Costs and Benefits of Decarbonizing Hungary's Economy by 2050

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EXECUTIVE SUMMARY

In 2021 Hungary prepared its Long-Term Low Emission Development Strategy, the National Clean Development Strategy (NCDS) to meet its legally mandated climate neutrality target enshrined in Act no. XLIV of 2020 on Climate Protection. The low-emission scenarios outlined in the 30-year-long roadmap are cross-sectoral trajectories that specify the costs and benefits of the transition, including avoided costs and labor market impacts by 2050. This report explores and discusses these costs and benefits in detail and makes recommendations for Hungary to facilitate the planned and coherent implementation of decarbonisation, with the potential to gain broad support from the public and economic actors.

That is, the objective of this report is to present the socio-economic implications of decarbonizing Hungary's economy by 2050, based on NCDS's analysis and modelling across key emitting sectors i.e., energy and transport, industry, agriculture, forestry, and waste.

Hungary's carbon-free vision is a "development that nurtures sustainable economic growth and creates green jobs and economic development opportunities while minimizing environmental pollution and greenhouse gas emissions". Although a cleaner development pathway bears higher costs and requires significant investments, it also presents major innovation, technology, investment, and business opportunities for sustainable economic growth.

The NCDS, which was prepared with the extensive and regular involvement of stakeholders, translates Hungary's climate neutrality vision and its sectoral ambitious goals to actions, measures, and radical, deep economic transformation programs and the associated costs.

A change in the circumstances in which the strategy was prepared was, that the COVID-19 outbreak has modified the modelling boundary conditions as well, as its impacts had to be considered when constructing long-term development trajectories. Consequently, model results showed that the early implementation of investments can serve as an incentive for recovery during the economic crisis by creating thousands of new and green jobs and increasing the well-being of the Hungarian people.

The NCDS was novel in a way that it applied two different but compatible, complementary, and interlinked models. The Green Economy Model (GEM) intersectoral top-down model that uses System Dynamics, and the HU-TIMES (The Integrated MARKAL-EFOM System) bottom-up equilibrium optimization model used to analyze the different pathways of energy flows within the energy subsectors. The cross-sectoral nature of the exercise called for the integration of two models (TIMES and GEM), due to the predominant role of the energy sector in the generation of emissions, and to the complementarity nature of the two models.

By applying the two models in an integrated fashion, the NCDS proposed and assessed two low-carbon development scenarios and a benchmark, or "do-nothing" (Business-as-usual) scenario. In essence, the difference between the two scenarios is the timing of actions and the implementation of policy decisions. The more ambitious scenario (so called Early Action scenario) prioritizes the majority of measures and investments to be made early in the trajectory, while the less ambitious pathway (Late Action scenario) schedules these actions later.

Cross-sectoral modelling has revealed that the total investment costs to implement the EA scenario will require to invest a HUF 24.7 thousand billion , taking the BAU scenario's cost estimates as reference. Conversely, the additional cost according to the LA scenario is HUF 13.7 thousand billion. The difference between the two scenarios originates in the energy sector, which requires, being the largest emitter, the most investments and improvements. The additional annual investment need accounts for 4.8% of the GDP in the EA scenario.

The level of cumulative investment demand of the EA scenario correlates with the current emissions of each sector and the cost of technology to be deployed:

Sector	Emissions in 2020 (million tons CO2e)	Investment needs by 2050 (thousand billion HUF)
Energy	38	22.4
IPPU	7.3	0.13
Agriculture	7	0.74
Waste management	3.5	0.48
LULUCF (natural sink)	-3	0.9

In contrast, full decarbonization of the Hungarian economy will also generate significant avoided costs and added economic benefits across the whole economy. Assessing the period up to 2050, the value of avoided costs and added benefits are observed to exceed the investment costs, they add up to HUF 38.3 thousand billion. Moreover, these avoided costs and additional benefits will continue to increase well after 2050.

Estimated balance sheet of decarbonization in Hungary by 2050 (EA scenario, compared to BAU scenario; thousand billion HUF):

Costs (investment costs)	24.7
Benefits (avoided costs and added benefits)	38.3
Balance	+13.6

The main driver for the cumulative benefits is the targeted investments in sectoral low-carbon technologies and techniques that lead to significant boost in economic growth and create additional green jobs compared to the BAU scenario.

The government revenues are forecasted to increase by HUF 11.1 billion cumulatively in the EA scenario. According to the EA scenario, it is estimated that the annual GDP growth will amount to an average 2.9% between 2021 and 2050. Early investments identified by the EA scenario and the gradual and consistent reduction of emissions will result in a 20.7% higher GDP by 2050, compared to the BAU scenario. In addition, the EA scenario indicates nearly 183,000 new jobs created by 2050 compared to the BAU scenario.

However, to realize the full potential of the financial and employment benefits of decarbonization, the transition roadmap (the NCDS) will need to be comprehensively and inclusively implemented, updated, mainstreamed, and improved in light of the latest technological innovations, political, economic and social circumstances as well as geopolitical challenges. This report makes recommendations on the governance and management aspects of implementation to ensure a smooth and planned transition with the broadest possible involvement of the public and stakeholders.

1 1 EUR = 350 HUF

2 Arithmetic average of annual real GDP growth rates projected for the period 2021-2050. A common method for calculating average annual growth rates is the use of the geometric average, which can be used to estimate an increase of 2.6% in the period under review. (See more information at: https://www.unescap.org/sites/default/files/Stats_Brief_Apr2015_Issue_07_Average-growth-rate.pdf)

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Abbreviations

AFOLU	Agriculture, forestry and other land use)
BAU	Business-As-Usual
CBA	Cost-benefit analysis
CCUS	Carbon Capture, Utilisation and Storage
CE	Circular economy
CO_{2eq}	CO2 equivalent
COVID-19	Új típusú koronavírus
CSP	Concentrated solar power
EBRD	European Bank for Reconstruction and Development
EEA	European Environment Agency
EGD	European Green Deal
ESCO	Energy Services Companies
ESG	Environmental, Social, and Governance
ETS	Emission Trading System
EUA	European Union Allowance
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GEM	Green Economy Model
GGGI	Global Green Growth Institute
GHG	Greenhouse Gases
GIS	Geographic Information Systems
HIPA	Hungarian Investment Promotion Agency
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial processes and product use
IRENA	International Renewable Energy Agency
KSH	Központi Statisztikai Hivatal (Central Statistics Office)
LCOE	Levelized cost of energy
LiDAR	Light Detection and Ranging
LPG	Liquefied petroleum gas
LULUCF	Land-use, land-use change and forestry
MIT	Ministry for Technology and Innovation
PA	Paris Agreement
RDF	Refuse-derived fuel
NDCS	Nationally Determined Contributions
RFID	Radio Frequency Identifications
S3	Smart Specialization Strategy
SCC	Social cost of carbon
SDG	Sustainable Development Goal
SMART	Specific, Measurable, Achievable, Relevant and Time-bound
SUP	Single-Used Plastic
TRL	Technology Readiness Level
UNFCCC	United Nations Framework Convention on Climate Change

1. BACKGROUND AND RATIONALE

1.1 Objectives of the report

The primary objective of the report is to present the socio-economic implications of decarbonizing Hungary's economy by 2050, based on the National Clean Development Strategy adopted in September 2021 by the Government of Hungary[1]. The report also aims to demonstrate that during the modelling horizon (up to 2050) the direct and indirect benefits are outweighing the costs of long-term decarbonization efforts. This is illustrated primarily through sectoral and cross-sectoral emission and economic analyses conducted using a System Dynamics modelling and extended Cost – Benefit Analysis (CBA). Two low-carbon development pathways or scenarios were constructed to test the impacts of different mitigation approaches against a business-as-usual (BAU) or "do-nothing" scenario. In addition, the report formulates recommendations for policy makers on how to promote and achieve decarbonization of the Hungarian economy.

The objectives of the report are as follows:

- Present and assess the costs and benefits of decarbonizing Hungary's economy based on analysis and modelling across key emitting sectors i.e., energy and transport, industry, agriculture, forestry and waste.
- Identify the present and future mitigation technologies and practices to maximize the benefits of low and zero-carbon interventions in Hungary.
- Encourage private and public sector to accelerate investments in decarbonization strategies, technologies and solutions across key sectors aligned with Paris Agreement targets.
- Formulate recommendations on how to facilitate decarbonization efforts in Hungary and beyond.
- Provide lessons learned from Hungary's process of developing its long-term clean development strategy.

1 Government Decision 1620/2021. (IX. 3.)

2. HUNGARY'S PLAN AND VISION TO BECOME A CARBON NEUTRAL ECONOMY

For Hungary "*clean development is a model of development that nurtures sustainable economic growth and creates green jobs and economic development opportunities while minimizing environmental pollution and greenhouse gas emissions*". Although a cleaner development pathway bears higher costs and requires significant investments, it also presents major innovation, technology, investment, and business opportunities for sustainable economic growth. The country has developed its low-carbon pathways based on the currently available and future technological solutions that allow reaching the climate neutrality target in a socially just and cost-efficient way.

2 National Clean Development Strategy (2021), Ministry for Innovation and Technology, Budapest, Hungary

In 2020, Hungary became the first country in the Central Eastern European region and the seventh in the world to adopt a climate neutrality target in the form of a law by its National Assembly.

The NCDS was based on a set of guiding principles which leads policymaking in the respective areas:

- **Utilization of zero-carbon energy sources**: A climate-neutral Hungarian economy shall be built on the utilization of renewable energy sources as well as on nuclear capacities. The 2050 climate neutrality target cannot be reached without the utilization of nuclear energy, thus both sources need to be considered.
- **The "polluter pays" principle, environmental responsibility, and social fairness**: The costs of the green transition should be primarily borne by the highest-emitting companies. Therefore, proposed measures should be based on proportional and reasonable logic.
- **Cost-efficiency**: Commitments shall be met at the lowest possible net cost to Hungarian taxpayers, consumers, and businesses.
- **Maximizing benefits**: The social and economic benefits for Hungary from the green transition shall be maximized.
- **Sovereignty and security of supply**: Only those actions and policy options that respect Hungary's sovereign decision-making power, energy independence, and security of supply shall be considered.
- **Sustainability**: Only those technologies and low-carbon solutions that are ecologically and socially sustainable will be promoted.

Since such a great technological, social, and economic leap would virtually affect every citizen in the country, Hungary NCDS's transformational scenarios were based on extensive stakeholder consultations, as well as robust modeling and analysis, while also paying attention to reduce the risk of stranded assets and avoiding carbon-intensive lock-ins in infrastructure.

Hungary's vision and long-term goals by 2050 and by sectors are the following:

- **Energy**: a decarbonized clean, smart, and affordable energy sector for the Hungarian people and businesses that is decentralized, efficient, secure, interconnected, sovereign, and builds upon renewable and nuclear energy. The decarbonization of the energy system will provide green jobs and help people financially by making them "prosumers."
- **Transport**: a more sustainable, greener, safer, and better-connected transport system supported by high-tech infrastructure and built on the right balance between public and private transport while recognizing the right to choose one's travel method. It will incentivize low-carbon transport modes and provide cleaner air, less noise pollution, and safer living spaces.
- **Industry and businesses**: a climate-friendly, innovative, and knowledge-based industry and circular economy where Hungarian high-tech and green small and medium-sized enterprises (SMEs) have a leading role.
- **Agriculture**: a healthy, productive, climate-resilient, and high-quality agriculture sector that ensures food security for all Hungarians and an efficient market environment that can produce items for export.
- **LULUCF**: healthy and climate-resilient forests and grasslands. The afforestation programs will utilize more resilient variants of local native tree species. Natural sink capacities that are essential to achieve climate neutrality by 2050 will be maintained and expanded.
- **Waste**: a clean country with minimum or nearly zero waste. Waste should be treated as raw material and must be reduced, reused, and recycled to the fullest extent.
- **Financing**: a financial sector that is in harmony with sustainability and aligned with the climate neutrality goals as well as a climate-friendly budgetary policy that supports green economic growth. The flow of public and private funds is consistent with the financial needs of national green and climate protection investments.

2.1. HUNGARY'S LONG - TERM STRATEGY FOR CLIMATE NEUTRALITY: THE NATIONAL CLEAN DEVELOPMENT STRATEGY

According to Article 4.19 of the Paris Agreement (PA), "All Parties should strive to formulate and communicate long-term low greenhouse gas emission development strategies, mindful of Article 2 taking into account their common but differentiated responsibilities and respective capabilities, in the light of different national circumstances". Related to the call in this paragraph, PA calls on Parties to communicate these strategies by 2020.

In addition, Article 15(1) of the EU Regulation 2018/1999 (hereafter: the Governance Regulation) states that by 1 January 2020, then by 1 January 2029 and every 10 years thereafter, each Member State shall prepare and report to the Commission a long-term strategy (or LTS) with a minimum 30-year horizon. Member States will have to update these strategies every five years if necessary.

In response to the call of the PA and EU's Governance Regulation and given that Hungary has been able to reduce its greenhouse gas emissions while increasing its economic output (GDP), the country's intention is to continue its "clean growth" pathway, thus Hungary's LTS has been named the *National Clean Development Strategy (NCDS or the Strategy)*. The first draft of the NCDS finalized in January 2020 served as basis for the final version of the Strategy, completed in December 2020. The document was finally and officially adopted by Government Decision 1620/2021. (IX. 3.) on 3rd of September and published on UNFCCC's website on 17th of September 2021.

Hungary's National Clean Development Strategy outlines a 30-year vision of socioeconomic and technological development pathways to reach climate neutrality targets while focusing on the well-being of the Hungarian people and ensuring the protection of natural assets and economic development. The Strategy, which was based on a wide stakeholder consultation process, applied a unique integrated modeling approach by not just looking at individual sectors of the economy but also exploring the system-wide and cross-sectoral dynamics of the decarbonization process. **Chapter 3** of this paper discusses the document and the methodology used in detail.

3 https://eur-lex.europa.eu/legal-content/HU/TXT/PDF/?uri=CELEX:32018R1999&from=EN

2.2. THE HUNGARIAN CLIMATE POLICY CONTEXT

Hungary, despite accounting for only about 0.1% of global emissions, has been committed since the start of international climate policy negotiations to fight climate change. It has set itself binding emission reduction targets during the first and second commitment periods of the Kyoto Protocol. Hungary was the first country within the EU whose parliament unanimously voted to ratify the Paris Agreement in 2016.

Hungary's decarbonisation effort dates back to the change of regime in 1990. After the collapse of the inefficient and resource intense socialist heavy industry, the country's greenhouse gases (GHG) emissions have dropped significantly, by about 42% of the 1985-87 Kyoto Protocol base year compared to current emissions, which is also a reduction of about 32% compared to the 1990 base year. The country has since steadily reduced its emissions with a stagnant trend since 2014.

In December 2019, Hungary voted in favor of the EU 2050 climate neutrality target, and the Hungarian parliament adopted the *Act no. XLIV of 2020 on Climate Protection*, which contains the legally binding obligation for the country to achieve climate neutrality by 2050.

Hungary has adopted a set of sectoral and economy-wide strategies and action plans that have underpinned the NCDS. In 2020 the *Climate Change Action Plan* was prepared that contains concrete measures for achieving the medium- and long-term goals of the *Second National Climate Change Strategy* completed in 2018. The National Energy and Climate Plan for the period up to 2030 and the new National Energy Strategy both contain specific objectives for the medium term, including a pledge to make 90% of Hungary's electricity generation carbon-free by 2030. Specific interventions of the *Climate and Nature Protection Action Plan*, adopted in 2020, also support environmental protection targets.

Besides to decarbonization efforts, Hungary also prioritizes energy security and sovereignty, climate protection, green economic development, prosperity, growth, and well-being of Hungarian families.

2.3. EUROPEAN UNION AND REGIONAL CLIMATE POLICY CONTEXT

NCDS's structure follows the guidelines of the EU legislation. Under the Governance Regulation, Member States' long-term strategies shall cover[4]:

- total greenhouse gas emission reductions and enhancements of removals by sinks;
- emission reductions and enhancements of removals in individual sectors, including electricity, industry, transport, the heating and cooling and buildings sector (residential and tertiary), agriculture, waste and land use, land-use change and forestry (LULUCF);
- expected progress on transition to a low greenhouse gas emission economy, including greenhouse gas intensity, CO2 intensity of gross domestic product, related estimates of long-term investment, and strategies for related research, development and innovation;
- expected socio-economic effect of the decarbonisation measures, including, inter alia, aspects related to macro-economic and social development, health risks and benefits and environmental protection;
- links to other national long-term objectives, planning and other policies and measures, and investment.

The EU has embarked on an ambitious transition process with the adoption of the common 2050 climate neutrality goal and the initiation of the European Green Deal (EGD). The EGD is the EU's main new growth strategy to transition to a sustainable, carbonless economic model, so it could become the first climate neutral continent by 2050. The current EU-level environmental and climate protection regulations in force and the ongoing elaboration and implementation of the EGD fundamentally influence the opportunities and policy decisions of Hungary.

Another important initiative of the EU is the REPowerEU[5], a plan to make Europe independent from Russian fossil fuels before 2030. It outlines a series of measures to respond to rising energy prices in Europe and to replenish gas stocks for subsequent winters based on diversifying energy sources, enhancing energy savings, and accelerating clean energy production.

The Hungarian government strongly believes that enhanced regional cooperation will be key to achieve and maintain climate neutrality. As a member of the Visegrad Four Group (V4) - alongside Czechia, Poland, and Slovakia - Hungary is planning to reinforce its climate - and environmentally related efforts within the group to determine effective and mutually beneficial local and regional policies and measures.

4 https://commission.europa.eu/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-long-term-strategies_en

5 https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en

3. VISION TO STRATEGY

For Hungary to gradually become a climate-neutral country by 2050 without jeopardizing economic growth and social welfare a guiding document, a roadmap, in other words, a robust strategy is needed. The NCDS translates Hungary's climate neutrality vision and its sectoral ambitious goals to actions, measures and radical, deep economic transformation programs. This 30-year long roadmap builds on the economy-wide low-carbon scenarios of the NCDS which assess the aggregate impacts of the decarbonization efforts and defines the paths of development, their concrete actions and the associated costs and benefits.

3.1 NOVELTY OF THE APPROACH AND METHODOLOGY

To produce a strategy that can be used as a roadmap for long-term across sectors, there is a need to model and explore potential future outcomes. The NCDS analytical work sought to simulate and model variables in economic, social, technological and innovation processes by applying sectoral targets and estimating GDP growth based on validated assumptions of demographic trends. This methodology is manifestly an innovation that has not been applied in Hungary before.

3.1.1 INVOLVING STAKEHOLDERS AND PUBLIC CONSULTATION

To reach the broadest possible consensus around long term decarbonization, MIT and GGGI applied a well-structured methodology to involve, consult and learn from a wide range of stakeholders and the general public. With each stage of consultation, the quality, robustness, and consistency of the Strategy were improved, and more aspects were considered. The steps of NCDS's stakeholder engagement were the following:

1. **Initial stage**: as a first step MIT held several consultations with experts from the ministries and background institutions in the second half of 2019 to discuss the general content of the NCDS.
2. **Surveying the public**: as a second step MIT carried out an online public consultation between 18 and 25 of November 2019, which consisted of a survey about the needs, objectives and policy development directions. More than 200,000 answers were received, which were carefully evaluated and incorporated into the document. Based on the first two rounds of consultations MIT prepared a draft version of the Strategy in January 2020.
3. **Consulting with private sector**: to further develop the NCDS, MIT continued stakeholder consultation throughout 2020 by organizing so-called "Climate Breakfasts". Through this event series, representatives from the private sector, financial institutions, business associations, clusters and civil society groups shared their best practices, views on low-carbon development and the ways to reach the national climate neutrality target and the associated challenges, opportunities, and needs.
4. **Validating modelling approach and results**: as the final stage, GGGI together with MIT organized three consultation workshops whereby the modelling approach was presented, and the scenarios and results were validated as well as the sectoral policies and priorities were discussed.

3.2 CONSIDERING COVID-19 IMPACTS

The unforeseen emergence of the COVID-19 pandemic has also changed the modelling boundary conditions of the Strategy, as its impacts had to be considered when constructing long-term development trajectories. At the same time, in the double grip of the health and financial crisis caused by the pandemic, the transition to a green economy opens new types of investment opportunities. The early implementation of investments can serve as an incentive for recovery during the economic crisis by creating thousands of new and green jobs and increasing the well-being of the Hungarian people.

The inclusion of COVID-19 into the scenarios required the addition of several new variables, such as the impacts of the outbreak (e.g., consumption) and the implications of response measures (e.g., public stimulus). The addition of these variables introduced new dynamics, and feedback loops in the GEM model (e.g., reduction of GDP, reduced economic performance, etc.). The model assumed that if the stimulus is allocated well after the lockdowns, it will kickstart production and consumption to levels that will allow to stimulate employment, increase government revenues, and limit the constraints posed by medium- and longer-term debt. Concerning environmental performance, the reduction of economic performance reduces energy consumption and air pollution, and hence societal impacts. With economic recovery the opposite dynamics will return, as described earlier. As a result, little change is expected to these dynamics, unless permanent impacts emerge (e.g., remote and flexible working remains common practice).

3.3 MODELLING CROSS-SECTORAL INTERLINKAGES AND SYNERGIES

The first draft of the NCDS took stock of the relevant sectors and formulated initial policy suggestions respectively. This exercise allowed the identification of opportunities, the mitigation potential of sectors and the main intervention. As a subsequent step, the further development of the NCDS went beyond sectoral assessment and looked at the aggregated, synergistic impacts of possible economy-wide decarbonization pathways. In addition to direct impacts, such as required investment, *this approach has helped revealing indirect benefits and avoided costs of carbon neutrality, such as higher employment creation, aggregated GDP, government revenues, and avoided energy costs, social costs of carbon, and transport-related negative externalities*.

The NCDS was also novel in a way that it applied two different but compatible, complementary, and interlinked models:

The **Green Economy Model (GEM)** intersectoral top-down model that uses System Dynamics as its foundation (Bassi, 2015). This methodology supports the estimation of the macroeconomic outcomes of decarbonization, including the economic evaluation of several social and environmental externalities in addition to changes in the labor market. This integrated modelling approach - which considers the interlinkages existing between population, economic activity, and environmental outcomes - has been customized for Hungary for the assessment of various economy-wide emission reduction pathways. Therefore, it supports the estimation of the macroeconomic outcomes of decarbonization, including the economic valuation of several social and environmental externalities, in addition to job gains and losses.

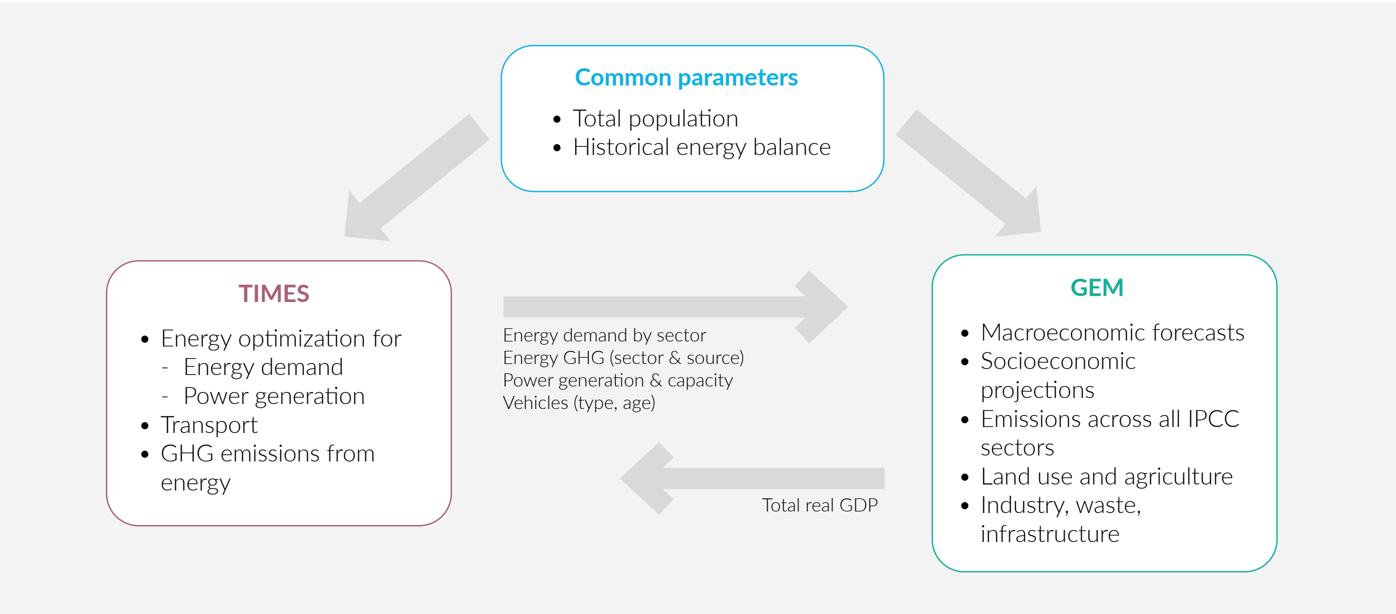
The **HU-TIMES (The Integrated MARKAL-EFOM System)** bottom-up equilibrium optimization model used to analyze the different pathways of energy flows within the energy subsectors, customized to Hungarian context. HU-TIMES was used iteratively with the GEM to simulate the energy sector and to outline the emission routes of the energy use sub-sectors.

Model integration

The cross-sectoral nature of the exercise called for the integration of TIMES and GEM, due to the predominant role of the energy sector in the generation of emissions, and to the complementarity nature of the two models (TIMES being a bottom-up technology-rich model, and GEM being more aggregated and cross-sectoral).

The figure below shows how GEM and TIMES interact: GEM uses inputs from TIMES such as energy demand per sector and per fuel. GDP is estimated endogenously in GEM, to generate demand for energy services. There is, therefore, a feedback loop between the two models that is captured by the model integration. As a result, GDP figures estimated in GEM are passed on to TIMES for a re-simulation of the different scenarios on energy demand and associated emissions. This allows the two models to work with the same GDP figures for the same scenarios. While GEM generates GDP for TIMES, TIMES generates energy prices, power generation capacity (which affects employment in GEM) and emissions that impact various indicators, sectors and dynamics in GEM.

Figure 1. Model integration to support the development of NCDS scenario development



3.4 OVERVIEW OF THE LOW-CARBON SCENARIOS

Offering trajectory options to the Government of Hungary, the NCDS proposed and assessed two low-carbon development scenarios and a benchmark, or "do-nothing" scenario. In essence, the difference between the two scenarios is the timing of actions and the implementation of policy decisions. The more ambitious scenario prioritizes the majority of measures and investments to be made early in the trajectory, while the less ambitious pathway schedules these actions later.

The reference scenario and the two low-carbon development scenarios are presented in detail below:

1. **Business-as-usual (BAU)** scenario: The emission trajectory of the BAU scenario follows current trends, assuming that all existing sectoral policy strategies and measures remain in effect as of 2021, and that there will be no new interventions.

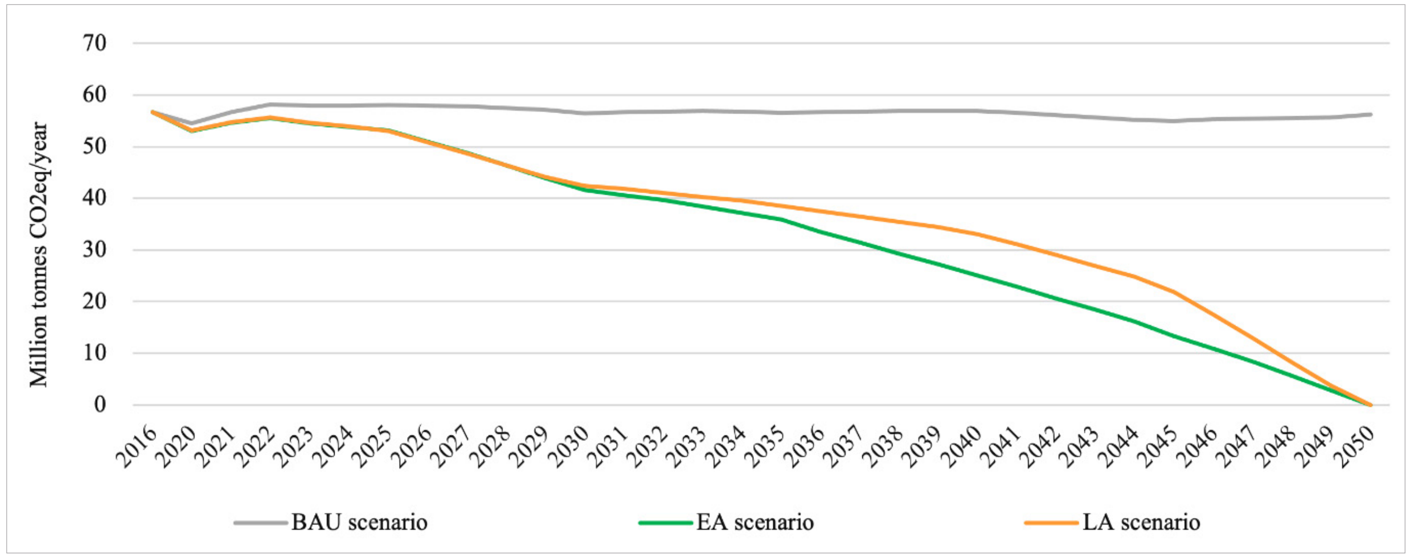
2. **The Late Action (LA)** climate neutrality scenario: This scenario aims to reduce emissions in the energy sector at a delayed and slower pace until 2045, and then with an increased effort until 2050. This allows the lower cost levels of low and zero emission technologies to be exploited. The scenario assumes that, in line with the targets set in the climate act, the final energy consumption could reach a maximum of 785 petajoules (PJ) in 2030, with the share of renewable energy increasing to at least 21%. After 2030, non-waste sectors will be on the lowest cost trajectory toward climate neutrality until 2050, which will result in accelerated emission reductions by 2050, due to the postponement of investments pending on a decrease in technology costs.

3. The **Early Action (EA)** climate neutrality scenario: the EA approach envisages achieving climate neutrality by 2050 while considering the short- and medium-term benefits of job creation and a reduction of environmental externalities, the economic potential of the first mover, improved productivity, and higher GDP growth. The EA scenario assumes that Hungary's final energy consumption in 2030 will be a maximum of 734 PJ, and that renewable energy penetration will reach 27%. The emission reduction trajectories for industry; land-use, land-use change and forestry (LULUCF); waste management; and agriculture are the same as in the LA scenario. Between 2030 and 2050, emissions will follow a linear trajectory to reach net zero emissions.

For all three scenarios, the same demographic trends were identified, while GDP values were estimated endogenously by the GEM model.

According to both climate neutrality scenarios, net zero emissions will be reached by mid-century. However, the clean energy transition will vary based on different assumptions, and the generation of socioeconomic benefits will differ in their development pathways.

Figure 2. Expected change of total annual net GHG emissions for the whole economy under the three scenarios examined (CO2eq/year)



The EA scenario will require stronger mitigation efforts, however the increased investments will boost country's economic growth. The end-user demand will increase including the demand for traveling and buying household appliances. The EA scenario follows a more gradual emission reduction pathway since the investments serving the energy transition and decarbonization are carried out sooner. Furthermore, the EA scenario is characterized by an accelerated larger-scale "clean" electrification and decarbonization of the electricity system.

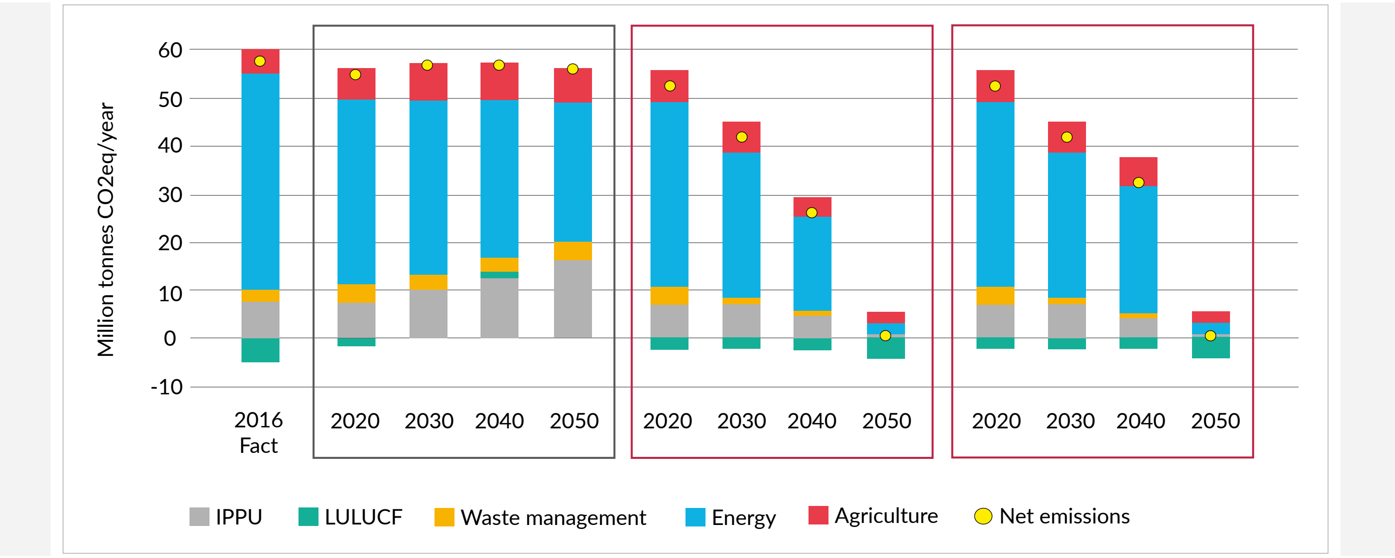
Typically, relatively smaller mitigation costs are reported in the near term through to 2030 compared to the medium or longer term (2050). ·

In the EA scenario, sectoral emissions after 2030 are consistently lower than in the LA scenario.

Table 1. GHG reductions of sectors by 2050 compared to 1990 levels in the EA scenario (%)

Sector	Reduction vs. 1990 (%)
Energy	-98%
Industry (IPPU)	-98%
Agriculture	-79%
LULUCF	-71%
Waste	-87%
Total	-100%

Figure 3. Sectoral distribution of net GHG emissions for the three scenarios (CO2eq/year)



6 Riahi, K. et al. Te Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: an overview. Glob. Environ. Change 42, 153–168 (2017)

7 Clarke, L. et al. in Climate Change 2014: Mitigation of Climate Change (eds Edenhofer, O. et al.) 413–510 (IPCC, Cambridge Univ. Press, 2014)

8 Increase in net absorption

4. ACHIEVING CARBON NEUTRALITY: COSTS, BENEFITS AND INVESTMENT NEEDS

Without a thorough and in-depth cost-benefit analysis covering as many aspects as possible, a country cannot make far-reaching decisions that will fundamentally change its economic, infrastructural, and technological conditions and the lives of communities and families. One of the goals of the NCDS was to conduct such an analysis not just for the whole economy but also the relevant sectors.

4.1. SECTORAL ASSESSMENT

According to the Governance Regulation Member States shall conduct assessment of individual sectors including electricity, industry, transport, the heating and cooling and buildings sector (residential and tertiary), agriculture, waste and land use, land-use change and forestry (LULUCF). Consequently, the NCDS considered the following sectors in its assessment:

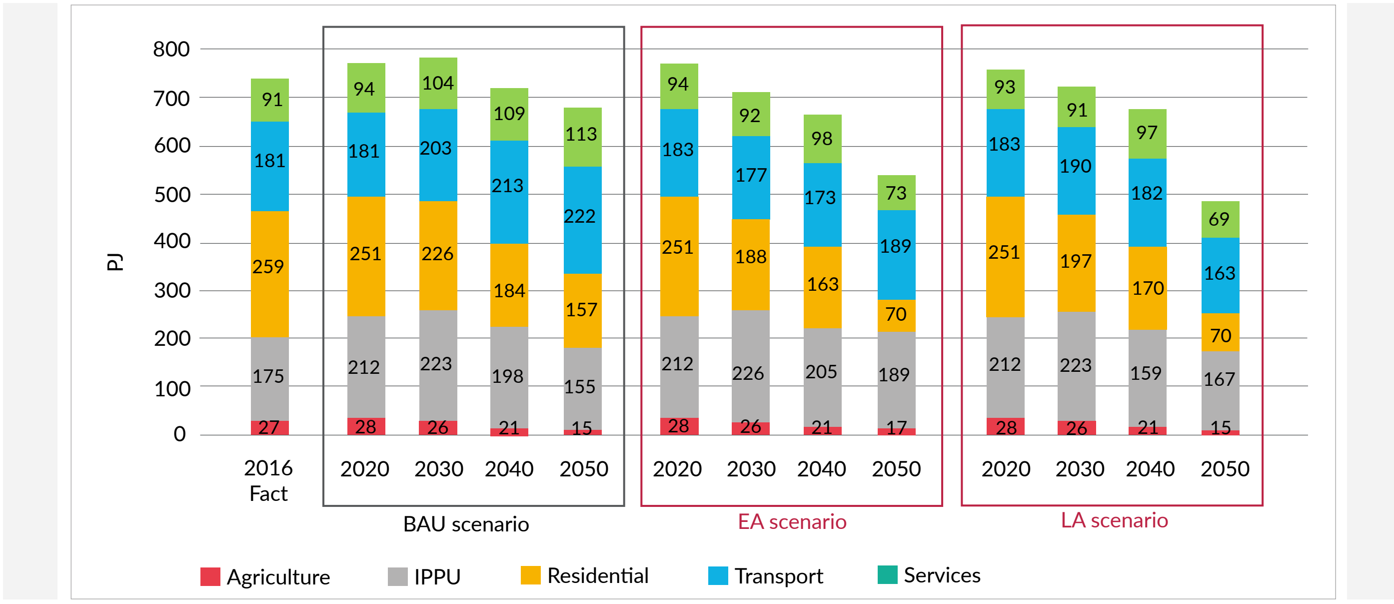
9 https://ec.europa.eu/info/energy-climate-change-environment/implementation-eu-countries/energy-and-climate-governance-and-reporting/national-long-term-strategies_en

4.1.1 Energy

The energy sector - including the energy supply and the energy consumption of the industry and transport sectors and others (such as tertiary or residential sectors) - has the most significant role in reducing emissions. This is because the energy sector accounts for 70% of total emissions and has the largest potential to reduce emissions. Within the energy sector, the households (residential) subsector has the largest energy saving potential.

The Strategy set out a sectoral goal to create a decarbonized clean, smart, and affordable energy sector for the Hungarian people and businesses. Create green jobs and help people financially by making them "prosumers".

Figure 4. Final energy consumption forecasted by 2050 according to the EA and LA scenarios



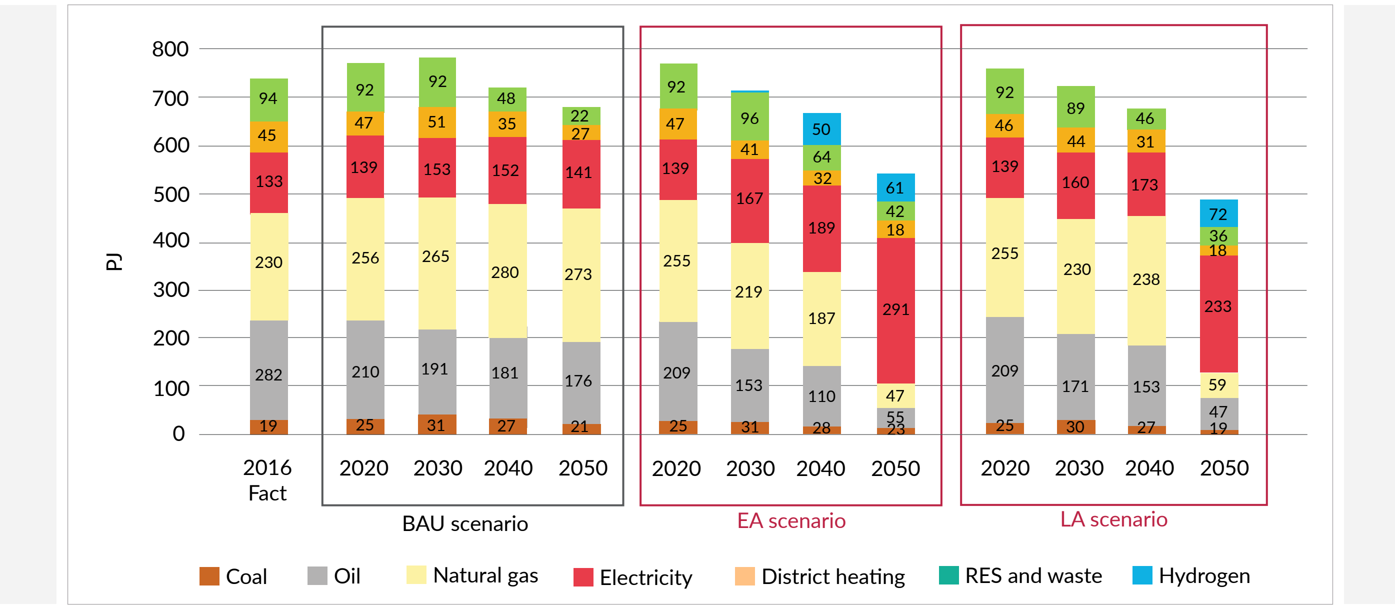
The final energy consumption is forecasted to be 538 PJ and 484 PJ by 2050 according to the EA and LA scenarios, respectively.

The energy consumption of the industrial sector is different in the three examined scenarios. In the BAU scenario, the increase in energy consumption is dominant due to the higher GDP, which will be compensated by energy efficiency investments. A consistently decreasing trend can be observed from 2030 onward. Overall, the two climate neutrality scenarios show a decreasing trend; however, some increase is forecasted until 2030. After 2030, energy consumption in the EA scenario will decrease at a lower rate than in the LA scenario. This is explained by higher GDP growth and therefore higher rate of industrial production in the EA scenario.

The service and transport sectors follow similar trajectories in the climate neutrality scenarios. In the BAU scenario, the energy consumption of both sectors slightly increases. The two climate neutrality scenarios show a 10–20% reduction compared to the current levels, due to energy efficiency investments and the use of more efficient fuels.

The fuel mix of the final energy consumption (Figure 5) must change significantly to reach the 2050 climate neutrality target.

Figure 5. Fuel mix of the final energy consumption



The most significant change caused by the two climate neutrality scenarios is due to large-scale electrification. For the EA scenario, the use of electricity accounts for over half of the total energy consumption, which is similar to the rate of the LA scenario.

As a result of electrification in the transport sector, the consumption of petroleum will decrease drastically—to nearly a quarter of the current level—by 2050. The other significant change, which will start in the 2040s, is the decline in natural gas consumption and the complete disappearance thereof in some sectors. Natural gas is partly replaced by hydrogen, mainly in the transport and industrial sectors. Table 2 depicts the energy consumption (targets) per fuel/ technology at the end use energy sectors under the EA scenario. In addition, electricity demand will increase under the EA scenario and therefore clean energy technologies should be deployed to contribute to the achievement of the economy-wide net zero emission target. Table 3 depicts the electricity generation technologies and associated adoption rates for 2030 and 2050 under the EA scenario.

To achieve net zero GHG emissions in the energy sector by 2050, the following measures need to be implemented based on currently available and future technologies:

1. Acceleration of **energy efficiency improvements** in all sectors and sub-sectors including residential, commercial, industrial and agriculture;
2. **Electrification** in all sectors of the economy, especially in the transport, residential, and commercial sectors, based on nuclear and renewable energy sources and nuclear power;
3. Increasing the utilization of **renewable energy** and **energy storage systems**;
4. Sustainable utilization of **bioenergy**, expanding the application of **second-generation (or advanced) biofuels**, as well as the more efficient usage of fuels and the gradual decrease in using liquefied petroleum gas (LPG);
5. **Application and development of Carbon Capture, Utilization and Storage (CCUS) technologies**;
6. Use of **hydrogen** and upscaling of the related hydrogen technologies.

Table 2. Technologies/ fuel types in the energy end use sectors under the EA scenario

Technology/ fuel	Electricity		RES, biomass, biofuel, waste		Hydrogen	
Measures	2030	2050	2030	2050	2030	2050
Energy consumption of the **household sector** (PJ)	22	2030	59	2	1	0
Energy consumption in the **service sector** (PJ)	30	2050	1	1	0	11
Energy consumption in the **industrial sector** (PJ)	72	2030	15	8	1	28
Energy consumption in the **transport sector** (PJ)	40	2050	18	28	1	14

Table 3. Mitigation technologies in the electricity sector in the EA scenario (TWh)

Technologies	2030	2050
RES, biomass, biofuel, waste	1	11
Water & geothermal	1	2
Solar	11	56
Wind	1	22
Nuclear	34	19
Natural Gas	3	0

4.1.2 Industrial Processes and Product Use (IPPU)

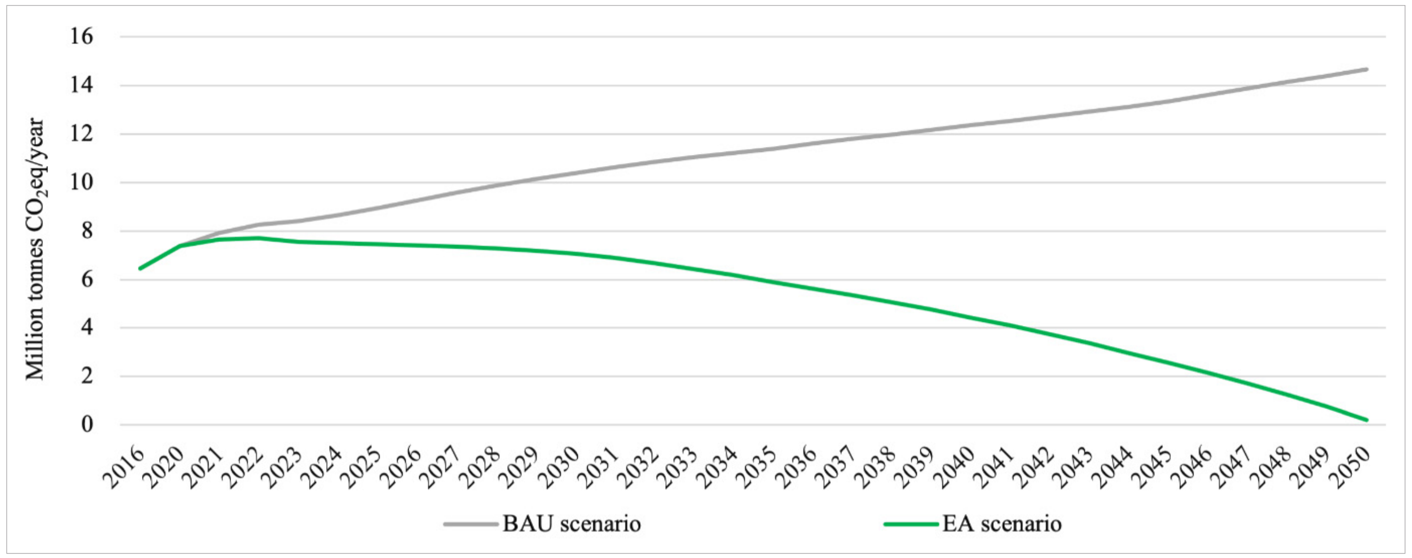
Under the BAU scenario, due to increasing production and without additional measures GHG emissions will double by 2050, exceeding 14 million tons of CO2eq/year. According to the EA scenario, industrial processes will become slightly less carbon free in the medium term than the economy as a whole, but a significant further reduction can be achieved by 2050.

Emissions reduction, material, process and energy efficiency measures and technologies (including, inter alia, digitization and automation, alternative "clean" raw materials) and even more so the transition to a circular economy will significantly reduce emissions to about 215 thousand tons of CO2eq/year levels

The following measures and technologies need to be introduced to achieve the sector's decarbonization:

1. CCUS technologies;
2. Alternatives to replace fossil fuel sources as raw material;
3. Digitization and automation to improve production and process efficiency;
4. Improve material efficiency mainly in the chemical and construction industries;
5. Introduction of carbon-free or low-carbon hydrogen and its derivatives as well as alternative biological raw materials;
6. Transition to circular economy;
7. Raising public awareness to shape consumption patterns.

Figure 6. Expected change of GHG emissions from industrial processes and product use between 2020 and 2050



4.1.3 Agriculture

According to the BAU scenario, the slow, steady growth of GHG emissions started in 2011 will continue until 2050. Emissions in the sector would increase by 8.4% by 2050, from 7.085 million tons of CO2eq/year in 2020 to 7.679 million tons of CO2eq/year. In contrast, in the EA scenario, GHG emissions from the agricultural sector are expected to decrease by 70.46% by 2050, i.e. from 7.085 million tons of CO2eq/year in 2020 to 2.093 million tons of CO2eq/year.

The following key technological and farming methods will drive emission reduction:

1. Reduction in fertilizer use;
2. More efficient use of organic fertilizers;
3. Wide application of precision farming;
4. Automatization, and digitization
5. Investments targeting feeding, irrigation, and energy efficiency are key.

4.1.4 Land-use, land-use change and forestry (LULUCF)

Forests continue to play a huge role in sequestering atmospheric CO2 from human activities. Forests within the LULUCF sector will be responsible for 100% of net CO2 sequestration in the future.

In the BAU scenario a moderate afforestation will take place (3500 ha/year). As a result, forest cover will not increase significantly, and as the average age of forests increases, the mortality rate of tree stocks will increase. Gradually, old forests, which are decomposing their organic matter and becoming CO2 emitters, are becoming predominant. Under the EA scenario the forest cover rate will increase from the current 20.8% to 27% by 2050, and the annual "net" afforestation will reach 13,000 hectares.

To further improve the carbon sequestration potential and capacities of the sector the following measures will need to be considered:

1. Introduction of digitization and automation tools in forestry, and in the afforestation programs;
2. Introduction of predominantly more drought-tolerant of native tree species;
3. Reduction of logging in the medium term and increase afforestation efforts in the long term;
4. Part of the revenue from EU ETS trading should be used for natural carbon sequestration, afforestation, long-term forest maintenance and the development emissions-optimal stock structure;
5. Maintenance of stocks with the most optimal CO2 equilibrium and business model.

4.1.5 Waste management

In the BAU scenario, all waste generation and management options remain at the current level and will only change in proportion to population and GDP change. Under the EA scenario all objectives to achieve climate neutrality and waste management meeting the expectations of the circular economy will be achieved by 2030, ahead of the 2050 target.

The following investments need to take place to achieve both the circular economy and decarbonization objectives in the waste sector:

1. Reducing landfilling;
2. A minimum of 60% of the generated waste must be diverted from the currently mixed municipal waste stream;
3. Improving waste treatment methods
4. Reducing the amount of industrial waste, full recovery of industrial waste by 2050.
5. Public awareness raising to encourage waste prevention
6. Increase the share of home and community composting

Figure 7. Expected change of GHG emissions in the agricultural sector between 2016 and 2050

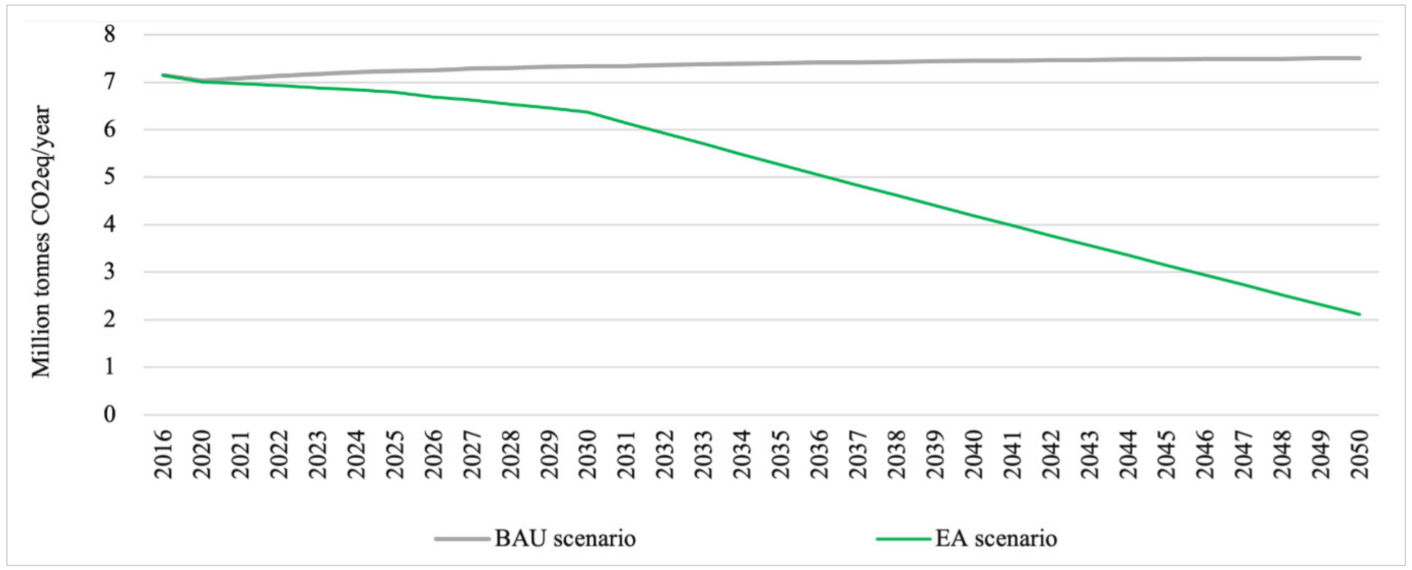


Figure 8. Forecast of GHG emissions from waste management according to the BAU and EA scenarios

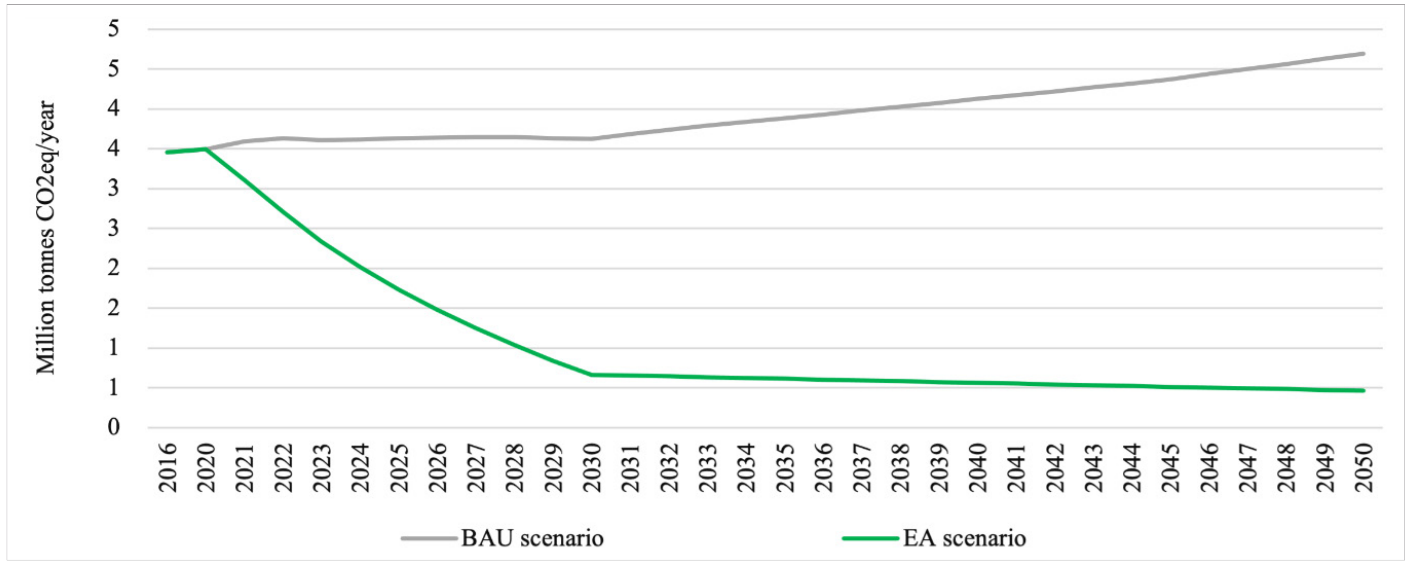


Table 4 summarizes the main mitigation measures and their adoption rates (targets) in industry, agriculture, LULUCF and waste sectors under the EA scenario.

Table 4. Rate of adoption of sectoral low carbon measures in the EA scenario

Sector	Measures	2030	2050
Industry	Reduction in IPPU emission intensity (%)	33	100
Agriculture	Precision fertilizer adoption rate (%)	33	100
	Reduction in manure dumped on pasture (%)	0	100
	Share of agriculture land under improved soil management practices (%)	25	50
Waste management	Waste (metals, plastics, paper, glass, etc.) recovery rate (%)	60	100
Forestry	Afforestation (ha/year)	10,600	12,200

4.2. OVERALL COSTS AND BENEFITS OF CARBON NEUTRALITY

To achieve climate neutrality by 2050, significant investments will be required in the upcoming decades. However, the possible benefits of decarbonizing the national economy in the medium and long term will exceed these costs.

Costs of decarbonization

According to the EA scenario, the total investment costs will be HUF 24.7 thousand billion , taking the BAU scenario's cost estimates as reference. Conversely, the additional cost according to the LA scenario is HUF 13.7 thousand billion. The difference between the two scenarios originates in the energy sector, which requires, being the largest emitter, the most investments and improvements. The additional annual investment need accounts for 4.8% of the GDP in the EA scenario.

Table 5. The level of cumulative investment demand of the EA scenario correlates with the current emissions of each sector and the cost of technology to be deployed.

Sector	Emissions in 2020 (million tons CO2e)	Investment needs by 2050 (thousand billion HUF)
Energy	38	22.4
IPPU	7.3	0.13
Agriculture	7	0.74
Waste management	3.5	0.48
LULUCF (natural sink)	-3	0.9

10 1 EUR = 350 HUF

Benefits of decarbonization

In contrast, **full decarbonization of the Hungarian economy will also generate significant avoided costs and added economic benefits across the whole economy**. Assessing the period up to 2050, the value of avoided costs and added benefits are observed to exceed the investment costs, they add up to **HUF 38.3 thousand billion**. Moreover, these avoided costs and additional benefits will continue to increase well after 2050.

The main driver for the cumulative benefits is the targeted investments in sectoral low-carbon technologies and techniques that lead to significant boost in economic growth and create additional green jobs compared to the BAU scenario.

Based on the EA scenario, the cumulative surplus GDP amounts to approximately HUF 19.8 billion. (Table 4, Figure 10). The government revenues are forecasted to increase by HUF 11.1 billion cumulatively in the EA scenario (while the LA scenario shows a growth of HUF 6.2 billion).

Table 6. Estimated costs and benefits of decarbonization in Hungary by 2050 (EA scenario, compared to BAU scenario; thousand billion HUF).

Costs (investment costs)	24.7
Benefits (avoided costs and added benefits)	38.3
Balance	**+13.6**

Table 7. Cost-benefit analysis for the periods 2020–2030 and 2020–2050 (additional costs and benefits compared to the BAU scenario)

	EA scenario 2020-2030	LA scenario 2020-2030	EA scenario 2020-2050	LA scenario 2020-2050
Investment costs – billion HUF				
Agriculture	82	82	745	745
Waste management	851	852	480	476
IPPU	79	80	129	131
Energy	1 297	644	22 391	11 352
LULUCF	35	35	964	964
Total investment costs	**2 344**	**1 693**	**24 709**	**13 668**
Avoided costs - billion HUF				
Material	693	685	2 393	556
Avoided energy cost	638	630	2 142	305
Avoided fertilizer cost	56	56	251	251
Nonmaterial	527	279	4 993	3 441
Avoided social cost of carbon	487	480	2 604	2 269
Transport-related negative externalities	40	-200	2 389	1172
Total avoided costs	**1 221**	**964**	**7 387**	**3 997**
Added benefits – billion HUF				
Real GDP	582	482	19 783	11 170
Government revenue	246	215	11 142	6 200
Additional job creation – number of jobs				
Total net new jobs	16 283	17 962	182 566	123 690
Indirect employment creation	10 340	11 349	64 983	60 678
Direct employment creation	5 943	6 613	117 583	63 012

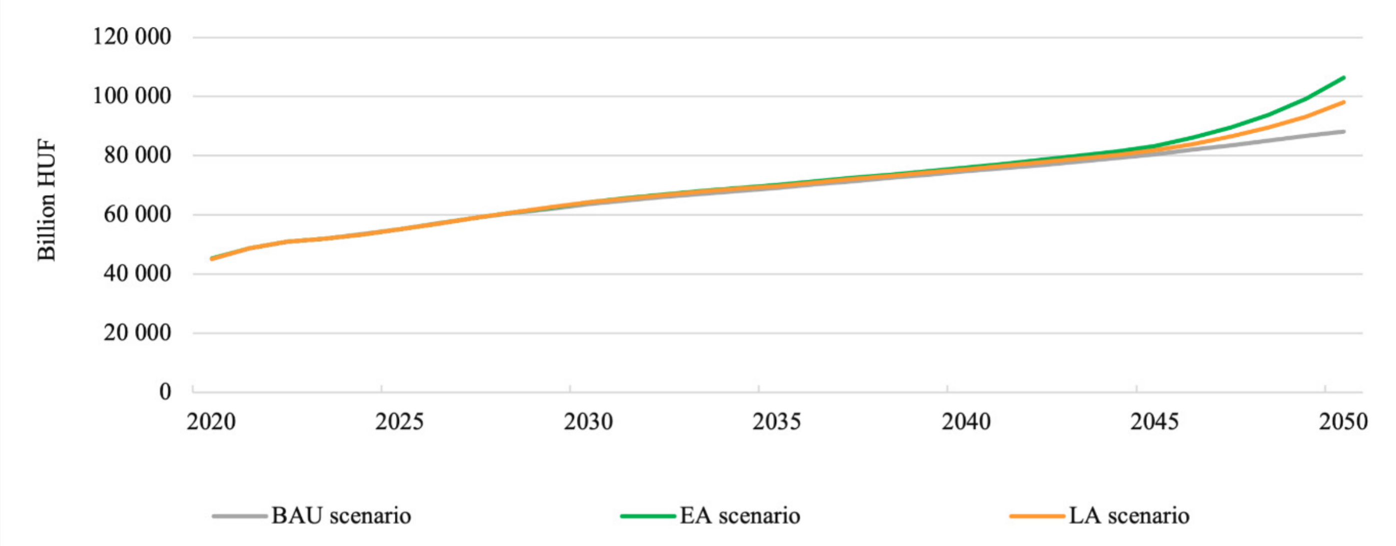
Source: Own modeling result

According to the analyzed decarbonization pathways, the **largest investment needs will occur in the energy sector**, which is currently (2022) the largest emitting sector of the economy. The electrification of other sectors and subsectors of the economy will place further investment needs on the energy sector. In addition to increasing the renewable energy generation capacities, phasing out fossil fuel from residential heating systems and the transport sector, which predominantly relies on imported natural gas and crude oil, imposes financing needs comparable to the post-World War II reconstruction.

To reach full decarbonization across the whole economy, the capacities of natural carbon sinks (forests, grasslands, wetland ecosystems) will need to be increased significantly, i.e., extensive afforestation, reforestation, and ecosystem restoration shall be carried out to compensate other sectors' remaining emissions. This requires the **second highest investment needs** after the energy sector's. Agriculture, which is responsible for approx. 13% of the total emissions comes third in terms of investment needs. The reason for this is that the food production, soil management, replenishment, and animal husbandry practices will need to be changed to low carbon, but alternatives with high investment needs.

Pertaining to waste management, the EU legislation package on circular economy objectives will need to be reached regardless of the decarbonization efforts. Putting the circular economy into practice will help reduce GHG emissions in the sector. To achieve the goals, Hungary needs to significantly increase the amount of separately collected and treated waste in the coming years and minimize landfilling.

Figure 9. Real GDP developments by scenario



Source: Own modeling result

IPPU sector will require the least investment to be carbon neutral as most of the manufacturing processes have already undergone efficiency improvements not just for environmental considerations but also for cost-cutting reasons. The scenario assumes a reduction in IPPU related emissions between 2020 and 2050 as a consequence of cleaner production processes and improved management of fugitive emissions related to industrial processes.

In terms of economic performance trajectory, economic growth will be considerably higher after 2028. By 2034, the GDP and GDP growth trajectory will follow a similar path for the BAU and EA scenarios. **According to the EA scenario, it is estimated that the annual GDP growth will amount to an average 2.9% between 2021 and 2050**. The expected growth rate in the same period is 2.5% in the BAU scenario.

Early investments identified by the EA scenario and the gradual and consistent reduction of emissions will result in a **20.7% higher GDP by 2050**, compared to the BAU scenario (Figure 10).

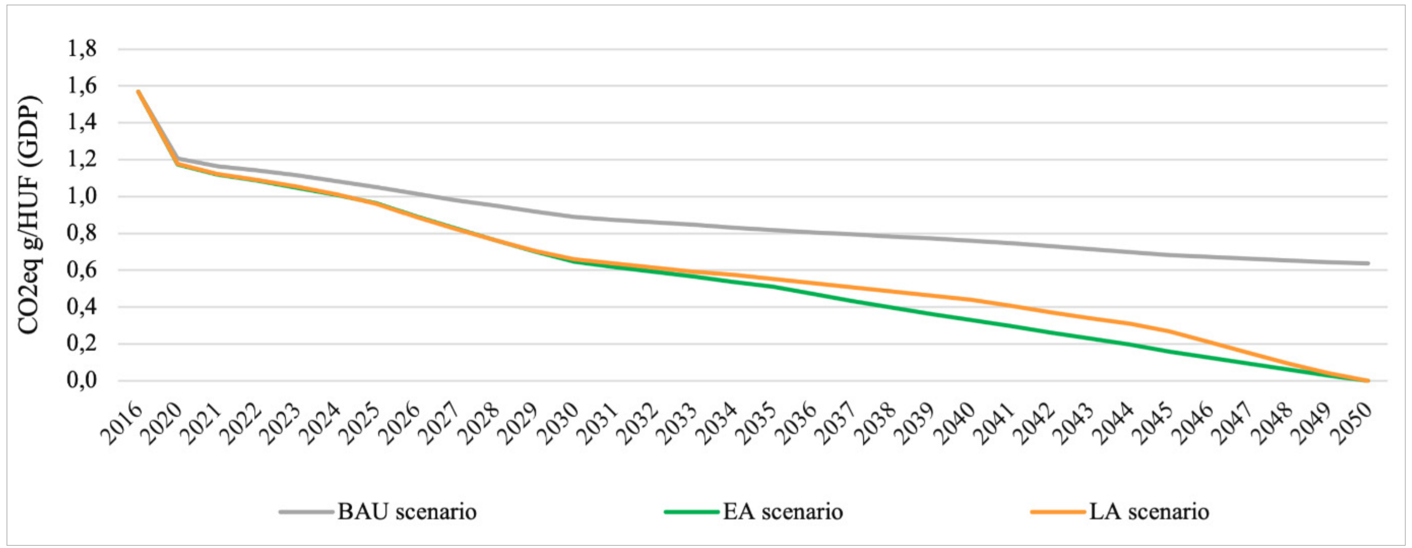
11 Arithmetic average of annual real GDP growth rates projected for the period 2021-2050. A common method for calculating average annual growth rates is the use of the geometric average, which can be used to estimate an increase of 2.6% in the period under review. (See more information at: https://www.unescap.org/sites/default/files/Stats_Brief_Apr2015_Issue_07_Average-growth-rate.pdf)

In addition, according to the EA scenario, **the carbon intensity of the Hungarian economy will gradually decrease** from 1.6 tons of CO_2eq/million HUF in 2016 to zero in 2050, while in the BAU scenario, a carbon intensity of 0.6 tons of CO_2eq/million HUF is expected by 2050 (Figure 11).

According to the analysis, the decarbonization of the national economy creates new jobs in the analyzed sectors. The EA scenario indicates nearly **183,000 new jobs** created by 2050 compared to the BAU scenario. Direct employment will be created as the result of interventions in the fields of power generation, energy efficiency, public transport, waste management, and forestry in the phases of building, operation, and maintenance. Indirect employment creation is the result of impacts of low-carbon investments, mainly in the industrial and service sectors. Investments alone related to the decarbonization of the energy sector, clean energy infrastructure, and increased renewable energy capacities (including solar and wind energy, biomass, water, and geothermal energy) can create an additional net **41,000 direct jobs** by 2050 compared to the BAU scenario.

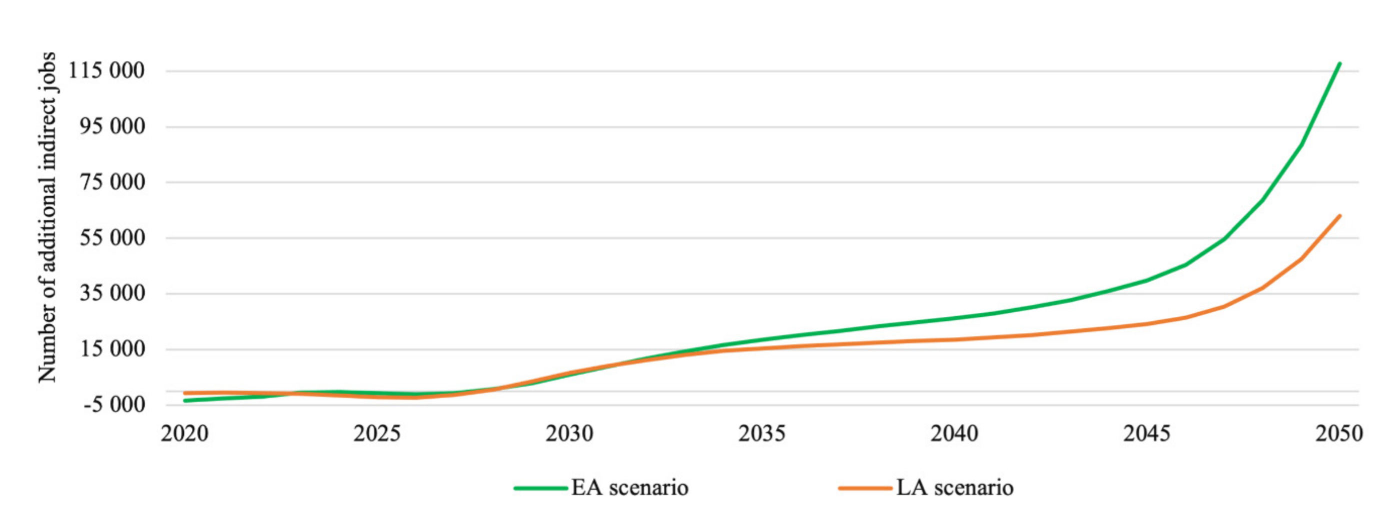
The **cost-benefit analysis shows that the EA scenario brings considerably more economic and employment benefits compared to the LA scenario**. Furthermore, accelerating the energy transition and the early implementation of investments can incentivize a recovery from the economic crisis caused by the COVID-19 pandemic and the energy security threats imposed by the Russian invasion to Ukraine.

Figure 10. Carbon intensity of the Hungarian economy by scenario



Source: Eurostat projection, own modeling result

Figure 11. Indirect job creation in the EA and LA scenarios compared to the BAU scenario



5. PROMOTING DECARBONIZATION IN HUNGARY

5.1 BUILDING SUPPORT FOR THE NATIONAL CLEAN DEVELOPMENT STRATEGY

Building support and justification for decarbonization in the public is a prerequisite for successful implementation of the long-term vision. By demonstrating that reducing emissions will deliver specific and quantifiable benefits to Hungary helps to support the initial public expenditures and policy reforms. A subsequent and in-depth evaluation of which sector and subsector gains the most from decarbonization would be useful in the coming years to ensure that benefits are equitably distributed across all communities and sectors. Clearly demonstrating that benefits will likely exceed costs can also help attract foreign and financial sector investments to help finance bankable aspects of the transition. Lastly, while the costs associated with decarbonization in the near term will require the raising of funds internally and externally, these investments could also yield important short-term economic benefits (e.g. improvement on the Balance of Payments) as Hungary recovers from the COVID-19 pandemic and enters into an inflationary period exacerbated by the energy supply shocks and consequent energy security crisis.

5.2 GUIDELINES ON THE IMPLEMENTATION OF THE NATIONAL CLEAN DEVELOPMENT STRATEGY

A successful implementation first requires that, based on the economy-wide Early Action decarbonization trajectories developed by the NCDS, each sector and subsector define intermediate targets and milestones, including relevant transformation pathways and the associated measures. The pathways and measures will be periodically reviewed as part of the learning process to ensure that they are consistent with the targets. Over time, these boundary conditions will be amended in light of the latest technological innovations, political, economic and social circumstances as well as geopolitical challenges, such as the armed conflict in Ukraine which seriously impacts the European and global energy markets.

Implementation of the NCDS will require first identifying key risks, inhibiting, and reinforcing factors as well as potential *hedging and shaping actions* (Dewar, 2002; Marchau et al., 2019). Hedging actions, in this context, are actions that reduce the sensitivity of the Strategy to the identified uncertainties. Shaping actions are those that ensure unfavorable conditions do not occur in the first place.

In addition to identifying goals, targets, milestones, risks and other factors, there are key steps that should be taken to keep the Strategy on track in achieving net zero emissions by 2050. These are:

1. *Ensuring that NCDS is aligned with the Government's mission, vision and values*. It is to be noted that the Government's mission and vision, or even values may need to change in response to changing circumstances and should be reviewed regularly.
2. *Appointing/establishing a coordinating governmental body, such as the Interministerial Committee on Climate Change and granting it special executive powers*. The consequent implementation of the Strategy is highly dependent on a coordinating governmental body with proper executive powers and leadership capabilities.
3. *Creating an NCDS implementation plan*. The plan should define the steps necessary to achieve the objectives set in the NCDS and include schedules, responsibilities and resources needed for key activities and measures. The implementation plan should be aligned with and based on Hungary's **Climate Change Action Plans** updated every 3 years and the **National Energy and Climate Plans** updated every 10-year periods
4. *Allocating budgetary resources for implementation. As chapter 5 of the NCDS notes*, carefully planned budget allocation aims to align the country's expenditures and

12 Chartered Management Institute, 2020., Implementing Strategy. https://www.managers.org.uk/wp-content/uploads/2020/03/CHK-259-Implementing-Strategy.pdf, Retrieved on 4 September 2022

revenues with Hungary's climate and other environmental goals. The budgeting needs to ensure that measures are properly resourced and can be implemented within the planned timescales.

5. *Assigning responsibilities to relevant ministries*. Strategic responsibilities and objectives need to be clearly assigned so that line ministries understand their roles within the Strategy and are able to take ownership of specific strategic tasks and outcomes.
6. *Aligning structures and processes*. The activities of line ministries and their departments need to be coordinated and their expertise and capabilities made available for achieving the objectives of the Strategy.
7. *Aligning people*. The work and roles of ministry employees need to be aligned with the Strategy, so that their efforts contribute to the achievement of it.
8. *Communicating the NCDS*. It is key to develop a communication strategy that will promote the overall vision of the NCDS and articulate the well-defined goals. Communication strategy should consider the messages to be communicated; audience to be reached; the behavioral changes needed; communication channels to be used; and measures to evaluate the level of success or failure. This current Knowledge Product is a key component of the communication strategy to implement the Strategy successfully.
9. *Review and report on progress of implementation.* The governmental body responsible for the implementation should carry out regular revisions on progress (as also prescribed by EU's Governance Regulation) to check that the NCDS is being implemented as envisioned. This allows the Government to reflect on priorities and identify any issues that may need to be tackled.
10. *Make strategic adjustments as necessary*. Implementing the NCDS will be a challenging and a dynamic process which takes place among ever changing economic, social, geopolitical and technological circumstances. This will require decisions on regularly changing the development directions, technological options, allocation of resources for optimal benefits as the context evolves.

5.3 FUTURE OF THE OF THE NATIONAL CLEAN DEVELOPMENT STRATEGY

The NCDS is not to be considered as a static document because it will need to be regularly updated as prescribed by the Governance Regulation and the Paris Agreement. Regular updates are a fundamental requirement, but it is essential that the strategy ultimately becomes a horizontal document used as a reference point by all other policy areas. Decarbonisation affects all areas and aspects of life, and it is therefore recommended that each major policy decision should be considered in the light of the extent to which it supports or hinders the achievement of the 2050 climate neutrality target. From this point onwards, the LTS is no longer a particular climate protection document, but a complex framework for economic and industrial development, innovation, health, education and welfare that will determine Hungary's long-term development up to and beyond 2050.

The models and analysis from the NCDS and this study are helping support government and stakeholder discussion about how to conduct future revisions of the Strategy to best maximize the potential benefits — in particular employment and economic outcomes, which are so critical as Hungary recovers from the COVID-19 pandemic and enters a financial and energy crisis.

5.4 MAINSTREAMING DECARBONIZATION IN OTHER POLICY AREAS

Mainstreaming decarbonization is the systematic integration of low-carbon considerations throughout the Government of Hungary's operations, other sectoral strategies, and plans. To be successful at the economy-wide level, decarbonization shall be at the forefront not just of energy-related sectors, but other national policy areas, from fiscal policies, throughout health, social and education policies, to legislative policies. Five principles should be considered when the Government of Hungary provides a framework for decarbonization mainstreaming:

1. **Commit** to NCDS: commitments to low-carbon transition shall be demonstrated by all ministers and senior management, as well as defined in strategic priorities, policy goals and targets.
2. **Manage** climate-related aspects and risks: this entails assessing the policy area/sector's portfolio, pipeline and new investments and taking appropriate actions to improve the long-term sustainability of those measures/investments.
3. **Promote** climate objectives of the policy area: facilitating the application of approaches, instruments, tools, and knowledge on how best integrate low-carbon considerations to policy decisions, measures, and resilient investments.
4. **Improve** climate performance: setting up operational tools to improve the climate performance of activities by using systems to track, monitor and incorporate climate considerations into day-to-today operations.
5. **Account** for climate action: transparency and disclosure of climate information. Transparency and disclosure of climate information provides decision-makers, investors, shareholders and the market in general with critical information that can help drive greater climate action by a wider number of institutions, companies and consumers.

13 Mainstreaming Climate in Financial Institutions. Available at: https://www.mainstreamingclimate.org/what-is-climate-mainstreaming/five-voluntary-principles/principle-1-commit-to-climate-strategies/, November 2022

5.5 RECOMMENDATIONS FOR FUTURE ASSESSMENTS

During the subsequent NCDS revisions, different suggestions should be considered. It is important to keep on using the most updated available data that will allow the GEM to provide more robust and reliable economy-wide decarbonization trajectories, given that forecasting multiple climate actions simultaneously is a data instensive exercise.

The compatibility of the HU TIMES energy system model and the GEM allowed their combined application and soft linking as part of an integrated modelling framework. The integrated modeling approach was based on alignment between two complementary models. The more iterations the models communicate with each other, the higher the granularity and accuracy of the long-term trajectory. In future revisions, it is recommended to facilitate an iterative process between the models while involving relevant stakeholders for achieving accurate and robust outcomes.

More specifically, it is recommended that a coordinated working group is set up (involving key business and industry stakeholders), with each line ministry leading the data provision and planning of its own policy area and/or impacted sector. This will ensure ownership and that knowledge and expertise is directly reflected in the modelling exercise.

GGGI at a Glance

Headquartered in Seoul, Republic of Korea, GGGI currently has **47 Member States** and operations in **46 countries**.

The Global Green Growth Institute (GGGI) is a treaty-based international, intergovernmental organization established in 2012 at the Rio+20 United Nations Conference on Sustainable Development.

Founded to support and promote the mainstreaming of green growth, GGGI programs and projects are targeted at supporting and promoting strong, inclusive, and sustainable economic growth in developing and emerging economies.

Our Vision

A low carbon, resilient world of strong, inclusive, and sustainable growth

Our Mission

Support members in transformation of their economies to a green growth economic model

Our Position

A trusted advisor and development partner embedded in member and partner governments

GGGI's Unique Value

The combination of policy advice and development of bankable projects to implement green policies that attract green and climate finance, though embedded country operations, gives GGGI a unique value proposition.

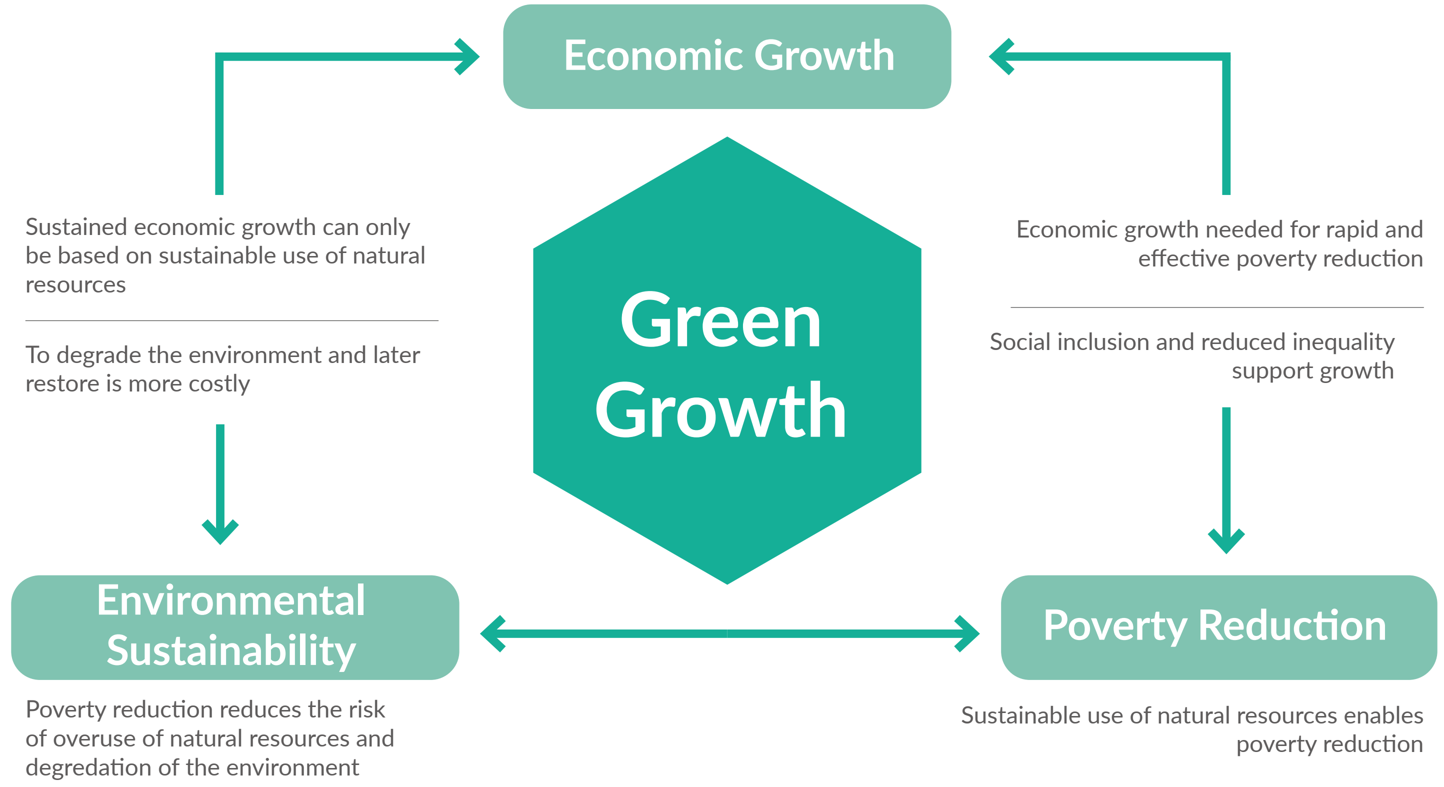
GGGI works across various thematic areas considered to be essential to transforming national economies:

- Renewable Energy
- Green Buildings and Industries
- Waste
- Sustainable Landscapes
- Sustainable Transportation
- Gender and Inclusive Development

Why 'Green Growth'

GGGI works with countries to avoid the perils of industrialized nations that experienced rapid growth at the expense of the environment and focuses on accelerating the transition to a new model of development: Green Growth.

In contrast to the traditional definition of economic growth, Green Growth is an economic development approach that simultaneously considers the full range of economic, natural, and social values to ensure that the growth is good for the economy, good for the planet, and therefore, good for the people. Green Growth is more important now than ever, as climate change threatens populations around the world.



In particular, Green Growth aims to achieve five desired outcomes:

- Sustained economic growth
- Healthy and productive ecosystems providing services
- Inclusive and equitable growth
- Social, economic and environmental resilience
- Greenhouse gas emission reduction