Resume of the ENFRA project

The infrastructure and energy sectors in Estonia have been established considering all local climate aspects and impacts. Energy production and infrastructure function properly in Estonia in highly variable weather conditions daily and between seasons. The infrastructure is sound and consumers are provided with energy without failure when it is 35^{o}C, -40^{o}C, during drought and heavy rain. Also, the infrastructure functions properly during no wind up to the highest wind speed 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 a shorter or longer 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. Also, providing undisturbed and continuous power to consumers is 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 climate aspects, the both negative and positive impacts are marginal. Impacts of the climate change to the infrastructure and energy sector are expected to have considerable impact only by the end of the period, changes until 2030 are almost non noticeable. Major impacts of the climate change by subsector are described below.

Infrastructure, including infrastructure for transport, water and sewage as well as power grid, and gas and communication network, are already now quite resilient to weather and also 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 are more related to higher requirement for maintenance of the infrastructure. However, this might increase in some parts and decrease on the other. Therefore 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 inflict the higher costs on maintenance rather than damages on the infrastructure. For example, the storms do not break but rather bring wind-throw and litter on 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 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 the positive effects from fewer spring flooding reduce the load on the storm water collection system and wastewater treatment, and thus lower the costs. At the same time, the rainfall is expected to increase also during the winters that increases load on the storm water collection system and wastewater treatment. Also, the level of the upper aquifer rises, 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 communication and gas network primarily indirectly as the network performance is dependent on the availability of electricity. Power grid, however, is mainly influenced by extreme weather events, such as storms, that damage overhead lines, in particular. Thus, the communication and gas networks are potentially threatened only by power cuts caused by extreme weather conditions. However, the power grid will be significantly modified as the overhead lines will be 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 inflict the maintenance of the land under air cables. Also, increase of days with glazed frost might bring along ice storms that cover the cables and other parts of outdoor power grid with thick ice that can inflict damage on power grid and cause malfunctions.

Buildings stock in Estonia compared to other EU member states is characterised by high energy consumption and low quality. Majority of apartment buildings are concrete element buildings built during the period of 1961-1990 and accommodating 72% of country's apartments and 88% of living spaces. High contrasts describe also commercial sector buildings where future energy consumption will depend on the year a building dates from and can in case of old buildings result in stagnation of energy consumption on a high level. Construction of new buildings has been slow and with the uneven quality. 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, 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 the most affected by increase of the frequency of extreme precipitation, heat waves through the whole country and flooding events of coastal areas. The rise in annual average temperature may as a positive effect lower the average heat consumption but at the same time raise cooling demand and with that electricity consumption. High temperatures have the biggest impact on office buildings and hospitals, buildings 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 coastal built up areas.

In the **transport sector** the main impacts are related to rise in precipitation and average winter temperatures that 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 cities. The main negative aspects include the following: increasing number of traffic interruptions, risks related to icy roads and streets, lower bearing capacity of secondary roads and higher pedestrian and cyclist risks in traffic due to prolonged dark period. More frequent extreme weather episodes where accumulating impacts 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 better access during winter period, prolonged season for cycling and walking, prolonged navigation period on the Baltic Sea as well as inland waterways.

The share of electric vehicles in Estonian and European vehicle stock is expected to increase considerably after 2030. Higher winter temperatures will further encourage the shift towards EV-s, however the EV-s are more vulnerable to disruptions in electricity supply and extreme weather episodes. Higher average temperatures and shorter period with snow cover can also lead to both positive and negative impacts – it will likely lead to increased demand in mobility of people and goods, both road and water-borne transport, which leads to general positive socio-economic impacts. However, it is also likely to increase traffic safety risks, increase the load on road network and energy demand. The impacts of unknown nature are related to prolonged vegetation 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 impact of coastal processes and other climate conditions to accessibility to islands, coastal regions and smaller ports. Fourth, the vulnerability of transport technologies and fuels used in transport is 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 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 supper demand is increasing due to higher energy demand for cooling). One of the major risks determined is water scarcity both for cooling the power plants and for mining and production of the fuels. The rise in global sea-levels is also considered as major climate change threat as most of global fuels are supplied using sea transport. None of above listed risks are occurring in Estonia in the magnitude and direction to have any impact to Estonian energy security, security of supply and energy reliability. From the climate risks foreseen until 2100 is increased number of extreme weather events which can cause power cuts and disturbances of electricity distribution system.

Energy resources are in rather limited extent impacted by the expected climate change until 2100. At the time of compiling the current report oil scale had the highest share in the primary energy usage among the energy resources of Estonia. Contrary to that the country's renewable resources, like solar- and wind energy, have the highest usage potential. It was found that the changing climate will have positive as well as negative influences on the Estonian energy resources during the evaluation period until 2100. In general the impact of climate change on the renewable resources is greater, than 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 one resource.

The renewable energy targets and trends lead to a bigger share of renewable energy in the overall energy portfolio. Concurrently to that also the vulnerability of energy resources will increase, since climate change has a bigger impact on renewable energy resources.

The appropriate timing, equipment and infrastructure is crucial to increase the resilience to those impacts of the changing climate, this applies not only to renewable resources but also the harvesting of some fossil resources like peat. After the harvesting, the impact continues during the storage period, fuels that are stored unsheltered, generally lose in quality. The negative impact on fuel storage will increase during the evaluated period until 2100, because precipitation will increase and average temperatures will rise as well, which leads to higher moisture contents and faster decay.

Energy efficiency will mostly be affected by more frequent extreme weather events (heavy wind and rain, thunderstorm, heat and cold waves), increase of air temperature, precipitation and average wind speed as well as by shorter snow cover duration. Along with climate change, various megatrends such as decreasing and ageing of population, urbanisation, 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 it will increase cooling needs. Increasing precipitation and average wind speed, along with bigger dwelling surfaces per capita, may increase the heating demand in warm seasons. In the transport sector, higher air temperature is also projected to have a positive effect on fuel efficiency. This increase in efficiency will be offset by more ice on roads, anti-slip measures, stronger winds and the use of air conditioners in vehicles which will increase the fuel consumption. Furthermore, shorter snow season and less ice on sea may entail transport growth in winter. In agriculture, the increase of annual precipitation will likely reduce the energy consumption required for irrigation. Periodically, however, the irrigation need may increase due to more frequent heat waves and spring droughts as a result of less snow in winter. The increase in 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 the most significantly affected by the increase of ambient air temperature which will decrease the effectiveness of cooling systems in fossil-fuels-based power plants. The climate change impact on renewable energy sources (wind, solar, hydro-energy) is projected to be smaller. Some positive changes may arise from the shorter snow season for the efficiency of solar panels and collectors while the increase in air temperature and cloudiness may reduce the efficiency. The increase of average wind speed will be favourable for the wind energy efficiency, 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; less snow cover in winter may decrease the efficiency of geothermal heat pumps.

Heating and cooling is 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, and which are assed in this chapter, are based on the report „Future climate scenarios of Estonia until 2100“. The following assessments are only valid when the scenarios in the forementioned report become reality.

The temperature during the heating period has direct effects on consumption volume, transportation losses, efficiency and necessary power to cover peak demand. An important aspect 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 changes. Cooling is mostly affected by heatwaves in the summer, but also by direct sunlight and wind speeds. The vulnerability of cooling devices and the related infrastructure reveals with exceptional weather conditions, like the forementioned heatwaves, but also weather events like storms that disrupt the electricity supply. During the reference years the period with residential cooling demand was significantly shorter than the heating period. Due to the climate changes the difference decreases, but the heating period will remain longer than the cooling period, even in the end of the evaluation period.

Electricity production at present time is mostly not vulnerable to climate change as the local fossil fuel, oil shale is used and power production facilities built taking into account local weather conditions. There will be the change of paradigm towards the generation of electricity from the by-products of oil production. Still, any out of climatic actors do not and will not impact negatively to 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 with hydrogen, wind and solar entering to power market with full speed. In particular combination of these three resources will give a huge positive effect to diffused and clean generation. No pollution, instead energy accumulation starts to come into everyday life. Most important role will be playing the fuel cells functioning on hydrogen.

Wind energy will be vulnerable to climatic actors. However, the technological development will eliminate these factors. Solar energy will be developing very fast and in the second half of century the number of micro and ministations producing electricity is dominating in smaller scale. Energy of falling water will not be much impacted by change of climatic actors. So does also biomass as the electricity generation based on biomass is in-side activity.

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 the overall objective, the policy makers and parties of the infrastructure and energy sectors are aware of future climate change impacts. The equipment and buildings necessary for ensuring the infrastructure and energy supply will be built resistant to climate change. In collaboration between local governments and citizens, the technical basis and capacity has been created to effectively eliminate the consequences of the negative effects of extreme climate events (heat waves, forest fires, floods or severe storms, etc.). The area-specific measures 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 60 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 26 proposed measures and their total implementation cost during the period of 2016-2020 is 187.7 million euros. As the measures in the area of infrastructure, 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 320 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 480 million euros. Without taking into account additional revenues from the implemented tax measures, the overall cost of the full implementation of the adaptation measures in the period 2016-2030 would be 1.547 billion euros. Costs of the implementation of the all planned adaptation measures during the first implementation period (2016-2020) would be 313 735 500 euros.

The predominant climate change adaptation measures in both key areas 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 conducting surveys (182 million euros). Investments, regulatory measures and informative measures have a lower cost (39, 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