Kazakhstan: Economy-wide Effects of Adaptation in Infrastructure

Applying the e3.kz Macro-econometric Model to the Cases of Climate Resilient Roads and Buildings

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Executive summary

Kazakhstan faces extreme weather events like storms and floods, which affect the economy in many ways and will increasingly occur due to climate change. One of Kazakhstan's cornerstones of economic growth and trade is the infrastructure sector. In this sector, **transport and building infrastructure is for example at risk of being damaged by floods, landslides and storms**. Importantly, such damages may impact other industries if the infrastructure is disrupted *(OECD 2018)*. It is therefore crucial to enhance the resilience of Kazakhstan's infrastructure by adapting to climate change.

A useful tool for assessing adaptation measures regarding their effects on the whole economy is the conduct of macroeconomic analyses with the model e3.kz. It has been developed in cooperation between the Ministry of National Economy (MNE) of the Republic of Kazakhstan, the Economic Research Institute (ERI), Zhasyl Damu JSC under the Ministry of Ecology, Geology and Natural Resources of the Republic of Kazakhstan (MEGNR), GWS and GIZ. **By modelling different adaptation measures those with high effectiveness** as well as **positive effects on the economy and the environment can be made out**. On this basis, **policymakers can identify "win-win" actions.**

In this brief, the effects of the measures "(re-)construction of storm-proofed buildings", "'Green Belt' mass afforestation" and "(re-)construction of climate resilient roads" are investigated. The results show that these adaptation measures reduce climate change induced costs for road and building infrastructure while benefitting various economic sectors and the whole economy. Importantly, the analysis demonstrates:

- Construction works for climate-proofed infrastructure benefit domestic production.
- **GDP increases annually up to 0.46% (respectively 389 bn. KZT)** when investing in the (re-)construction of climate resilient roads and **up to 7,700 additional jobs are created per year**.
- Additionally, **nature-based solutions contribute to the long-term strategy on achieving carbon neutrality by 2060**.

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Current situation in the transport and building sector

Well-functioning infrastructures are an important foundation for economic and social development and trade and the transport sector heavily depend upon it. In 2019, around 17% of Kazakhstan's GDP was related to the trade and 8% to the transportation and storage sector *(COMSTAT 2020)*. About 16% of the workforce (respectively 1.4 million people) were employed in the trade sector. The transportation and storage sector accounted for 7% of the workforce (respectively 0.6 million employed people) *(COMSTAT 2021)*.

Due to its central location between Asia and Europe, Kazakhstan holds a strategic position as a transit country. Apart from the gas and oil pipeline network, road and rail infrastructure are the most dominant transport infrastructures regarding freights carried and cargo turnover *(UNECE 2019a)*. The development of the transport infrastructure is one goal in the Kazakhstan 2050 strategy. The Belt and Road Initiative (BRI[1]) , also known as the New Silk Road, is an important cornerstone. According to a World Bank *(2019)* analysis, this initiative and its transport corridors has the potential to substantially improve trade, foreign investment, and living conditions for Kazakh citizens. However, the potential as a transit country has not yet been fully exploited *(ADB 2019a)*.

The state of infrastructure is identified as a bottleneck for Kazakhstan's economic development. About 75% of existing infrastructure needs to be replaced or rehabilitated – of which the transport infrastructure is particularly affected *(OECD 2019)*. Due to the size of the country and the extensive transport network, construction and maintenance of the transport infrastructure is costly *(ADB 2019a, ITF 2019)*. In recent years, however, efforts have been made to re-establish and further expand national and international transport corridors e. g. through the infrastructure programs Nurly Zhol and Central Asian Regional Economic Cooperation (CAREC) *(ITF 2019)*.

The need for investments in building infrastructure is also high: this is due to ageing and energy-inefficient buildings but also because of a growing population und urbanization in Kazakhstan *(UNECE 2019b).* The domestic energy demand in the residential sector accounted for 11 Mtoe in 2018 *(IEA 2021).* Considering the expected growth in housing stock and living space, energy efficiency improvements are a strategic national priority for Kazakhstan which is anchored in the Green Economy concept *(2013)*.

Despite progress, the current state of the physical infrastructure requires large investments which offers the opportunity to make the infrastructure climate resilient. Due to the long-lived nature of infrastructure assets, decisions made now will lock-in vulnerability if they fail to consider climate change impacts *(OECD 2018)*. Thus, it is important to coordinate and align infrastructure and climate (adaptation and mitigation) policies to create co-benefits and avoid adverse side effects *(OECD 2018, UNECE 2019b).*

Impacts of climate change on transport and building infrastructure

Climate change will impact transport and road infrastructure. The infrastructure is highly susceptible to increasing temperature, altered precipitation patterns and extreme weather events even more if the condition of roads, railways, buildings etc. is not satisfactory. Increasing temperature may "lead to road surface deterioration, cause expansion of bridge joints and paved surfaces, and buckling of railways tracks" *(UNESCAP 2021a)*. In buildings and also outside, heat stress may impact labor productivity *(ILO 2019)* and well-being of humans which is amplified by the Urban Heat Island effect in major cities meaning a higher temperature in the city compared to cooler rural surroundings caused by dark surfaces, heat sources in residential and industrial areas, a lack of vegetation and air pollution *(World Bank 2021).*

Accelerated glacier melt and extreme precipitation cause floods, mudflow or landslides which physically damage the infrastructure. Increased soil moisture impacts the structural integrity of roads, bridges, and tunnels. Extreme precipitation and floods wash out road surfaces, damage bridges and railway tracks and lead to travel disruptions *(UNECE 2019b, UNESCAP 2021a, USAID 2012).*

[1] The BRI is an initiative of China seeking to connect Asia with Europe to improve regional integration, increase trade and foster economic growth.

Moreover, floods damage interior furnishings or, in the worst case, can wash away entire houses. Extreme wind events may blow off roofs, cause trees to fall and the flying objects cause damage to the infrastructure. Dust and snowstorms, which additionally reduce the visibility, may increase the risk of traffic accidents.

Climate projections expect further increase in air temperature as well as in frequency and intensity of extreme weather events *(Navarro and Jordà, 2021).* Thus, infrastructure damages, costs for reconstruction and losses due to disruptions, reduced speed and failures of transportation are expected to worsen without adaptation measures *(ADB 2019a).*

Besides these risks of climate change, the transportation sector may profit in wintertime due to less harsh frost days, heavy snowfall and snowstorms typically leading to a temporary closure of highways, as for example in the winter of 2013 in Northern, Central, and Eastern regions of Kazakhstan.

Options for building climate resilience in the transport and building sector

Climate resilient infrastructure is a key to reduce or even prevent from adverse climate change impacts. Several options exist for adapting the infrastructure to climate change. Basically, adaptation options can be proactive or reactive. While proactive adaptation anticipates likely future impacts of climate change, reactive adaptation implements "build back better"[2] measures to increase climate resilience after experiencing the negative impacts of climate change.

The construction and maintenance of road and building infrastructure offers the opportunity for adapting to climate change. Climate resilient measures can thus be directly incorporated into the planning and implemented at relatively low additional cost. According to ADB *(2019b)* and the World Bank *(2012)* additional 7% to 9% of total investments are needed to make roads climate resilient. Costs for climate-proofed buildings[3] depend on "how" it is achieved ("green" nature-based solutions vs. "non-green" solutions) and against "what" climate impact (heat waves, floods, storms). The policy brief *Economy-wide Effects of Adaptation in the Energy Sector* presents energy efficiency improvements in the housing sectors as an option to minimize impacts of heat waves.

Structural adaptation measures such as investments into protective infrastructures (e. g. dams), improvement of design standards and mandatory building codes (climate-proofed transport and building infrastructure) as well as refurbishment provide physical protection and increases robustness *(OECD 2018).* Adaptation measures for transport infrastructure are, for example, new pavement structures to reduce the risk of increased diurnal temperature range. The creation of drainage structures may help to prevent erosion and protect the embankment *(ADB 2019a, b).* Efficiency improvements in buildings and nature-based solutions (e. g. the "green belt" mass afforestation in Astana, "green" buildings[4] or solar-system based air conditioning) provide win-win solutions for mitigation and adaptation *(adelphi and Development Alternatives 2019, Brolsma et al. 2021).* Restoring natural wetlands and floodplains may also help to retain excess water.

Management (or non-structural) adaptation measures such as the relocation of infrastructure from e. g. flood-prone to flood-safe areas, regular inspections and repair plans as well as improved meteorological forecasting tools and early warning systems also help to be better prepared *(OECD 2018, World Bank 2011).*

Macroeconomic analysis of adaptation measures

The e3.kz model for Kazakhstan was developed to analyze the economy-wide impacts of climate change and sector-specific adaptation measures. It helps to identify adaptation measures that are highly effective and have positive effects on the economy, employment, and the environment. This can only be achieved if the socio-economic relationships are captured, as well as the relationships between economic activity, energy demand and the environment, as with the so-called E3 (economy, energy, emission) models.

[2] Building Back Better (BBB) is a strategy aimed at reducing the risk to the people and communities in the wake of future disasters and shocks. The BBB approach integrates disaster risk reduction measures into the restoration of physical infrastructure, social systems and shelter, and the revitalization of livelihoods, economies and the environment.

[3] https://climate-adapt.eea.europa.eu/metadata/adaptation-options

[4] The World Green Building Council (n.d.) defines a 'green' building as "a building that, in its design, construction or operation, reduces or eliminates negative impacts, and can create positive impacts, on our climate and natural environment".

In scenarios, assumptions are made about the frequency and intensity of extreme weather events and are combined with sector- and country-specific climate damages. Costs and benefits of adaptation measures are covered as well, which are borrowed from expert studies. If no specific data is available, own assumptions are made which can later be adapted if better data becomes available. All these initial impacts cause chain reactions in the e3.kz model. The model results do not only show the direct effects but also the indirect and induced macroeconomic consequences (GDP, jobs, imports, sector-specific output) for Kazakhstan due to economic interrelationships. On the one hand, model results show what could happen under climate change scenarios (awareness raising). On the other hand, policymakers can identify those adaptation measures that are highly effective and have positive effects on the economy, employment, and the environment (win-win options). Thus, they are better prepared. The results can be used as a decision-making basis for prioritizing adaptation measures and to set-up an adaptation strategy in Kazakhstan.

Economy-wide impacts of climate change adaptation in the transport and building sector

The macroeconomic effects of the adaptation measures "(re-)construction of storm-proofed buildings" and "'Green Belt' mass afforestation" are presented as adaptation options to extreme winds. Both options help to reduce damages caused by extreme wind while the later also contributes to carbon absorption as part of the long-term strategy to achieve carbon neutrality by 2060. "(Re-) construction of climate resilient roads" is presented as an example for reducing flood impacts on roads.

(Re-)construction of storm-proofed buildings

Extreme wind events are expected to occur every four years with a similar intensity as today according to Navarro and Jordà *(2021).* The rehabilitation and modernization of the building infrastructure is key to prevent storm damages and to reduce (involuntary) reconstruction costs. The extent of damage ranges from a few million KZT to 2.5 billion KZT per event. Damage is mainly caused to buildings, cars and energy infrastructure. Typically, extreme wind events blow off roofs and flying objects cause damage to windows, cars and power transmission lines.

Production losses in various economic sectors resulting from power outages and impaired production sites can be quite severe depending on the damage and duration of power loss. According to the World Bank enterprise survey in Kazakhstan, power outages caused losses in sales of 1.7% on average and sector specific losses ranging from 0.5% (fabricated metal products) to 7.7% (other manufacturing) *(World Bank 2019b).*

Scenario assumptions and implementation

Involuntary replacement investments must be undertaken to repair the damage each time when such an event occurs. Thus, instead of repeatedly bearing the costs and losses, investments in storm-resistant buildings are reasonable.

Table 1: *Key assumptions*

ADAPTATION MEASURES	CUMULATED INVESTMENT (2022 – 2050)	ADAPTATION BENEFITS
Storm-proofed buildings	• 87 bn. KZT	• Up to 65% reduction in (involuntary) reconstruction costs to repair the damage in buildings and power lines • Up to 65% reduction in (involuntary) replacement costs for cars • Up to 65% reduction of losses in service sectors due to power outages

Source: [1] Stewart and Deng 2014

One option is to strengthen the connection between roof batten and roof truss which increases the costs by 1-2% of the houses' value and at the same time reduces the risk of the roof being destroyed by wind by 50-65% *(Stewart and Deng 2014)*. Exemplarily, in this scenario it is assumed that 10% of the existing and new buildings are made stormproof until 2050, especially in regions that have already been affected by extreme wind events, such as Astana. Necessary investments account for maximum 87 bn. KZT.

Assuming that about half of the residential buildings are owned by the real estate sector and the other half by private owners, both sectors must bear the investment costs. Private households are assumed to spend less for non-essential consumption and to finance it from savings. The real estate sector passes on the costs to the consumers.

As the modernization of buildings progresses over time, damages caused by storms are expected to be reduced by up to 65% including less reconstruction costs for damaged buildings, cars and powerlines as well as reduced losses in service sectors due to power outages. At the same time construction activities are increasing which leads to positive impacts also in several other sectors such as manufacturing of non-metallic mineral products producing concrete.

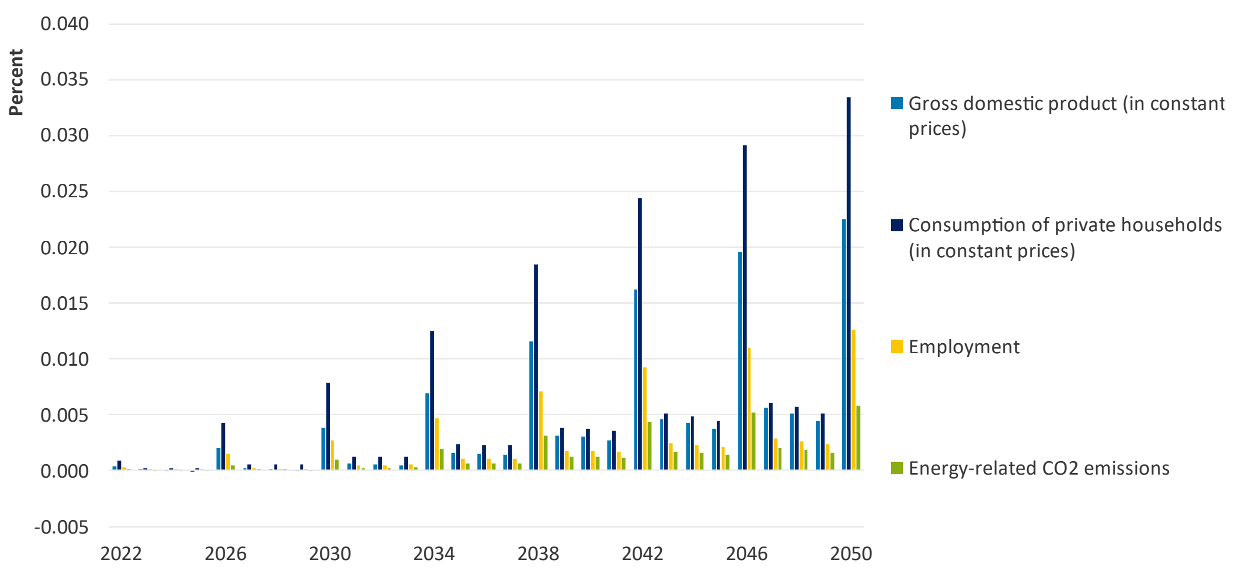
Model results

The economy-wide effects of the (re-)construction of storm-proofed buildings are small but positive. GDP increases by up to 0.02% respectively 19 bn. KZT per year compared to a situation with extreme wind and absence of adaptation measures. Construction works to make the buildings storm-resilient and reduced losses during extreme wind events support economic growth. The success of storm-resilient buildings lowers the (involuntary) defensive spending to repair the damages resulting in reduced reconstruction activities. However, the overall impact is positive.

Household consumption increases by up to 0.03% respectively 21 bn. KZT per year compared to a situation with no adaptation and extreme wind. Closure of service sectors caused by power outages in extreme wind years can be partly prevented due to adaptation and thus consumer demand can be satisfied.

Figure 1: *(Re-)construction of stormproof buildings – Effects of the adaptation measure on GDP and components, employment and CO_2 emissions (differences in % compared to the extreme wind scenario)*

LONG-TERM ECONOMIC BENEFITS OF ADAPTATION



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Employment is increasing in the service and construction sectors resulting in total by up to 0.01% (1,300 persons per year). With a slightly higher GDP compared to a situation with no adaptation measures taken and extreme wind occurring, energy demand and CO_2 emissions are increasing within a limited scope. If no additional mitigation measures are considered, economic growth and CO_2 emission cannot be decoupled.

"Green Belt" mass afforestation

"Green Belt" mass afforestation is a nature-based solution which contributes to damage reduction caused by extreme wind and to carbon absorption. The "Green Belt" of Nur-Sultan which consists of approximately 12 million trees around the city is a prominent example of how to reduce wind speed, improve soil moisture and reduce soil emissions. The number of storms could be reduced from 15 to 5 in summer and from 37 to 22 in winter (Table 2) and thus damages caused by extreme wind such as blown off roofs can be reduced. It should be noted that mass afforestation may have negative impact on biodiversity if monocultures are planted.

Scenario assumptions and implementation

According to the Prime Minister of the Republic of Kazakhstan, 15 million trees are going to be planted in settlements helping to reduce damages from extreme wind and to absorb approximately 360 kt of CO_2 per year. The "Green Belt" of Nur-Sultan may serve as an example on how to implement this adaptation measure and what the costs and benefits are. Damage reduction is assumed to be on average -55% and thus proportionally to the lower number of storms.

The total costs account for 6,000 bn. KZT which is assumed to be paid by the government but at the expense of other government expenditures such as for arts and entertainment.

***Table 2**: Key assumptions*

ADAPTATION MEASURES	CUMULATED INVESTMENT (2022 – 2050)	ADAPTATION BENEFITS (by 2050)
"Green belt" mass afforestation	• 6,000 bn. KZT (15 mio. trees are planted in settlements[2]; on average a tree cost 400,000 KZT[3])	• Number of storms reduced from 15 to 5 (-67%) in summer and 37 to 22 (-41%) in winter[4] • Damages are expected to be reduced proportionally to the lower number of storms (on average by -55%) • 15 mio. trees absorb 360 kt CO_2 p.a.[5]

Sources: [2] Prime Minister of the RK 2020a; [3] The Guardian 2017; [4] Tulepov 2019; [5] The Environmentor

Model results

The macroeconomic impacts of the “green belt” mass afforestation are rather small. However, for the region benefiting from the measure, the impacts are much higher. As long as the benefits from the adaptation measure cannot be fully exploited, GDP is increasing more slowly compared to a situation without adaptation to climate change and extreme wind events. Subsequently, GDP is slightly higher (0.024% resp. 20 bn. KZT).

GDP growth is supported by increased household expenditures but is slowed down by higher imports related to the imported intermediate demand of the forestry sector in particular machinery, trailers and semitrailers as well as chemical products.

Private households profit from less repair expenses which frees up money for other consumption purposes. Additionally, like the previously discussed scenario, household consumption increases by up to 0.04% respectively 24 bn. KZT per year compared to a situation without adaptation measures and extreme wind because losses due to power outages in extreme wind years can be partly prevented and thus consumer demand can be satisfied.

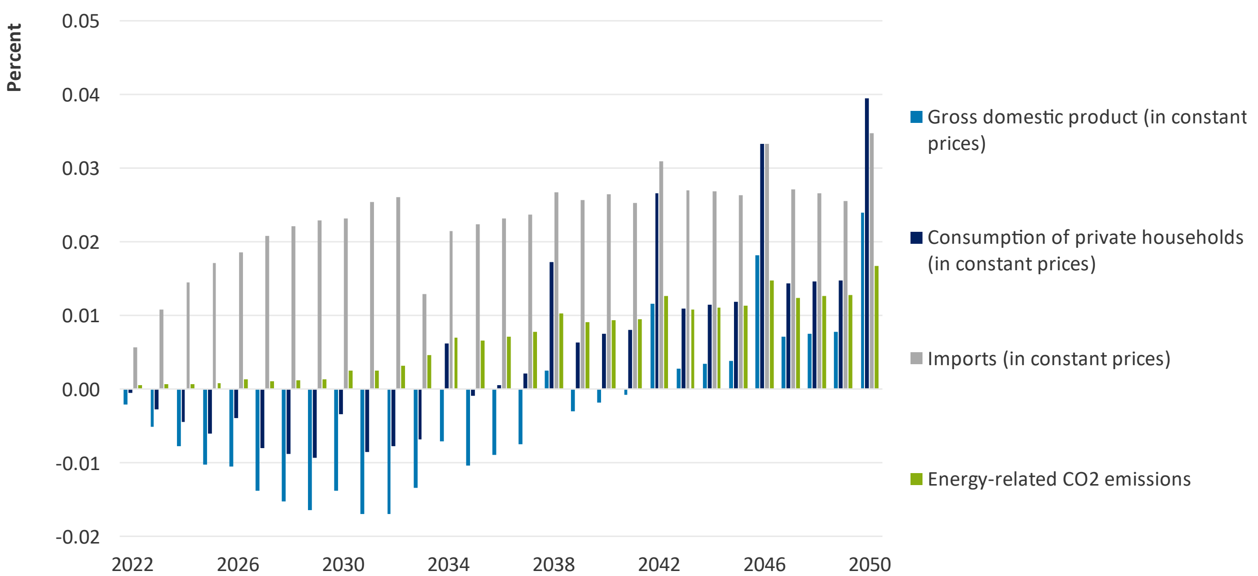
Government consumption is more or less on the same development path because the higher expenditures for afforestation are compensated by lower governmental support for arts, entertainment and recreation activity. That impacts production and employment in the aforementioned two economic sectors.

While the forestry sector profits in terms of employment (max. additional 3,300 jobs per year) and production (max. +104 bn. KZT per year). “Arts, entertainment, and recreation” sector suffers with max. 5,400 employed persons less and a lower production level of max. -93 bn. KZT per year. However, both employment and production in arts, entertainment and recreation are increasing over time but at a slower pace compared to a scenario without additional afforestation. In total, employment is at a lower growth path (-0.02%, respectively -2,400 jobs) compared to a situation with no adaptation and extreme wind.

While energy-related CO_2 emissions are increasing (max. +0.02% resp. 61 kt CO_2, Figure 2) with higher GDP, the afforestation measure allows for absorbing approximately 360 kt CO_2 per year once all 15 million trees have been planted. Overall, CO_2 emissions are decreasing.

Figure 2: *“Mass afforestation” – Effects of the adaptation measure on GDP and components and CO_2 emissions (differences in % compared to the extreme wind scenario)*

LONG-TERM ECONOMIC BENEFITS OF ADAPTATION



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(Re-)construction of climate resilient roads

The modernization of the transport infrastructure is key to prevent climate change damages. Extreme precipitation and floods are expected to occur more frequently and cause increasingly higher costs in the transport sector, negatively affecting jobs and economic growth.

The extent of damage in Kazakhstan ranges from one billion KZT to 19 billion KZT per event depending on the location where the event occurs. Non-climatic factors such as population density, degree of surface sealing in urban versus rural areas, land use, and infrastructure endowment influence the extent of damage. Typical recorded damages are destroyed and flooded roads, bridges, cars and buildings. Economic losses due to impaired production as a result of disrupted and delayed transport is not quantified and thus underestimates the costs of climate change and the benefits of adaptation.

The average direct damage per major extreme precipitation and flood event is estimated with 15,000 Mio. KZT and is expected to occur every five years.

Scenario assumptions and implementation

Construction and regular maintenance of road infrastructure offers the opportunity to adapt to climate change in a proactive manner. For example, the Nurly Zhol budget 2020-2025 amounts to 5.5 trillion KZT for approximately 20,000 km of roads to be built, reconstructed, and repaired. Climate-proofing (e. g. drainage structures, new pavement structure) of these roads increase costs by 7-9% of regular road investments which accounts for 64 to 82.5 bn KZT per year. According to road adaptation projects in Kazakhstan, international donors are financing 100% of the adaptation costs. It is assumed that each year until 2050, such road investment programs including climate-proofing measures are implemented.

With increasing investments in climate-proofed roads, the damages caused by extreme precipitation are assumed to be reduced by up to 50%. It must be noted that there is a high degree of uncertainty associated with the estimated benefits.

***Table 2**: Key assumptions*

ADAPTATION MEASURES	CUMULATED INVESTMENT (2022 – 2050)	ADAPTATION BENEFITS (by 2050)
Investment into climate resilient roads	• 2,117 bn. KZT[6,7] • Adaptation costs are financed by international donors[8]	• Up to 50% reduction of damages is assumed • Up to 1% lower trade costs[8]

Source: [6] Prime Minister of the RK 2020b; [7] World Bank 2012, ADB 2019b; [8] World Bank 2020 estimate lower trade costs of 2.5% which includes completion of BRI transport projects (incl. road and railways).

Model results

The economy-wide effects of the investments in climate-proofed roads are positive. The higher road investments have a positive impact on GDP which is at max. up to 0.46% respectively 389 bn. KZT higher per year compared to a situation with no adaptation measures in place and extreme precipitation occurring. The avoided damages due to adaptation, which reduce the (involuntary) defensive investment spending in flood years, is overlaid by regular adaptation investments.

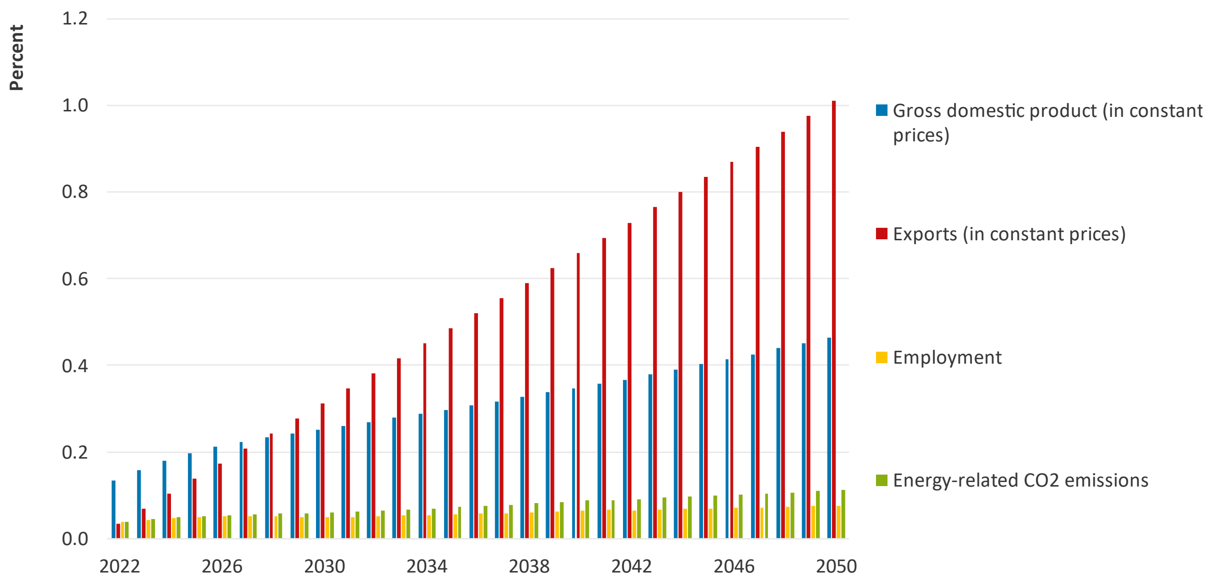
With ongoing road improvements, travel time and thus transport costs are decreasing by up to 1%. Exports are expected to increase by 1% and respectively by 121 bn. KZT.

The intensified construction activity positively affects production in several other sectors such as manufacturers of non-metallic mineral products. During the construction period additional jobs are created. Employed persons in the transport sector profit as well. In total, employment is increasing by up to 0.08% and respectively 7,700 persons per year compared to a situation without adaptation to climate change and extreme precipitation events.

On the one hand, the higher economic activity positively impacts income and spending opportunities of households which increase by 0.26% respectively 159 bn. KZT. On the other hand, total CO_2 emissions are rising by 0.1% (respectively 411 kt), especially in the transport and energy sector which is related to oil refineries.

***Figure 3**: (Re-)construction of climate resilient roads – Effects of the adaptation measure on GDP and components, employment and CO_2 emissions (differences in % compared to the extreme wind scenario)*

LONG-TERM ECONOMIC BENEFITS OF ADAPTATION



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Key messages

The government of the Republic of Kazakhstan adopted the Ecological Code in January 2021 which shows ambitions to mainstream climate change adaptation into policies and development plans at the national and sub-national levels. Modelling results will help to understand which planned adaptation measures (or a combination thereof) are better suited in terms of their economy-wide impacts. Thus, adaptation options which are supposed to be beneficial for the infrastructure sector should be examined regarding their impacts for the whole economy before implementation.

- The consequences of climate change are already noticeable and will occur more frequently and more severe. Jobs and income are endangered not only in the infrastructure sector. Policymakers should be aware of what could happen to manage adaptation strategies and to initiate a climate resilient economic development.
- Various adaptation measures exist for the infrastructure sector to reduce the damages and losses from different climate change impacts. Cost-benefit analysis should be done first to identify the most suitable individual technologies, following techno-economic assessments. However, the quantification especially of the benefits is not easily assessable and is associated with a high degree of uncertainty. Then**, macroeconomic analyses should be conducted to detect the economy-wide impacts of single measures and enable decision-makers to adopt win-win options**. These results are subject to several uncertainties due to the nature of climate change and the current limited knowledge. However, the results serve as a starting point for the development of an adaptation strategy.
- **Investments in adaptation provide co-benefits**, as the adaptation measures analyzed with the e3.kz model exemplarily demonstrate. Reduced damages to the infrastructure and losses in economic sectors support economic growth and trade. Measures that primarily support the domestic economy are even more beneficial. However, improvements of e. g. road infrastructure are expected to increase driving performance and thus CO_2 emissions if no countermeasures (e. g. CO_2 limits for vehicles or a switch to railways) are taken.
- Combating climate change requires a holistic approach including both mitigation and adaptation actions: The e3.kz model results show that economic growth and CO_2 emissions can be decoupled. **Combining climate protection and adaptation measures can create co-benefits** as the example of the nature-based solution in this brief demonstrates. Also, the currently elaborated Kazakhstan's Low-Emission Development Strategy indicates the close links between adaptation and mitigation, their co-benefits but likewise adverse side effects (DIW Econ, 2021).
- **Financing of adaptation measures through international funds is not assumed with the exception of "(re-)construction of climate-resilient roads"**. Given the promises of the industrialized countries to support climate protection measures such as adaptation measures with USD 100 billion per year in the future, the prospects for (partial) funding of the measures are good. If infrastructure development is more linked to the SDGs, additional financing modalities such as global climate finance could be acquired (UNESCAP 2021b). In this case, the **macroeconomic effects of the measures would be even better**.
- Although the financial and economic impacts are relevant for policymakers to decide which adaptation measure is most effective", other criteria must be considered as well such as health aspects and ecosystem services (biodiversity, regulation of the water balance).

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Data and basic assumptions are mostly up to date and were discussed with national sector experts in 2021. Further contextualization and expansion of the results of the scenario analysis as well as economic evaluation of different adaptation measures should be respectively coordinated with the Ministry of National Economy, the Economic Research Institute and the Ministry of Ecology, Geology and Natural Resources in Kazakhstan.

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