Estonian National Climate Adaptation Strategy for Infrastructure and Energy (ENFRA)

Background: predicted future climate in Estonia up to 2100 (RCP 8.5)

- Warmer winters and springs;
- More rain during the winter;
- Increased amount of zero degree days;
- More thunderstorms / storms, especially expected during summers;
- Increased wind speed;
- Permanent snow cover will be almost non-existent;
- Uncommon permanent ice cover on Baltic Sea as well as on inland waters;
- Spring floods less likely to occur;
- More frequent summer drought risks.

Project Resume

The infrastructure and energy sectors in Estonia have been established taking into consideration all local climate aspects and impacts. Estonian infrastructure and energy production in the country function properly in highly variable weather conditions daily and between seasons. The infrastructure is sound and consumers are provided with energy without failure with temperatures of +35^{o}C or -40^{o}C, during drought and heavy rain. Also, infrastructure functions properly both when there is no wind and when the highest wind speeds are recorded in Estonia (45 m/s). Only in the case of extreme weather events (precipitation over 30 mm per hour or storm winds over 25 m/s) or in the co-occurrence of several negative weather conditions have some infrastructure-related services been disrupted for either a short or long period of time.

The most vulnerable component of infrastructure is the electricity grid. Power shortages have an important effect on the availability of all vital services. At the same time, electric power companies are the ones who have implemented the most measures to cope with risks caused by climate factors and to eliminate power shortages. Providing undisturbed and continuous power to consumers is also highly regulated in Estonia. The projected changes in Estonian climate up to 2100 are both positive and negative. Taking into account the high amplitude of seasonal changes in the current climate, the predicted negative and positive impacts are both marginal. Impacts of climate change on the infrastructure and energy sectors are expected to have considerable impact only by the end of the century, changes until 2030 are almost unnoticeable. Major impacts of climate change by subsector are described below.

Infrastructure, including that for transport, water and sewage as well as the power grid, gas and communication networks, is already quite resilient to current weather conditions and to extreme weather events. In the future, it can be seen the average annual changes in climate parameters do not have any significant impacts on infrastructure. However, the more frequent and severe extreme weather events, such as heavy rainfalls, storms and heat waves can cause situations that disrupt the operation of the infrastructure.

The climate change induced impacts on transport infrastructure largely relate to higher maintenance requirements (of the infrastructure). However, as this might increase in some parts and decrease in others it is hard to anticipate whether in the future there will be more costs or cost savings from maintenance. For example, there will be less need for snow ploughing but more need for de-icing. Also, extreme weather events tend to inflict higher maintenance costs rather than damage the infrastructure. For example, the storms do not break but rather bring wind-thrown debris and litter onto the roads, ports, bridges, and airports. However, there are some circumstances caused by the climate change that might damage infrastructure, such as rail track buckling due to heat waves or bridge scouring due to flooding.

Climate change can also cause some positive impacts on water and sewage infrastructure that might be offset by some other negative impacts. For example, fewer spring floods reduces the load on the storm water collection and wastewater treatment systems, thus lowering the associated costs. At the same time, rainfall is expected to increase during the winters, increasing the load on the storm water collection system and wastewater treatment during this period, and counter-acting the savings from the spring. Also, the level of the upper aquifer rises during the winter, which will bring more water to the wells. But a lack of spring flooding, and the possible high consumption of water in the periods of droughts might offset this positive impact.

Climatic factors influence the communication and gas networks primarily indirectly as in each case the network performance is dependent on the availability of electricity. The power grid is mainly influenced by extreme weather events, such as storms, that damage overhead lines. Thus, the communication and gas networks are potentially threatened only by power cuts caused by extreme weather conditions. However, the power grid will soon be significantly modified and the overhead lines replaced with cables (underground or in the air). Therefore, after 2030, power cuts caused by heavy storms are rather unlikely. Nevertheless, the mild winters might affect the land under air cables, resulting in higher maintenance costs. Also, the increase in days with glazed frost may bring ice storms that cover the cables and other parts of outdoor power grid with thick ice, which can inflict damage on power grid and cause malfunctions.

Buildings in Estonia, when compared to other EU member states, are characterized by high-energy consumption and low quality. The majority of apartment buildings are concrete buildings built during the period of 1961-1990; these accommodate 72% of the country's apartments and 88% of the total living space. High-energy consumption and low quality also describe commercial sector buildings. Here, future energy consumption will depend on the year a building dates from and can, in case of old buildings, result the stagnation of energy consumption at a high level. The construction of new buildings has been slow and the associated build quality variable. Low quality and high age makes the building stock more vulnerable to climate change impacts.

Climate change impacts many aspects of buildings including energy efficiency and indoor climate as well as structures and construction materials. Because of this it is crucial to consider climate change impacts when planning new buildings and/or refurbishing existing building stock. Buildings are most affected by the increased frequency of extreme precipitation, country-wide heat waves and coastal flooding. The rise in annual average temperature may, as a positive effect, lower the average heat consumption, but at the same time will raise cooling demand and with that electricity consumption. High temperatures have the biggest impact on office buildings and hospitals, where people are staying during the daytime and are unable to choose/change their location, making the control of overheating more important than for houses. The rise in precipitation affects many aspects of buildings, having a negative impact on indoor climate and energy efficiency as well as on construction materials. Sea level rise and extreme weather events may in the future cause more flooding with greater impacts making climate change adaptation especially crucial for built up areas near the coast.

In the **transport sector** the main impacts are related to a rise in precipitation and average winter temperatures, which will have more permanent impacts from 2030 and 2050 onwards. The most vulnerable transport modes are road passenger transport and road freight, both in rural areas and in cities. The main negative aspects include the following: an increasing number of traffic interruptions, increased risks related to icy roads and streets, a lower bearing capacity of secondary roads and higher pedestrian and cyclist risks in traffic due to prolonged dark periods. More frequent extreme weather episodes are expected to result in accumulating impacts that can lead to major hazards and challenge the whole transport system. As to positive long-term climate change the following can be highlighted: increased mobility and improved access during winter period, a prolonged season for cycling and walking and a prolonged navigation period on the Baltic Sea as well as inland waterways.
The share of electric vehicles (EVs) in Estonian and European vehicle stock is expected to increase considerably after 2030. Higher winter temperatures will further encourage the shift towards EVs, however EVs are more vulnerable to disruptions in electricity supply and extreme weather episodes. Higher average temperatures and shorter periods of snow cover can also lead to both positive and negative impacts – it will likely lead to increased demand in the mobility of people and goods via both road and water-borne transport, which leads to general positive socio-economic impacts. However, it is also likely to increase traffic safety risks, and increase the load on road network and energy demand. The impacts of unknown nature are related firstly to the prolonged farming period – how it will impact local agricultural and forestry production and related freight transport, both regionally and internationally. Second, the impacts of climate change on domestic and international tourism and related transport demand are unclear. Third, the combination of impacts of coastal processes and other climate conditions on the accessibility of islands, coastal regions and smaller ports is undetermined. Lastly, the vulnerability of transport technologies and fuels used in transport is also of unknown nature.

Energy security, security of supply and energy reliability are not vulnerable to the expected climate change up to 2100. Energy security and security of supply depend foremost on the availability of domestic energy resources and on sufficiency of energy production capacities. US EPA lists major risks of climate change related to the change of demand patterns (in winter demand reduces due to the increase of average temperature and in summer demand is increasing due to higher energy demand for cooling). One of the major risks determined is water scarcity, both for cooling services in power plants and for mining and in fuel production. Global sea-level rise is also considered as major climate change threat as most imported fuels are supplied using sea transport. However, the risks listed above are occurring in Estonia at sufficient magnitude and direction to have any impact to Estonian energy security, security of supply and energy reliability. The main climate risk foreseen up to 2100 is an increased number of extreme weather events, which can cause power cuts and disturbances of electricity distribution system.

Energy resources are, to a rather limited extent, impacted by expected changes in climate up to 2100. At the time of compiling the current report oil shale had the highest share in the primary energy usage among the energy resources of Estonia. Contrary to that the country's renewable resources, such as solar- and wind-energy, have the highest usage potential. It was

found that the changing climate would have positive as well as negative influences on Estonian energy resources during the evaluation period until 2100. In general the impact of climate change on the renewable resources is greater than it is on fossil energy resources. This is due to the fact that the energy density of renewable resources is lower than that of the fossil fuels. Therefore these resources have to be gathered from a wider area and the impacts of climate change vary more, even within an individual resource.
The renewable energy targets and trends lead to a bigger share of renewable energy in the overall energy portfolio. Concurrently to that the vulnerability of energy resources will also increase, since climate change has a bigger impact on renewable energy resources.
The appropriate timing, equipment and infrastructure are crucial to increase the resilience to those impacts of climate change. This applies not only to renewable resources but also the harvesting of some fossil resources like peat. After harvesting, the impact on these fossil resources continues during the storage period, as fuels that are stored unsheltered generally loose quality. The negative impact on fuel storage will increase during the evaluated period until 2100, because precipitation will increase and average temperatures will rise, leading to a higher moisture content and faster decay of stored fuels.

Energy efficiency will mostly be affected by more frequent extreme weather events (heavy wind and rain, thunderstorms, heat and cold waves), increased air temperature, precipitation and average wind speed, as well as by a shorter duration of snow cover. Along with climate change, various megatrends such as decreasing and ageing of the population, urbanization, technology development and changing consumption habits, as well as rising fossil fuel prices, will also have an impact on energy efficiency.
Energy end-use efficiency will likely be affected by higher air temperature, which in winter will reduce heating demand in the residential and services sector, but in summer will increase cooling needs. Increasing precipitation and average wind speed, along with a bigger dwelling surface per capita, may raise the heating demand in warm seasons. In the transport sector, higher air temperature is also projected to have a positive effect on fuel efficiency. However, this increase in efficiency will be offset by more ice on the roads, increased need for anti-slip measures, stronger winds and the use of air conditioners in vehicles that will increase fuel consumption. Furthermore, a shorter snow season and less ice on sea may result in increased transport usage in winter. In agriculture, the increase in annual precipitation will likely reduce the energy consumption required for irrigation. Periodically, however, irrigation needs may increase due to more frequent heat waves and spring droughts due to less snow fall in winter. Increased energy use will also be driven by consumers′ demand for vegetables and berries grown all year round in greenhouses.
In energy production and transmission, efficiency will be most significantly affected by the increase in ambient air temperature, which will decrease the effectiveness of cooling systems in fossil-fuels-based power plants. The impact of climate change on renewable energy sources (wind, solar, hydro-energy) is projected to be smaller. Some positive changes may result, for example increased productivity of solar panels and collectors due to the shorter snow season, however, the increase in air temperature and cloudiness may also reduce their efficiency. The increase in average wind speed will be favorable for wind energy production, but more frequent storms and ice on wind turbines would have an opposite effect. The efficiency of heat pumps will be positively affected by higher air temperature in winter and more precipitation; however, less snow cover in winter may decrease the efficiency of geothermal heat pumps.

Heating and cooling are mostly affected by outdoor temperature changes and trends. Other climate parameters and their changes have only indirect effects on this field. The influences that climate change will entail are detailed in the report “Future climate scenarios of Estonia until 2100”. The following assessments are only valid when the scenarios in the aforementioned report become reality.

The temperature during the heating period (winter) directly affects the amount of energy consumed, potential transportation losses, the efficiency of the system and the necessary power to cover peak demand. An important aspect with regards to the resilience of the heating and cooling sector is the energy efficiency of the building stock. Buildings with higher efficiency are generally less affected by climate change. Cooling is primarily affected by heat waves in the summer, but also by direct sunlight and wind speeds. The vulnerability of cooling devices and the related infrastructure is revealed during exceptional weather conditions, such as heat waves, but also during more typical weather events such as storms that disrupt the electricity supply. During the reference period analyzed, the annual period with residential cooling demand was significantly shorter than the heating period. Under climate change the difference between these periods decreases, but the heating period will remain longer than the cooling period.

Electricity production at the present time is mostly not vulnerable to climate change as the local fossil fuel, oil shale, is used and the construction of power production facilities has taken into account local weather conditions. There will be a change of paradigm towards the generation of electricity from the by-products of oil production. However, the identified climatic actors do not and will not negatively impact oil shale based electricity generation, which will last up to mid of present century. In the second half of the century renewable energy resources will take over the lion’s share of national energy production, with hydrogen, wind and solar entering the power market with full speed. The combination of these three resources will have a huge positive effect on the production of diffused and clean energy. The most important role will be maintaining the functioning of fuel cells for energy generation from hydrogen.

Wind energy will be vulnerable to climatic actors, but technological development can mitigate these factors. Solar energy is developing very fast and in the second half of century the number of micro- and mini-stations are expected to increase, dominating small-scale energy production. Hydro-energy (gravitational/falling water) will not be significantly impacted by the change in climatic actors. Similarly, no significant impact is expected on energy generation from biomass, since this is carried out indoors and is thus protected from climate actors.

Strategic goals and measures for climate change adaptation in the Estonian infrastructure and energy sector.

The overall objective of the Estonian Climate Adaptation Strategy for Infrastructure and Energy is to ensure the functioning of the above mentioned sectors in case of any climatic events, so that the vital services dependent on infrastructure will be available to people.

In order to ensure this overall objective, the policy makers and parties of the infrastructure and energy sectors are made aware of future climate change impacts. The equipment and buildings necessary for ensuring the infrastructure and energy supply will be built to specifications that make them resilient to climate change. In collaboration between local governments and citizens, the technical basis and capacity has been created to effectively eliminate the negative effects of extreme climate events (heat waves, forest fires, floods or severe storms, etc.). The area-specific goals for the functioning of critical services, such as electricity, heating and fuel supplies, telephone communications, radio and television broadcasts and transport operation, both on roads, railways and by sea, are the existence and availability of the above-mentioned services at any given time when people need them, as well as consumer satisfaction with the quality of services. A sub-objective or sub-objectives, taking into account the specifics of the corresponding field, have been established for all eight sub-categories.

In the key area of infrastructure, a total of 57 climate change measures have been proposed in the three infrastructure subareas. The total cost of measures in the infrastructure subareas for the period of 2016-2020 is 163.1 million Euros, which is spread evenly over the years. In the key area of energy, there are 25 measures proposed, with a total implementation cost of 157.7 million Euros during the period of 2016-2020. As the measures in the area of infrastructure that are planned to be implemented during the period of 2021-2030 bring additional revenue to the state budget, which exceeds the planned costs for the same period, the total cost is reduced when measures are implemented as the sum of two time periods. In total, during the period of 2016-2030, the cost of climate change adaptation measures in the fields of energy and infrastructure will be 155 million Euros. Thereby, the budget revenues for the measures implemented in the area of infrastructure will be greater than the costs (total revenue of nearly 160 million during the period). The cost of adaptation measures in the energy sector will be approximately 315 million Euros.

The predominant climate change adaptation measures in these two key areas (infrastructure and energy) are regulatory measures, the implementation of which will not burden the state budget with additional cost. In the subsectors, the most costly measures will be the buildings sector (360 million Euros), followed by technical support systems (119 million Euros). The majority of the costs, 98%, are made up of investments. Investments are foreseen in three subsectors (buildings, technical support systems, transport), of which investments in the buildings subsector form about 70% of investment costs in the field of infrastructure. Investment-type adaptation measures are: supporting the reconstruction of existing buildings in order to achieve energy savings and to improve the indoor environment, the example set by the public sector in achieving energy savings, and the promotion of energy efficient new buildings (the construction of energy-efficient rental housing in order to foster the construction of nearly zero energy buildings).
The biggest cost is the field of energy is formed by economic measures (245 million Euros) and investments (39 million Euros). Research, regulatory measures and informative measures have a lower cost (18, 10 and 2 million Euros respectively).

The least expensive measures for the state are informative measures or communication activities on climate change risks and vulnerability, on the necessity of adaptation, and on the sector-based cost-effective ways to adapt to climate change, which are intended to be carried out in all subareas.

The authorities responsible for the measures are the Ministry of Economic Affairs and Communications, the Ministry of Finance, KredEx, and local governments. Possible sources are considered to be the state budget in particular, the EU Structural Funds and revenues from emission trading.

It is difficult to assess the benefits of climate change adaptation measures since there is a huge indeterminacy about the occurrence of extreme climate events that can significantly damage both health and property, and since the linkages between the mechanism and consequences of damages are not clear. The Stern report, the most cited source on climate economy, sets out the global economic impacts of climate change and estimates the costs caused by the increase of extreme weather events to be 0.5-1% of annual GDP in 2050. By extending the above estimate to Estonia, one may conclude that overall theoretical avoided cost to the society by implementing climate change adaptation measures would be between 1.5-3.0 billion Euros.