Kazakhstan: *Economy-wide Effects of Adaptation in the Energy Sector*

Applying the e3.kz Macro-econometric Model to the Cases of Underground Powerlines and Mitigation Options

Executive summary

OCTOBER 2021

Kazakhstan increasingly faces heatwaves and floods. Such extreme weather events affect the economy in many ways. In the case of the energy sector, one of Kazakhstan's key economic sectors, **energy infrastructure is for example at risk of being damaged by floods and landslides.** Importantly, such damages may impact other industries if the energy supply is disrupted (OECD, 2018). It is therefore crucial to enhance the resilience of Kazakhstan's energy 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**.** The macroeconomic model ***e3.kz*** 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, we investigate the effects of the measures ***expansion of underground powerlines*** and ***deployment of wind power and energy efficiency improvements in the housing sector***. The results show that **these measures reduce climate change induced costs in the energy sector** while **benefitting both the energy sector** and the **whole economy**. Furthermore, the analysis demonstrates:

- Underground power lines prevent damage to the energy infrastructure and reduce production losses due to energy failures.
- Investments in the expansion of underground powerlines result in up to 0.6% higher GDP (respectively 503 billion Tenge) and up to 17,000 (resp. 0.2%) additional jobs annually.
- Improvements in energy efficiency of the housing sector and deployment of wind power limit the risk of damage by heatwaves to energy production.

Published by:

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

of the Federal Republic of Germany

ECONOMIC RESEARCH INSTITUTE QAZAQSTAN

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Current situation in the energy sector

Energy plays an essential role for Kazakhstan's economic and social development. In 2019, around 16% of the GDP was related to the energy sector (incl. mining and energy supply) and about 5% of the workforce are employed in this sector, which equals 0.4 million people (COMSTAT, 2020).

Although Kazakhstan is aiming at greater economic diversification, the energy sector remains important and assures energy security for the whole economy. Kazakhstan is a major producer and exporter of all kinds of fossil fuels. Domestic energy demand is also high, especially in the industry (15 Mtoe in 2018) and the residential sector (11 Mtoe in 2018; IEA, 2021).

Coal, oil and gas are the dominant fuels in Kazakhstan's energy mix. So far, renewable energy plays a minor role. In 2018, the share of renewable energy accounted for 10.4% (mainly hydro, IEA, 2021). Thus, Kazakhstan emitted 364 Mt CO_2e in 2019 of which 73% accounts for fuel combustion. Energy industries have the largest share (47%), followed by manufacturing and construction (10%), transport (10%) and other sectors incl. the commercial, residential and agriculture sector (16%, UNFCCC, 2021).

The need for investment in energy infrastructure is high due to ageing and inefficient power generating facilities as well as transmitting infrastructure. Kazakhstan's Electricity Grid Operating Company plans to modernize and construct new power transmission lines and substations by 2025. Furthermore, the Green Economy Concept aims at 50% alternative and renewable energy in the energy mix by 2050 which is supported by the deployment of renewable energy and energy efficiency improvements (Green Economy Concept, 2013). Even more ambitious and challenging is Kazakhstan's commitment to achieve carbon neutrality by 2060, which was announced in December 2020.

Kazakhstan's current energy mix requires a lot of water for hydropower generation, for cooling in thermoelectric power plants and during fuel extraction (Rivotti et al., 2019). Due to expected rising demand for electricity, the water use in the energy sector would presumably increase, if the energy mix, power plant locations and water-cooling technologies remain unchanged. Additionally, climate change is likely to amplify energy security concerns as described below.

Impacts of climate change in the energy sector

Climate change exacerbates the vulnerability of national development and energy security which impacts the energy infrastructure as well as energy supply and demand. Due to the high importance of the energy system as a key economic sector, damages directly occurred in the energy sector cause indirect losses in other industries due to the disruption of energy supply (OECD, 2018). According to the World Bank enterprise survey in Kazakhstan (2019), 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).

Energy production can be impaired due to insufficient cooling and low water levels caused by higher evaporation with increasing temperature, heatwaves and limited precipitation during droughts. Moreover, glacier melting will reduce the hydropower generation capacity in the long term.

Furthermore, higher temperatures in summer increase the demand for cooling by 0.5 to 8.5 % if temperature increases by one degree. On the other hand, heating demand in wintertime may decrease (World Bank, 2021). In particular, the impacts of temperature rise, and heat stress is amplified by the Urban Heat Island effect in major cities. Research shows that labor productivity of the service sector and outside work (agriculture and construction) suffers from hot temperatures in summer (ILO, 2019).

The energy infrastructure is particularly vulnerable to destructive extreme weather events such as storms, floods and landslides which are expected to occur more frequently. Especially, the extensive, partly obsolete energy transmission and distribution infrastructure – pipelines, power lines, transformer station etc. – is endangered (UNECE, 2019). For example, in 2015, a flood and mudflow caused extensive damage to powerlines in Almaty (USAID, 2017). Heat and high humidity also have a negative impact on transmission capacity (EEA, 2019). In Kazakhstan, significant power losses occur due to unfavorable weather and poorly insulated power lines known as corona discharge and joule heating (KEGOC, 2018).

Climate projections expect further increasing air temperature, an expansion of the drought zones in the North and center. Additionally, an increase in extreme weather events is anticipated such as heat waves, droughts, floods, landslides, and mudflows (MNE, 2017; USAID, 2017; Navarro, Jordà, 2021). Floods are more prevalent in South and East Kazakhstan where the economic vulnerability and population density is high. In 1993, 2008 and 2011 floods caused economic damages of 60 to 100 million USD each. Glacier melting will increase the flood risk in the medium term but decrease afterwards. Glacial lake outburst floods and mudflows threaten in particular Almaty. Southern regions will also be more severely affected by extreme temperatures and droughts (World Bank, 2021).

Options for building climate resilience in the energy sector

The energy sector is required to respond to climate change in two ways: On the one hand, Kazakhstan is committed to undertake climate mitigation activities and, on the other hand, adaptation measures are needed to reduce the previously mentioned climate change impacts. 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 plan mitigation and adaptation activities accordingly to create co-benefits and avoid adverse side effects.

According to the World Bank (2011), several adaptation options exist to reduce the impacts of climate change in the energy system by 40% to 68%. Structural adaptation measures such as investments in protective infrastructures (e. g. dams), improvement of design standards (e. g. climate-proofed power plants, underground or insulated power lines) and refurbishment provide physical protection and increase robustness (OECD, 2018). Efficiency improvements provide win-win solutions for mitigation and adaptation in the context of rising energy demand and respective supply constraints due to climate change.

The development of alternative renewable energy sources reduces the vulnerability of the energy system to various climate impacts as a whole (MNE et al., 2017, World Bank, 2011). Wind and solar power are not water demanding but reliant on wind speed and solar radiation. They are often available when water is scarce or not usable for cooling purposes. Moreover, the deployment of renewable energy sources supports a decentralized energy structure, and thus, reduces the risk of suffering from large-scale outages compared to a centralized energy system. Management (or non-structural) adaptation measures such as the relocation of energy infrastructure, regular inspections and repair plans as well as improved meteorological forecasting tools 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 relationships between economic activity, energy and the environment are captured, as with the so-called E3 (economy, energy, emission) models.

In a climate change scenario, assumptions are made about the frequency and intensity of extreme weather events in combination with sector- and country-specific climate damages. Costs and benefits of adaptation measures are covered in adaptation scenarios, with assumptions stemming 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 of the climate change scenario 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).

Economy-wide impacts of climate change adaptation in the energy sector

The macroeconomic effects of the adaptation measures “expansion of underground powerlines" and “deployment of wind power and energy efficiency improvements in the housing sector", which is a mitigation measure in the first place, are presented as examples. Underground powerlines are better suited to prevent damages from extreme precipitation and storms. Investment in wind power has the advantage of not being water demanding. In combination with energy efficiency measures, these two mitigation actions can contribute to balancing out the effects of heatwaves with regard to even higher energy consumption and impaired power production.

Expansion of underground powerlines

The rehabilitation and modernization of the energy infrastructure are keys to prevent climate change damages and to limit production failures in other sectors due to power outages. Extreme precipitation and floods are expected to occur more frequently (every two years) and more severely causing increasingly higher economic losses in the energy sector, negatively affecting jobs and energy security.

Scenario assumptions and implementation

The modernization of power transmission lines is a prerequisite to maintain the energy security of the economy and people. To increase the climate resilience of the grid and to reduce power outages, a proactive replacement of uninsulated overhead lines with underground power lines is assumed until about half of the total 25,000 km of long-distance high voltage transmission lines have been renewed in 2050. The costs for one kilometer of underground cable are specified with 100 million Tenge and thus total investments amount to 1,250 billion Tenge over a 30-year-period. It is anticipated that the investment sum is divided into equal shares for construction work and electrical equipment. Investments are financed by the energy sector which pass the costs on to the consumers.

As the modernization of power lines progresses over time, the climate resilience of the energy system increases. Power losses and outages as well as triggered production losses in other economic sectors are assumed to be reduced by up to 50% by 2050. Thus, both export losses in export-oriented industries (e. g. manufacturers of metal products) and the imports of various manufacturing industries to compensate production failures can be reduced. Furthermore, the additional (involuntary) electricity production to compensate the power loss due to joule heating and corona discharge is assumed to be reduced by 50% by 2050.

***Table 1**: Key assumptions*

ADAPTATION MEASURES	CUMULATED INVESTMENT (2020 – 2050)	ADAPTATION BENEFITS (by 2050)
Investment in underground power lines	1,250 billion Tenge (50:50 construction works and electrical equipment)	• Up to 50% reduction of power loss and outages • Up to 50% reduction of the additional (involuntary) electricity production to compensate the power loss due to joule heating and corona discharge • Up to 50% reduction of production losses in various economic sectors due to power outages • Up to 50% reduction of (involuntary) reconstruction costs to repair damages to the energy infrastructure

In addition to the direct effects (construction works, imports of electrical equipment, higher output in economic sectors), these effects account for further indirect and induced effects, e. g., an increase of production in upstream and downstream sectors of construction as well as for price and income effects, which in turn influence consumption expenditures.

Model results

The **economy-wide effects** of the gradual replacement of overhead by underground powerlines in the energy sector **are positive**. Both the intensified construction activity and production in various economic sectors due to prevented power outages have **a positive impact on GDP which is up to 0.6% (respectively 503 billion Tenge) per year higher** compared to a situation where extreme precipitation and floods occur but no adaptation measures are taken. In the years without extreme precipitation and floods, the economy grows also faster initiated by the gradual replacement of overhead by underground powerlines.

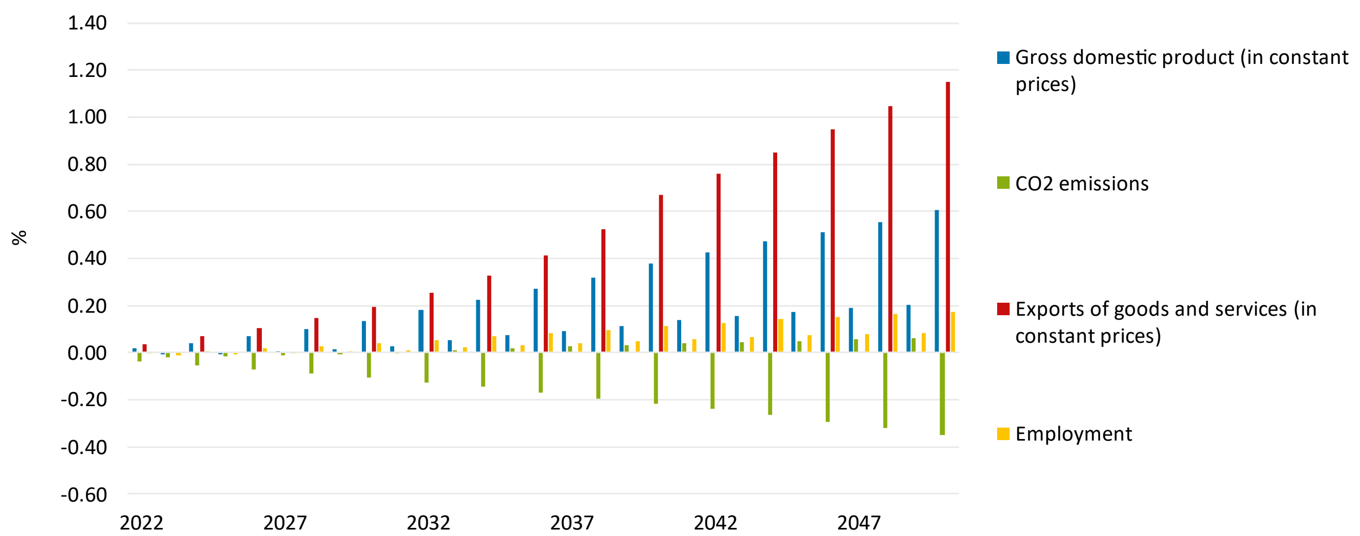
Foregone export chances and increases in imports in various manufacturing industries to compensate for production losses can now be partly prevented. The import of electrical equipment has per se a negative effect but does not prevail. Total exports increase by 1.2% (resp. 134 billion Tenge) while total import increase by 0.4% (resp. 75 billion Tenge).

GDP growth is supported by higher exports, investment and consumption expenditures by households. The increased construction activity associated with the adaptation measure brings more jobs in the construction sector and avoids job losses in manufacturing sectors. The number of additional jobs is increasing over time and reaches the maximum in 2050 which results in 17,000 (resp. 0.2%) employed persons more compared to a scenario without adaptation to extreme precipitation and floods.

Greater economic activity induces an increase in energy demand. CO_2 emissions in manufacturing sectors and construction increase. Lower additional (involuntary) energy production reduces input for coal and gas which in turn decrease CO_2 emission in energy industries. In total, **CO_2 emissions decrease by max. 0.35%.**

Figure 1: *Economic effects of **investment in underground powerlines** on components of GDP and employment (differences in percent compared to the extreme precipitation scenario)*

LONG-TERM ECONOMIC BENEFITS OF ADAPTATION



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Deployment of wind power and energy efficiency improvements in the housing sector

Both the expansion of water-independent energy technologies such as wind power and the reduction of energy consumption are important elements to prepare for heat waves and possible imbalances of energy supply and demand. At the same time, synergies between climate protection and climate adaptation measures are exploited.

Scenario assumptions and implementation

According to IRENA (2021), the wind power capacity in Kazakhstan can be increased by 2.8 GW. Until 2050, 2.9 trillion Tenge must be invested assuming costs of 2,472 USD per installed capacity in kW. Further cost reduction due to learning curve effects is not assumed. With this expansion and expected 3,154 full load hours per year, additional 8,831 GWh of electricity can be generated from wind power. Investments are financed by the energy sector which tries to pass on the costs to the consumers. Wind power serves as reserve power source during heat waves and may support – depending on the wind situation – the energy supply and reduces electricity imports.

The efficiency improvements in the building sector are borrowed from the “Low-emission development strategy of Kazakhstan” project (DIW Econ, 2021), which assumes an energy savings potential of 11% compared to a BAU (business as usual) scenario. Investments are assumed to be a quarter of the total investments of all efficiency measures specified in World Bank (2018) which amounts to nine billion Tenge over the entire period. Residential buildings are about half owned by the real estate sector and half by private owners. Thus, both sectors must bear the investment costs. Private households are assumed to spend less for other consumption and to finance it from savings. The real estate sector pass on the costs to the consumers. This measure helps to reduce both cooling demand during heat waves and heating demand in winter.

***Table 2**: Key assumptions*

ADAPTATION MEASURES	CUMULATED INVESTMENT (2021 – 2050)	ADAPTATION BENEFITS
Deployment of wind power[1]	• 2.9 trillion Tenge* (2.8 GW additional installed capacity at 2,472 USD / kW) • Capacity factor: 36 % → 8,831 GWh	• Preservation of power generating capacity during heat waves
Energy efficiency improvements in housing[2,3]	• 9 billion USD	• Reduced energy demand by -11% for housing compared to BAU in 2050

Source: [1]IRENA., 2021; [2]World Bank, 2018; [3]LEDS table 13 and table 20
** Based on an exchange rate of 425 KZT / USD.*

Model results

The **economy-wide effects** of the investment in wind power and in energy efficiency improvements **are positive**. The higher construction activity and the reduced power imports have **a positive impact on GDP which is up to 0.7% (respectively 558 billion Tenge) per year higher** compared to situation with no adaptation and heat waves.

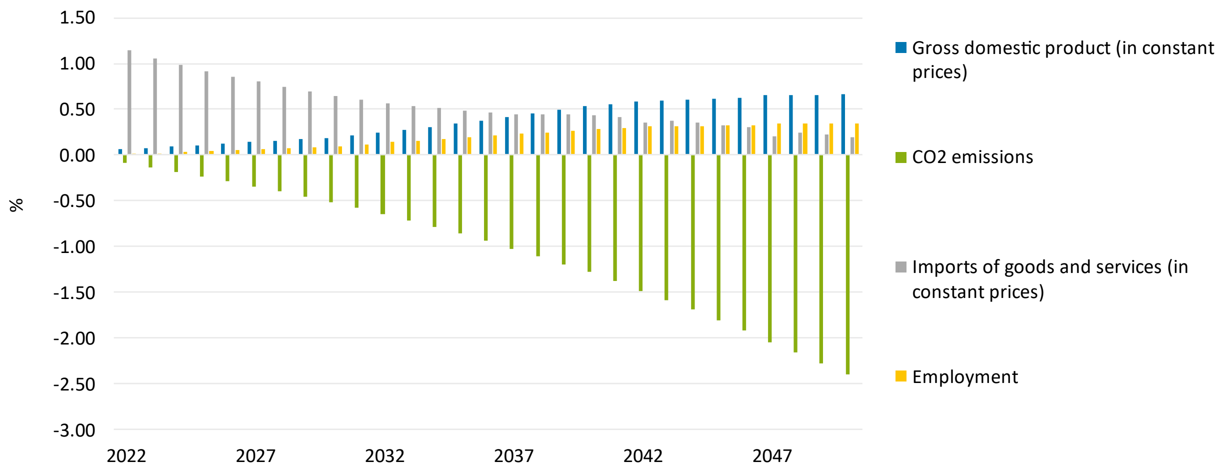
GDP effects are dampened by an increasingly lower energy demand. The latter was intended to be achieved by increasing energy efficiency. Additionally, the imports of wind turbines have a negative impact on GDP. Expenditure on refurbishment activities by private households can increasingly be offset by lower energy expenditure, leaving also financial scope for additional non-essential activities which are supporting GDP growth.

The refurbishment of houses increases the construction activity and thus the demand for building materials such as concrete and insulating material. During the construction period, additional jobs in the construction sector are created**. In total, employment increases up to 0.35%** (resp. 35,000 employed people) per year compared to a situation without adaptation and heatwaves. Furthermore, it can be expected that additional jobs for operation and maintenance of the wind turbines will also be created. The total employment effects would then be even higher.

The CO_2 emissions are rising slower compared to a heat wave scenario without adaptation resulting in up to -2.4% per year despite higher economic activity. The decoupling of economic growth and emissions can be achieved by exploiting synergies between adaptation and climate protection measures. Efficiency improvements combined with the use of more renewable energy to protect from climate change impacts in the energy sector therefore create **co-benefits with regards to climate change mitigation**.

Figure 2: *Economic effects of **investment in wind power and energy efficiency improvements in the housing sector** on components of GDP and employment (differences in percent compared to the heatwave 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 economy-wide impacts. Thus, adaptation options which are supposed to be beneficial for the energy sector should be examined regarding their impacts for the whole economy before implementation.

- The consequences of climate change are already noticeable and will become more frequently and more severe. Energy security might be at risk. Jobs and income are endangered not only in the energy sector. Policymakers should be aware of what could happen to manage adaptation strategies and to initiate a climate resilient economic development.
- Many adaptation measures exist for the energy sector. Cost-benefit analysis should be done first to identify the most suitable individual technologies following techno-economic assessments. Then, **macroeconomic analyses should be conducted to detect the economy-wide impacts of single measures and enable decision-makers to adopt win-win options.**
- **Investments in adaptation provide co-benefits**, as the two adaptation measures analyzed with the e3.kz model exemplarily demonstrate. Economic losses in the energy sector and in downstream industries can be reduced. Measures that primarily support the domestic economy are even more beneficial. For example, construction activities create jobs in Kazakhstan. Products such as electrical equipment and wind turbines are mainly imported and curtail the advantages. Nevertheless, in both cases jobs can be created in the energy sector and related industries.
- Combating climate change requires a holistic approach including both mitigation and adaptation action: Beyond the pure objective of ensuring adaptation to climate change, the e3.kz model results show that the decoupling of economic growth and CO_2 emissions can be enhanced. **Combining climate protection and adaptation measures can create co-benefits**. 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**. 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. In this case, the **macroeconomic effects of the measures would be even better**.

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The current work "Sectoral Policy Brief: Economy-wide Effects of Climate Change Adaptation in the Energy Sector" was developed by the experts of GWS (Gesellschaft für Wirtschaftliche Strukturforschung GmbH), in the framework of the IKI (International Climate Initiative) Global Programme on Policy Advice for Climate Resilient Economic Development (CRED), implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).

Data and basic assumptions for the "Investment in underground powerlines" scenario is 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.

Published by:
Deutsche Gesellschaft für
Internationale Zusammenarbeit (GIZ) GmbH

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This programme is part of the International Climate Initiative (IKI). The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) supports this initiative on the basis of a decision adopted by the German Bundestag.

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