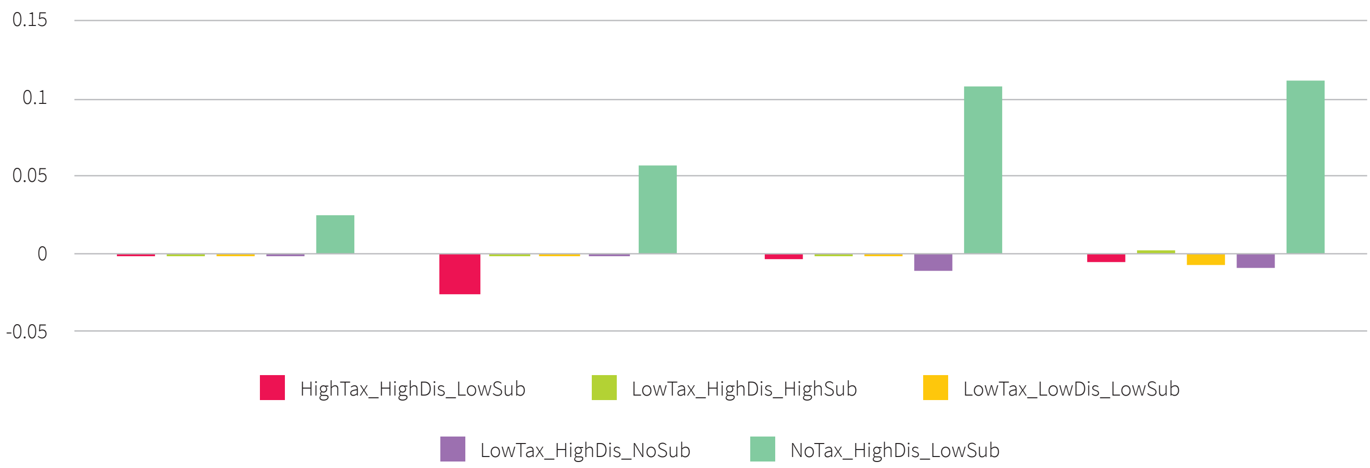
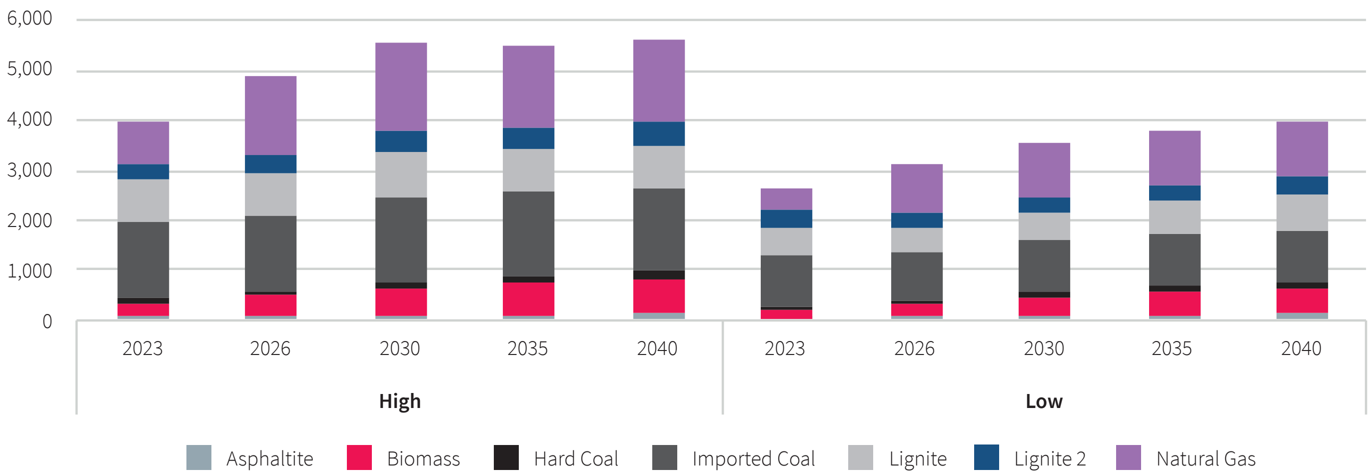


Figure 29: *Total carbon tax (Billion US$).*



Sensitivity Analysis: Macroeconomic Model

In this sensitivity analysis, we study the effects of rising the CO2 tax rate. We increase the per ton tax rate to reach 40US$ by 2040. The sector model studies the differential impact across the EL's inputs via the following table:

Table 21: *Carbon tax collected under high tax path (Billion US$).*

Carbon Cost (Bullion US$)	Asphaltite	Biomass	HardCoal	ImpCoal	Lignitie	Lignitie 2	NaturalGas	Totals
2023	0.060	0.271	0.114	1.502	0.306	0.060	0.846	3.993
2026	0.054	0.429	0.104	1.521	0.401	0.060	1.602	4.923
2030	0.060	0.582	0.115	1.705	0.447	0.060	1.737	5.549
2035	0.092	0.663	0.111	1.684	0.446	0.060	1.640	5.515
2040	0.131	0.706	0.159	1.659	0.440	0.060	1.655	5.610

Source Authors' calculations

Next, our task is to carry over this move to the macro CGE model. Before going any further, it has to be recalled that our modelling strategy relies on taking the sector model solutions from the EL sector and re-solving the CGE to obtain general equilibrium effects of the policy scenario. To achieve maximal sensitivity on the real side effects under the discipline of general equilibrium we extended the burden of the carbon tax across other sectors as well. Considering the industry as composed mostly of environmentally sensitive sectors, we have extended the burden of the CO_2 tax on the processes and energy utilization in the industrial sectors.

The overall macro general equilibrium dictates that the collected additional tax monies be distributed according to the specifics of a macro closure rule. Among many possible competing options, a more direct policy choice was to advance these monies as additional public sector income to be used as an investment fund for environmental abatement. This strategic choice has been advocated in the literature for attaining maximum efficiency of environmental abatement in the face of a second best policy instrument and has been used in many applications of environmental modelling exercises for Turkey (Acar et al., 2018; Yeldan & Voyvoda, 2015).

Thus, as the burden of the tax rate is implemented on the industrial sectors, the tax revenue is collected by the fiscal authority and is directed to public investments for further capital accumulation in aggregate industry. Thereby the sensitivity scenario as applied to the CGE framework, designs two sets of policy issues: first it uses a public policy tool –the CO_2 tax- as a direct instrument of abatement control; and then it uses the tax revenues earmarking them towards public investments to pursue green growth pathways.

This methodology allows us to study not only the micro sectoral effects of the CO_2 tax over the polluting sectors, but also traces out the macro effects of the tax burden, suggesting a green pathway allocation for public policy. This scenario ought to be seen as an additional step complementing the basic Shura scenario introduced in the main documentation and is a step towards the conduct pf additional research on the possible extensions of public fiscal policy under green conditionalities. The overall macro effects of the sensitivity scenario are displayed in Table 22.

The scenario results suggest that overall level of GDP is very marginally affected against the Shura Transition scenario. The potential loss in GDP over the Transition is minimal. This is due to two conflicting effects: one is the potential loss in output due to the unavoidable loss in efficiency emanating from the distortionary effects of the CO_2 taxes. The second-best nature of this policy instrument is highlighted by the second counterweighing positive demand effects of increased (public) investment expenditures. The net effect turns out to be almost even. The result is nevertheless an outcome of the elasticities and the intensity of the policy intervention –exactly the main purpose of this sensitivity analysis.

Table 22: *Macroeconomic indicators under each scenario.*

Macroeconomic Aggregates (Billions TL, 2018 Fixed Prices and Indexes 2018=100)										
	2018	2023			2030			2040		
	Base Year	Baseline	Transition Scenario	Transition Scenario w/High CO_2 Tax	Baseline	Transition Scenario	Transition Scenario w/High CO_2 Tax	Baseline	Transition Scenario	Transition Scenario w/High CO_2 Tax
GDP	3,724.4	112.8	112.8	115.0	143.4	144.8	146.6	197.3	204.0	203.3
Private Disposable Income	3,158.3	109.7	109.7	110.7	138.2	140.4	139.3	190.0	200.9	194.3
Fixed Investment Expenditures	1,101.6	112.3	112.3	114.4	140.1	142.3	142.5	188.7	199.2	194.6
Private Consumption Expenditures	2,111.3	111.0	111.5	112.1	141.1	140.5	140.9	195.8	197.7	194.1
Public Sector Revenues / GDP (%)	15.5	15.5	15.9	16.5	15.6	16.4	17.6	15.8	17.0	18.9
Public Sector Budget Deficit / GDP (%)	2.0	0.9	0.9	0.9	0.6	0.6	0.6	0.5	0.5	0.5
Public Sector Domestic Debp / GDP (%)	30.4	32.5	32.4	31.9	31.2	30.2	30.1	27.5	25.3	25.6
Trade Balance / GDP (%)	-2.95	-2.05	-1.77	-1.71	-0.69	0.21	0.33	0.73	2.45	2.60
Share of Industrial Labor Employment in Total (%)	14.3	14.5	14.6	14.6	14.8	15.0	15.1	15.0	15.4	15.5
Index of Real Wages (2018=100)	100.0	106.2	106.7	108.9	126.3	129.7	131.7	159.9	164.3	172.2

Compared against the base path, the sensitivity pathway is still superior. This suggests that a policy of carbon taxation coupled with a careful earmarking of the tax revenues to environmental abatement and public investment can expand both output and employment levels. This result is supportive of various similar designs proposed in Yeldan et al 2016 for the TÜSIAD Report (TUSIAD, 2016) and (Kolsuz & Yeldan, 2017).

Yet on the distributional side, the public sector investments –again unavoidably, crowds out the private incomes. Private disposable income recedes back by 6 percentage points across the Transition scenario. (Yet, against the base path private disposable income is still exceeded). As private disposable income falls, private savings and private investment falls (against the Transition). The fall in private investments is counteracted by the increase in public investments. Thus, aggregate investment is netted out.

But the most important results to contrast against all these backgrounds is the magnitude of abatement achieved. Total CO2 emissions are brought back by 22% over the Transition scenario by 2040. In 2030 this reduction is calculated to be 11%. Against the base path, these calculations are 34% for 2040 and 21% for 2030. This outcome is obtained by taxing away the polluting activities of IS and CE and re-implementing the public investment funds earmarking them for abatement. Table 23 documents the emission results of the scenario:

Table 23: *Emission indicators under each scenario.*

CO_2 Emission Indicators										
	2018	2023			2030			2040		
	Base Year	Baseline	Transition Scenario	Transition Scenario w/High CO_2 Tax	Baseline	Transition Scenario	Transition Scenario w/High CO_2 Tax	Baseline	Transition Scenario	Transition Scenario w/High CO_2 Tax
CO_2 Total Emissions, Mill tons	456.1	505.0	477.6	461.9	619.6	553.0	492.9	815.1	686.7	541.2
Total CO_2 (Eq), Mill tons	521.0	580.1	552.6	540.2	720.8	654.4	599.0	966.5	839.9	700.7
Total CO_2 (Eq)/GDP (kg/US$GDP)	0.660	0.652	0.621	0.595	0.637	0.573	0.518	0.621	0.522	0.437
CO_2 from Energy/ GDP (kg/US$GDP)	0.500	0.488	0.457	0.432	0.467	0.403	0.349	0.442	0.343	0.262
Total CO_2 /GDP (kg/ US$GDP)	0.578	0.567	0.536	0.509	0.547	0.484	0.426	0.524	0.427	0.337
Total CO_2 Emissions from Energy Production	325.0	357.6	332.4	320.0	431.2	397.9	323.5	553.4	428.0	326.2
Total CO_2 Emissions from Electricity Production	154.9	169.3	149.4	145.7	202.9	151.1	136.9	258.7	153.4	122.0
Total CO_2 Emissions from Coal Combustion	184.1	201.8	180.8	175.1	241.9	187.8	166.7	308.2	198.5	150.9
Total CO_2 Emissions from Energy Prod & Usage	394.6	434.7	407.2	391.7	529.0	460.3	404.0	688.6	552.3	420.6
Total CO_2 Emissions from Industrial Process	61.5	70.2	70.4	70.1	90.7	92.8	88.9	126.6	134.4	120.6
Total CO_2 Emissions from Household Waste	69.6	77.1	74.9	71.7	97.8	92.3	80.5	135.2	1324.3	94.3
Total Carbon Taxes (Billions US$)			0.916	2.647		1.154	3.112		1.600	3.963
Total Carbon Taxes/ GDP (%)			0.103	0.294		0.100	0.270		0.097	0.243

The CGE results reveal that these outcomes are achieved at a tax cost of 2.6 billion dollars in 2030, and 3.6 billion US$ in 2040. These are 0.29% and =.24% as a ratio to the real GDP, respectively. In sum, the intensity of CO_2 pollution per US$ value added falls to 337 grams in contrast to the 524 grams of the base path.

The scenario clearly underscores the power of the taxation instrument in substituting away the polluting activities across the industry. To follow up the sub-sectoral level effects Table 24 and Table 25 document the output and emissions findings.

Table 24: *Subsectoral economic impacts under high tax path (Billion US$).*

Sectoral Production (Index 2018=100)										
	2018	2023			2030			2040		
	Base Year	Baseline	Transition Scenario	Transition Scenario w/High CO_2 Tax	Baseline	Transition Scenario	Transition Scenario w/High CO_2 Tax	Baseline	Transition Scenario	Transition Scenario w/High CO_2 Tax
Agriculture	343.959	115.8	115.7	120.7	156.0	156.2	163.6	233.2	236.1	245.7
Mining	392.256	113.7	108.0	99.8	145.2	129.8	103.6	199.8	165.7	105.6
Electricity	614.558	112.5	108.8	108.8	148.4	135.1	135.1	215.6	187.4	187.4
Industry	2,288.302	114.7	116.1	117.8	150.6	159.0	159.6	214.5	244.1	240.6
Food Processing	374.179	113.1	112.9	116.8	146.7	146.1	151.6	208.0	207.7	214.3
Textiles	361.901	115.2	113.7	119.8	150.2	140.9	152.4	209.4	182.2	199.2
Paper Products	73.714	113.9	114.1	117.9	148.8	149.7	155.4	211.3	215.7	222.8
Iron, Steel Ind.	341.344	115.1	117.0	116.6	150.6	160.8	155.0	212.3	243.3	221.6
Cement Ind.	114.957	114.1	113.9	113.5	146.8	148.6	142.2	204.4	212.9	190.3
Petro Chemicals Ind.	404.858	116.2	115.2	112.0	160.5	164.3	152.8	248.3	280.3	249.7
Machinery & Automotives	617.349	114.3	120.3	122.3	147.5	176.0	179.5	202.6	288.3	296.9
Costruction	632.817	113.5	113.4	115.2	143.5	144.7	142.5	196.2	202.6	198.5
Services	3,443.004	112.0	112.2	114.8	140.2	141.5	144.8	188.6	194.7	197.6
Transportation	593.377	113.2	111.8	112.7	143.6	140.3	138.9	195.6	191.2	185.3
Professional Services	372.856	112.6	112.8	115.9	143.8	143.8	147.9	193.9	200.4	204.9
Health & Education	354.167	109.0	111.7	114.5	133.9	128.5	141.6	159.5	173.4	186.2

Table 25: *Subsectoral emission impacts under high tax path (Billion US$).*

Sectoral Production (Index 2018=100)										
	2018	**2023**			**2030**			**2040**		
	Base Year	**Baseline**	**Transition Scenario**	**Transition Scenario w/High CO_2 Tax**	**Baseline**	**Transition Scenario**	**Transition Scenario w/High CO_2 Tax**	**Baseline**	**Transition Scenario**	**Transition Scenario w/High CO_2 Tax**
Agriculture	9.769	10.829	10.498	10.158	13.348	12.490	11.103	17.757	15.953	12.569
Mining	2.389	2.642	2.443	2.113	3.184	2.687	1.830	4.069	3.048	1.448
Electricity	154.942	169.312	149.381	145.742	202.889	151.150	136.949	258.681	153.434	122.006
Industry	60.982	68.102	66.317	62.712	83.224	79.914	67.392	108.425	103.571	73.576
Food Processing	5.247	5.751	5.593	5.400	6.896	6.513	5.687	8.808	7.981	5.954
Textiles	0.568	0.638	0.614	0.606	0.781	0.696	0.641	1.004	0.798	0.653
Paper Products	1.017	1.129	1.104	1.070	1.362	1.305	1.146	1.742	1.620	1.209
Iron, Steel Ind.	5.804	6.527	6.458	6.132	7.948	7.956	6.748	10.175	10.1311	7.318
Cement Ind.	25.540	28.389	27.673	26.392	34.021	32.497	27.764	43.108	40.241	28.898
Petro Chemicals Ind.	16.808	18.976	18.196	16.744	24.061	22.561	18.102	33.120	31.372	20.918
Machinery & Automotives	5.998	6.693	6.678	6.369	8.155	8.386	7.303	10.469	101.248	8.626
Costruction	3.033	3.348	3.249	3.098	3.972	3.751	3.256	4.997	4.605	3.510
Services	93.932	103.388	100.463	96.182	124.556	117.936	102.946	159.456	147.395	113.118
Transportation	85.432	94.072	91.329	87.390	113.509	107.221	93.581	145.603	134.090	103.092

Table 24 reveals that the industry as a whole fall by 4 percentage points against the Transition scenario. Within industry iron and steel, cement and petrochemicals lose, and yet automotive and machinery gain. These are due to the general equilibrium effects of the policy, as polluting sectors dwindle resources are released to be employed elsewhere.

Finally, our results indicate that the (functional) distribution effects favour wage labour. Wage index exceeds the base path level by 5% in 2030, reaching out to 12% in 2040. These are 2% and 8% against the Transition scenario.

Appendix IV – Employment methodologies

Table 26 summarises the the total number of people employed in the renewable energy sector in Turkey in 2018 (IRENA, 2020). The UK Energy Research Center (2014) found that renewable energy and energy efficiency are more labour-intensive than fossil-fired generation, both in terms of shorter-term construction jobs, and jobs over the average plant lifetime. Therefore, if investment in new power generation is needed, renewables and energy efficiency can contribute to short-term job creation so long as the economy is experiencing an output gap, such as is the case during and shortly after a recession (UKERC 2014: 4).

Table 26: *Renewable energy employment in Turkey in 2018*

Renewable Energy Employment by Technology	Number of jobs in thousands
All RE technologies	102.9
Hydropower	47.7
Solar Photovoltaic	30.5
Solar Heating / Cooling	8.7
Wind Energy	6.7
Geothermal Energy	6
Municipal and Industrial Waste	2.2
Biogas	0.7
Liquid Biofuels	0.5
CSP	0
Solid Biomass	0

IRENA 2020

Employment factors approach

Employment factors is defined as the number of jobs created from the addition of new energy generation installed capacity and are broken down into three categories: manufacturing, construction and installation (C&I), and operations and maintenance (O&M), see Table 27.

Table 27: *Employment factors for renewable energy.*

Technologies	Manufacturing [Job-yrs/MW]	C&I [job-yrs/MW]	O&M [Jobs/MW]
Onshore Wind	4.7	3.2	0.3
Solar PV utility scale	6.7	13.0	0.7

Ram et al., 2020

Since Turkey-specific employment factors are unavailable, regional employment factors can be derived using regional multipliers for 2015-2050, with Turkey falling in the Eurasian region (Table 28).

Table 28: *Regional Multipliers: Factors for Labour Intensity for Production - Regional Distribution; OECD=1 (Ram et al., 2020)*

	2015	2020	2025	2030	2035	2040
Europe	1.05	1.08	1.10	1.13	1.17	1.19
Eurasia	1.86	1.80	1.75	1.70	1.65	1.65
MENA	2.26	1.94	1.66	1.51	1.37	1.32
Sub-Saharan Africa	7.49	6.42	5.51	5.00	4.54	4.38
SAARC	5.18	3.99	3.07	2.56	2.13	2.00
Northeast Asia	2.22	1.89	1.60	1.50	1.41	1.42
Southeast Asia	2.52	2.20	1.93	1.77	1.63	1.58
North America	1.00	1.00	1.00	1.00	1.00	1.00
South America	3.14	2.69	2.31	2.10	1.90	1.84
Global	2.18	1.99	1.81	1.70	1.60	1.56

Ram et al., 2020

Decomposition analysis

Using data from the BU power system on the share of renewables (wind & solar) and the coefficients of renewable labour input share, we use CGE results on average wages to estimate the employment generated due to the power system transition (Table 29).

Table 29: *Net employment gains due to wind and solar (via decomposition analysis).*

	2018	2023		2030		2040	
	Base Year	Baseline	Transition	Baseline	Transition	Baseline	Transition
Share of Wind & Solar in Electricity Generation	0.095	0.132	0.187	0.240	0.299	0.320	0.383
Value of Electricity Output (Billion 2018 TL)	614.6	691.2	668.6	911.9	830.1	1324.9	1151.8
Share of Labour Input in Renewables	0.095	0.097	0.097	0.098	0.098	0.101	0.101
Index of Real wages	100.0	106.2	106.7	126.3	129.7	159.9	164.3
Estimated Employment in Wind & Solar data (persons)	37,200	28,909	39,513	63,839	71,322	110,959	113,537
Net Employment Gains due to Wind & Solar (persons)			10,604		7,484		2,578

Source: Authors' calculations from CGE analysis

As the BU power system model provides information on the share of wind and solar in total power generation (1) and the share of labour in the renewables sector (3), information on the aggregate value of electricity output (2) and real wage costs (4) come from the CGE model. Using these ratios[13], total wage remunerations in renewables are calculated, data is used to calculate the total net employment gains due to wind and solar (6)

[13] (L^E=TotalWages / W_E, with Total wages = share of renewables x share of labour in renewables x total value of output

Appendix V - Input-Output Analysis in a Nutshell

Within the IO framework, production in an n-sector economic structure can be defined as follows:

$X=AX+Y$	45

Here, X stands for gross output, Y stands for aggregate demand, both in the form of (n×1) vectors, whereas A A_d is an (n×n) matrix that represents the relationship between the sectors. Equation (45) can be simplified as follows:

$X=(I-A)^{-1} Y$	46

Aggregate demand can be written as Y=C+I+G+EX, and is composed of household consumption C, investment I, government expenditure G, and exports EX. The impact of, e.g., a decline in exports on sectoral output could be written as such:

$\Delta X=(I-A)^{-1} \Delta EX$	47

The sum of column j within the ΔX matrix prresents the effect of a change in export demand on the output level of the economy.

With the help of equation (48), it is possible to decompose the sectoral value-added (VA) effects, employment (EMP) effects, and greenhouse gas emissions effects (GHG) as a result of the change in the final demand in a specific sector. If K denotes an (n×n) diagonal coefficients matrix,

$Z=K(I-A)^{-1} Y$	48

Equation (48) helps to find the direct and indirect effects arising from a final demand change. For instance, the value-added coefficients, $K_{VA}=VA_j/X_j$, that lie on the diagonal of the value-added coefficients matrix represent the ratio of sector j's value-added to the gross output of the corresponding gross output. Similarly, the diagonal coefficients $K_{EMP}=EMP_j/X_j$ ve $K_{GHG}=GHG_j/X_j$ represent employment and greenhouse gas emissions coefficients for sector j respectively.

The impacts of sectoral final demand changes on sectoral employment

The decline in EL demand resulting from energy transition will have various sectoral employment implications. Part of these implications will be in the form of direct effects (i.e., on the sector of interest itself), while the rest of the effects will be indirect owing to the input-output relationships between the corresponding sector and the other sectors.

In the current report, the effects of energy efficiency (i.e., a decrease in electricity demand, represented by a decline in EL final demand within the CGE model) are analysed with the help of the following equation.

$\Delta EMP=K_{EMP} (I-A)^{-1} \Delta EL$	49

According to Equation (49), the total employment impact of a decline in the final demand of the EL sector is demonstrated by the sum of column j in the matrix for ΔEMP.

Appendix VI - Literature Summary of Socioeconomic Impacts for Turkey

***Table 30:** Literature Summary of Socioeconomic Impacts for Turkey*

Study	Year	Scenario	GDP (billion TL)	GDP %Δ	Investment (billion TL)	Imports (billion TL)	Unemp. rate	Emp. rate	CO_2 emissions (million tones)	CO_2 emissions %Δ	GHG (MCO_2e)	GHG (MCO_2e) %Δ
Kumbaroğlu 2003	2030 BAU		759,61 billon $		290,55 billon $	240,61 billon $						
	2030 scenario	300 US$/ton tax on NO_x emissions	760,47 billon $	↑ 0,11	290,79 billon $	240,01 billon $			Emission intensity decreases from 0,058 to 0,033 ton/toe in case SO_2 tax is implemented.			
Telli Voyvoda Yeldan 2008	2020 BAU						10%		656			
	2020 scenario	%90 carbon emission quota		↓ 7,1	↓ 4				591	↓ 10		
	2020 scenario	%20 energy tax		↓ 7,4			19%		485	↓ 26		
	2020 scenario	%10 energy tax		↓ 3,9			15%		560	↓ 15		
	2020 scenario	Abatement investment financed by energy taxes		↓ 21	↓ 27				461	↓ 30		
Voyvoda, Yeldan, Berke, Şahin, Gacal 2015	2030 BAU		2256		438			27.7	659		787	
	2030 scenario	Carbon tax+RE investment fund + autonomous increases in energy efficiency	2074	Same with that of BAU	415	coal 25% ↓, natural gas 35% ↓		27.2	506	↓24	621	↓21
Bouzaher, Şahin, Yeldan 2015	2030 BAU		3013		554	841		26			984	
	2030 scenario	1. Greening urban economy via env taxes	2669	↓11	504	633		20			746	↓24
	2030 scenario	1.+ Climate change mitigation via innovation	3084	↑ 2	571	812		26			757	↓23
Acar, Yeldan 2016	2030 BAU		2371		440		7.8%	34	682		882	
	2030 scenario	1. Eliminate subsidies on coal production	2368	↓0,2	440		7.9%	34	662	↓3	802	↓2,5
	2030 scenario	1.+ Eliminate regional investment subsidies on coal	2359	↓0,5	439		8.2%	34	639	↓6	777	↓5,4
Yeldan et al. TÜSİ-AD 2016	2030 BAU		2033		452			29.3	683		811	
	2030 scenario	1. Carbon tax for 21% emissions mitigation w.r.t. BAU	2130	↓9	418			27.1	540	↓21	652	↓9
	2030 scenario	1.+ A decrease in employment taxes neutralizing the fiscal impacts of (1)	2248	↓4	425			29.3	577	↓16	695	↓14
Kolsuz, Yeldan 2017	2030 BAU		3012		554	841		26			984	
	2030 scenario	1. Greening urban economy via green jobs	2796	↓7	513	710		23			723	↓27
	2030 scenario	1.+ Labor market reform	3061	↑ 2	539	791		29			789	↓20
Kat, Paltsev, Yuan 2018	2030 BAU	ETS under planned nuclear development and a renewable subsidy scheme (BAU)										3.1% lower than NoN & 30% lower than the INDC BAU
	2030 scenario	ETS under no nuclear technology allowed (NoN)										
Acar, Voyvoda, Yeldan 2018	2030 BAU		2726		727		7.4%	30.4	644		789	
	2030 scenario	1. Removing fossil fuel subsidies 2. Carbon tax 3. RE investment fund 4. Autonomous increases in energy efficiency	2828	↑ 5	763		6.2%	30.8	509	↓21	666	↓16

Appendix VII – Long-term impacts to 2040

Table 31: *Sectoral Production Results*

Sectoral Production (Billions US$ for 2018, Index 2018=100 for other periods)							
	2018	2023		2030		2040	
	Base Year	Baseline	Transition Scenario	Baseline	Transition Scenario	Baseline	Transition Scenario
Agriculture	72.873	115.8	115.7	156.0	156.2	233.2	236.1
Mining	83.105	113.7	108.0	145.2	129.8	199.8	165.7
Electricity	130.203	112.5	108.8	148.4	135.1	215.6	187.4
Industry	484.810	114.7	116.1	150.6	159.0	214.5	244.1
Food Processing	79.275	113.1	112.9	146.7	146.1	208.0	207.7
Textiles	76.674	115.2	113.7	150.2	140.9	209.4	182.2
Paper Products	15.617	113.9	114.1	148.8	149.7	211.3	215.7
Iron, Steel Ind.	72.319	115.1	117.0	150.6	160.8	212.3	243.3
Cement Ind.	24.355	114.1	113.9	146.8	148.6	204.4	212.9
Petro Chemicals Ind.	85.775	116.2	115.2	160.5	164.3	248.3	280.3
Machinery & Automotives	130.794	114.3	120.3	147.5	176.0	202.6	288.3
Costruction	134.071	113.5	113.4	143.5	144.7	196.2	202.6
Services	729.450	112.0	112.2	140.2	141.5	188.6	194.7
Transportation	125.715	113.2	111.8	143.6	140.3	195.6	191.2
Professional Services	78.995	112.6	112.8	142.3	143.8	193.9	200.4
Health & Education	75.035	109.0	110.7	128.5	133.9	159.5	173.4

Table 32: *Sectoral Trade Results*

Sectoral Exports (Billions US$, 2018 Prices)							
	2018	2023		2030		2040	
	Base Year	Baseline	Transition Scenario	Baseline	Transition Scenario	Baseline	Transition Scenario
Agriculture	6.004	7.360	7.347	10.763	10.641	17.803	17.375
Industry	158.962	184.972	189.687	247.199	271.093	357.073	435.917
Food Processing	14.079	16.387	16.310	21.911	21.386	32.043	30.256
Textiles	30.040	35.187	34.535	46.431	42.154	65.009	52.082
Paper Products	2.525	2.928	2.921	3.914	3.852	5.698	5.492
Iron, Steel Ind.	19.806	23.062	23.428	30.801	32.775	44.322	49.991
Cement Ind.	4.312	5.009	4.967	6.581	6.530	9.342	9.286
Petro Chemicals Ind.	23.996	28.483	28.328	41.322	43.429	68.141	82.408
Machinery & Automotives	64.204	73.917	79.198	96.239	120.967	132.519	206.401

Sectoral Imports (Billions US$, 2018 Prices)							
	2018	2023		2030		2040	
	Base Year	Baseline	Transition Scenario	Baseline	Transition Scenario	Baseline	Transition Scenario
Agriculture	9.753	10.549	10.547	12.872	13.086	16.958	17.985
Industry	178.837	200.275	202.627	253.327	266.806	347.614	395.669
Food Processing	7.152	7.765	7.775	9.636	9.880	13.034	14.136
Textiles	8.205	9.098	9.101	11.535	11.676	15.910	16.694
Paper Products	3.986	4.432	4.464	5.596	5.809	7.680	8.496
Iron, Steel Ind.	33.498	37.755	38.421	47.614	51.195	64.664	76.303
Cement Ind.	1.875	2.085	2.102	2.602	2.711	3.523	3.929
Petro Chemicals Ind.	57.211	64.182	65.223	82.218	87.190	115.066	132.764
Machinery & Automotives	66.899	74.958	75.541	94.127	98.345	127.737	143.347

Table 33: Total employment impacts in 2030 and 2040, Baseline and Transition scenarios

	Total Employment	Total Employment Baseline	Total Employment Transition	Total Employment Baseline	Total Employment Transition	Change in employment Transition	Change in employment Transition - Baseline
	2018	2030	2030	2040	2040	2040-2018	2040
AF: Accommodation & Food	1,611,000	1,794,140	1,758,632	1,913,918	1,837,536	226,536	-76,382
AG: Agriculture	4,739,000	5,561,928	5,464,541	6,211,261	5,973,047	1,234,047	-238,214
AT: Air Transport	295,028	331,862	297,799	345,489	285,435	-9,593	-60,054
AU: Automotive	215,077	254,916	318,015	271,577	413,180	198,103	141,603
CE: Cement	305,010	352,609	351,345	382,566	380,250	75,240	-2,316
CH: Chemicals	409,504	527,758	570,186	647,399	766,906	357,402	119,507
CN: Construction	1,972,000	2,221,913	2,201,917	2,360,761	2,328,219	356,219	-32,542
EL: Electricity	288,000	327,769	325,602	359,125	357,069	69,069	-2,056
ES: Education Services	1,682,000	1,907,678	1,977,101	2,066,473	2,204,936	522,936	138,463
FO: Food Processing	610,158	698,053	684,522	766,377	733,510	123,352	-32,867
FS: Financial and Real Estate Services	1,043,998	1,179,915	1,174,826	1,281,935	1,275,573	231,575	-6,362
HE: Health Services	1,383,000	1,569,705	1,632,394	1,701,246	1,825,581	442,581	124,335
IS: Iron and Steel	172,456	205,219	213,974	225,170	242,517	70,061	17,347
MI: Mining	150,000	173,094	152,552	188,753	150,561	561	-38,192
MW: Machinery, White Goods	990,347	1,158,639	1,243,710	1,257,136	1,431,208	440,861	174,072
OE: Other Economy	4,676,522	5,296,785	5,381,217	5,665,234	5,833,521	1,156,999	168,287
PA: Paper Products	144,412	168,956	167,580	186,545	182,637	38,225	-3,908
PE: Petroleum Products	10,380	12,159	9,825	13,369	9,072	-1,308	-4,297
PR: Professional Services	1,336,826	1,512,926	1,508,165	1,628,968	1,619,929	283,103	-9,039
PS: Postal and Courier Services	93,460	104,856	104,380	112,320	111,669	18,209	-651
RT: Retail trade	3,960,000	4,448,133	4,434,663	4,815,652	4,806,868	846,868	-8,784
TE: Textiles, Clothing	1,241,675	1,476,856	1,372,758	1,615,693	1,366,057	124,382	-249,636
TR: Transportation	1,174,709	1,343,411	1,337,621	1,458,005	1,447,127	272,418	-10,878
TS: Tourism	233,439	253,534	242,871	260,155	238,665	5,226	-21,490
Total employment	28,738,000	32,882,814	32,926,196	35,735,127	35,821,073	7,083,073	85,946

Table 34: *Employment impacts due to energy demand, 2030 and 2040*

	2018	Baseline 2030	Transition 2030	Gain 2030	Baseline 2040	Transition 2040	Gain 2040
AG: Agriculture	5.687	4.296	4.082	-215	4.639	4.275	-364
MI: Mining	40.847	41.473	38.128	-3.346	45.69	38.411	-7.279
FO: Food Processing	542	458	443	-15	482	468	-13
TE: Textiles, Clothing	1.747	1.279	1.214	-64	1.383	1.258	-126
OE: Other Economy	42.735	36.321	35.196	-1.125	39.493	37.013	-2.48
PA: Paper Products	1.883	1.318	1.285	-33	1.454	1.37	-84
PE: Petroleum Products	309	201	167	-34	220	155	-65
CH: Chemicals	5.869	2.366	2.34	-27	2.744	2.664	-80
CE: Cement	3.650	3.425	3.335	-89	3.778	3.548	-231
IS: Iron and Steel	1.426	705	688	-16	789	738	-52
MW: Machinery, White Goods	9.930	6.074	6.086	12	6.716	6.634	-82
AU: Automotive	189	104	107	3	114	117	3
EL: Electricity	166.930	185.198	183.01	-2.187	200.522	196.863	-3.658
CN: Construction	7.516	7.918	7.783	-135	8.748	8.332	-416
RT: Retail trade	18.969	18.479	17.954	-526	19.219	19.054	-165
TR: Transportation	13.133	11.916	11.435	-482	12.73	11.99	-740
AT: Air Transport	1.585	1.266	1.19	-75	1.37	1.217	-153
PS: Postal and Courier Services	958	913	891	-23	988	946	-42
AF: Accommodation and Food	2.899	2.615	2.537	-79	2.715	2.677	-38
PR: Professional Services	17.747	15.962	15.53	-432	17.201	16.447	-753
FS: Financial and Real Estate Services	23.984	24.919	24.488	-431	26.38	26.242	-138
TS: Tourism	300	254	245	-9	267	254	-12
ES: Education Services	1.137	1.084	1.055	-29	1.174	1.119	-55
HE: Health Services	22	22	21	0	24	23	-1

Table 35: *Jobs to be created in the Turkish wind and solar sectors by 2030 and 2040, assuming only onshore wind and utility-scale solar PV are deployed. Source: author's calculations*

	2030			2040		
Technologies	Manufacturing [Job-yrs]	C&I [job-yrs]	O&M [Jobs]	Manufacturing [Job-yrs]	C&I [job-yrs]	O&M [Jobs]
Wind onshore	303.780	206.829	19.390	372.240	253.440	23.760
PV Utility-scale	414.482	804.219	43.304	442.200	1.716.000	92.400

NOTES

About Istanbul Policy Center at the Sabancı University

Istanbul Policy Center (IPC) is a global policy research institution that specializes in key social and political issues ranging from democratization to climate change, transatlantic relations to conflict resolution and mediation. IPC organizes and conducts its research under three main clusters: The Istanbul Policy Center–Sabancı University–Stiftung Mercator Initiative, Democratization and Institutional Reform, and Conflict Resolution and Mediation. Since 2001, IPC has provided decision makers, opinion leaders, and other major stakeholders with objective analyses and innovative policy recommendations.

About European Climate Foundation

The European Climate Foundation (ECF) was established as a major philanthropic initiative to help Europe foster the development of a low-carbon society and play an even stronger international leadership role to mitigate climate change. The ECF seeks to address the "how" of the low-carbon transition in a non-ideological manner. In collaboration with its partners, the ECF contributes to the debate by highlighting key path dependencies and the implications of different options in this transition.

About Agora Energiewende

Agora Energiewende develops evidence-based and politically viable strategies for ensuring the success of the clean energy transition in Germany, Europe and the rest of the world. As a think tank and policy laboratory, Agora aims to share knowledge with stakeholders in the worlds of politics, business and academia while enabling a productive exchange of ideas. As a non-profit foundation primarily financed through philanthropic donations, Agora is not beholden to narrow corporate or political interests, but rather to its commitment to confronting climate change.

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