Analysis of the opportunities to increase climate ambition in Estonia

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Summary

Reaching climate neutrality in Estonia (where anthropogenic greenhouse gas emissions are in balance with their binding) with the help of all the sectors (private, public and non-profit) by 2050, is technically **possible** (that is with the widespread implementation of the analysed measures) and **potentially profitable with the strategically wise investments for all the sectors in long-term**.

The longer we delay with the strategically important decisions and the implementation of measures, the more complex and costly will be the achievement of becoming climate neutral and the target of reducing greenhouse gas (GHG) emissions in general. Moving towards the goal of climate neutrality requires a much faster and broader investments in energy efficiency and the use of renewable energy, as the measures and speed of implementation that we have today, would result in significantly higher GHG emissions in 2050 compared to the net zero emissions scenario.

Based on the data available today and on the assumptions of this study **the public and private investment volume for the implementation of the measures covered by this analysis is approximately 17.3 billion EUR for the period of 2021-2050**. The prerequisite for this investment volume is that 85% of the measures analysed in this report will be fully implemented and the remaining 15% will be implemented partially or not at all. **The volume of investments is highly dependent on the key assumption of the climate neutrality scenario that was built in this study that assumed Estonia to meet most of its energy demand with the domestic energy production also in 2050.** Assuming a large-scale import of electricity, the needs for the volume of investments would decrease by about 30-50%. The cost of the climate neutrality scenario is not an additional investment compared to the 80% reduction target that Estonia has already adopted so far. It must be considered that over the 30-year period the costs of the technologies and other relevant parameters will change, so this investment volume is an indicative estimate that needs to be updated in the future.

In order to achieve this goal, it is necessary that all the stakeholders contribute, both the private and public sectors, including all ministries, local governments, citizens and companies, and a change both in production and consumption sector is required. From the total amount of 17.3 billion EUR that is expected to be invested in the analysed measures, the main share in the amount of 13.1 billion EUR falls to the private sector. Activities funded by the public sector organizations (which include both public sector own investments and grants) amounts to approximately 4.2 billion €. **These annual investments would account for about 4% of GDP in the next decade, about 2% in period 2031-2040 and less than 1% in period 2041-2050.** Although several measures, if being implemented, would generate economic savings, it does not mean that this potential is being tapped into and utilised today. It often requires removing regulatory barriers, creating a favourable investment framework, raising awareness, and so on.

Achieving this objective during the implementation of the measures, will in the long-term provide an opportunity (in addition to job creation) to restructure and improve the competitiveness of the economy and to be better prepared for the future developments. **Strategic investments in the next decade will support innovation and the creation of new high-value-added jobs in low-carbon sectors.** By investing in the development of human capital, it is possible to prevent the lack of technical competence (absence of necessary specialists). Changes in the structure of the economy is a natural process that can be designed by the proposed (and other supporting) measures in such a way that the process has a positive long-term impact on

direct cost-benefit accounting, on GDP and on employment. Calculations showed **that the lifecycle weighted average marginal cost of the measures** (reduction of CO_2 ton equivalent divided by net cost) **is negative, meaning that the revenues (savings) outweigh the additional costs**. However, the calculation of direct costs of measures showed that on first decade of the period (2021-2050) the costs (cash flow related) outweigh the revenues due to the investment phase, yet this will change during the subsequent decades (when the operating income of the measures starts to outweigh the operating costs and investments), so all in all the revenues are higher than the costs.

Presumably the reduction of GHG emissions to zero is not entirely possible (for example in sectors such as agriculture, transport, industry). Therefore, the precondition for achieving the climate neutrality is the LULUCF sector contributing with CO2 removal or the deployment of CCS / CCU technologies. Without fulfilling these preconditions, the oil shale sector does not fit in the 2050 picture. The construction of additional oil production and refining plants will in the short term reduce oil shale GHG emissions compared to today's power generation and mitigate job losses, but in the long term will significantly increase the risk of not reaching climate neutrality with their additional emissions. These investments would also be subject to high regulatory (e.g. additional, stricter EU/global restrictions on fossil fuel production) and economic risks (rapid rise in CO2 prices, faster than expected development of alternative fuels market, etc.) and would lead to significant export of emissions that are inconsistent with global climate policy goals.

During the period of 2021-2030 we need to focus more on the cost-effective measures in key sectors that have high emission reduction potential. Most importantly we need to 1) significantly accelerate investments in the energy efficiency of buildings, transport and industry, as in the long term these measures will not only lead to the reduced GHG emissions but also financial savings and reduce the need to invest in new energy generation capacities 2) significantly convert the electricity and heat generation to be based on renewable energy sources and increase the share of low GHG / climate neutral energy carriers in transport 3) agree, within the framework of the Forestry Development Plan, on a national target for carbon capture in the LULUCF sector and design and implement specific measures to support this objective.

Assuming that during the next decade (2021-2030) forward-looking measures with high emission reduction potential are adequately implemented and the next ones are being prepared, **it is not essential** nor even expedient, **to make all decisions for 2031-2050 based on today's knowledge.** First of all, the key actions until 2030 should be agreed upon, the success of their implementation should be evaluated on a regular basis, and the decisions about the extent and necessity of implementing the remaining measures can be taken at a later stage, taking into account technological developments, regulations and relevant market conditions.

Each ministry/sector, in cooperation with its partners, should discuss and agree upon a roadmap of key actions that should be taken to achieve the climate neutrality. These roadmaps should be considered and implemented in the decision-making processes in the future, and overall progress should be regularly monitored by the Government Committee of Climate and Energy. There is currently enough knowledge for the implementation of activities that bring immediate benefits and long-term effects (such as renovation of buildings).

Climate neutrality scenario

Based on the measures analysed in this study a possible climate neutrality scenario was developed. In order to assess the feasibility of achieving net zero emissions, a "baseline" of projected 2050 emissions was identified using the Baltic Energy Technology Perspective Survey, which was supplemented with expert of different sectors and authors of this report. If the measures analysed in this study were to be implemented, the total emissions would likely reach 2.25 Mt CO_2 equivalents by 2050 and the emissions from the energy sector would be close to zero. Investments in carbon capture/use (CCS/CCU) technologies are not included in the scenario, but indicative costs and possible solutions for these technologies are reflected in the study.

The scenario is built based on the assumption that energy security is to a large extent achieved by using local energy capacities without requiring large-scale imports. The modelling tool developed within the study also allows the development of alternative scenarios, such as emissions reduction through a complete de-commissioning of oil shale electricity accompanied by the development of renewable energy infrastructure and large-scale energy imports to cover the demand for electricity. While opting for this alternative scenario would potentially reduce the cost of reaching climate neutrality by several billion euros, it raises the question of energy dependency and whether such a high import dependency is socially acceptable, economically desirable or even possible given the developments in the Baltic-Nordic electricity market. Over the next 30 years, all the Baltic-Nordic countries will need to invest significantly in new generation capacity and large-scale imports may not be possible if investments are not being made at a sufficient pace in all neighbouring countries. The Estonian system operator Elering has indicated based on an annual analysis on security of supply of electricity, that given the EU regulations, it is increasingly important to conduct regional analyses with system operators in neighbouring countries. These estimates should be considered when determining future investment needs and pace.

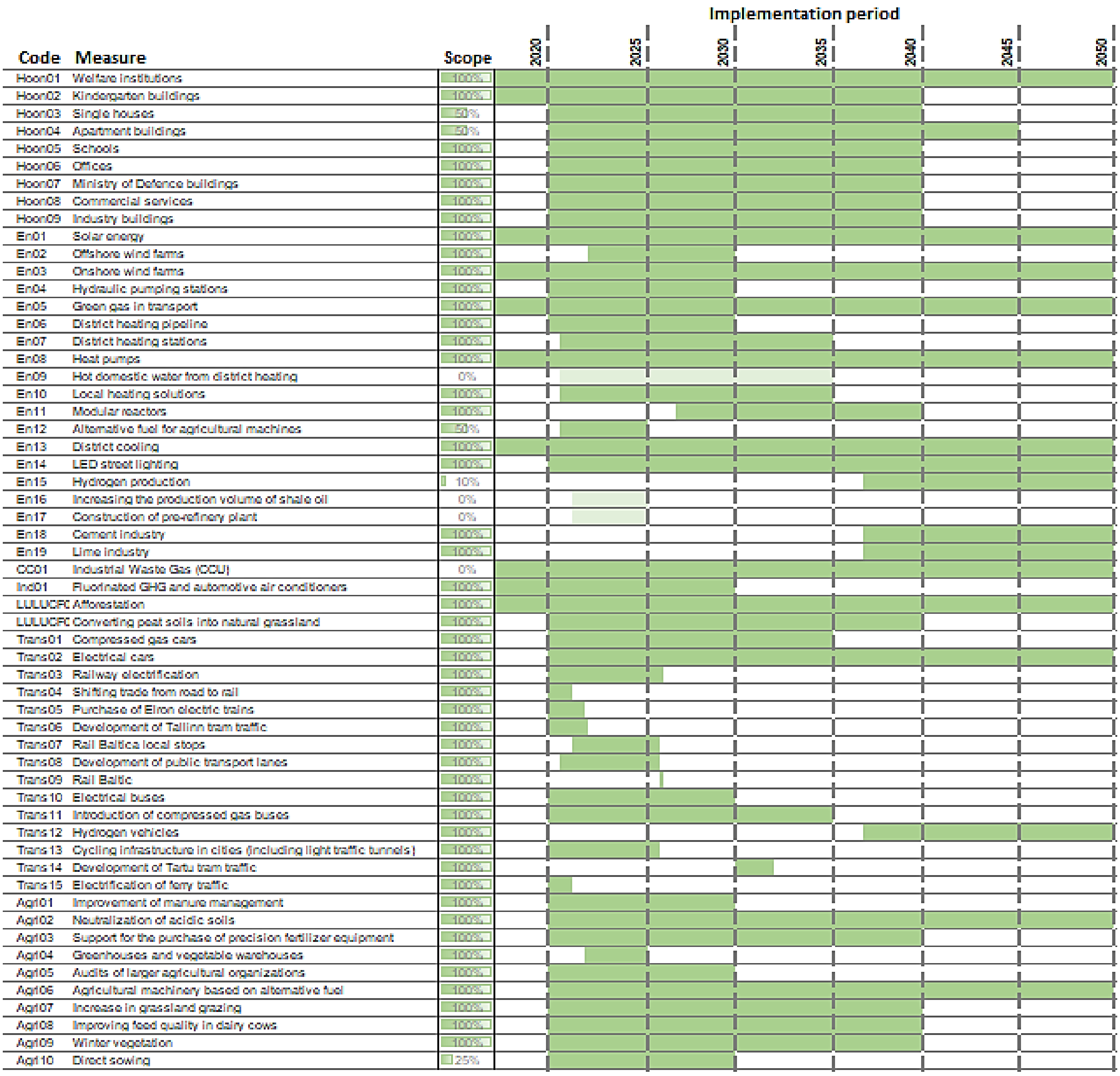


Figure 1. Expected activity volumes and implementation periods for the climate neutrality scenario.

Based on the above, we have compiled a scenario for achieving climate neutrality, for which the main results are presented in Table 1 below:

Activities will result in 2050	
677	MW capacity of installed solar plants
1300	MW capacity of installed offshore wind farms
500	MW capacity of installed onshore wind farms
500	MW capacity of installed pumped storage plants
15000	Cars using compressed gas
3000	Compressed gas trucks
504 000	Vehicles that use electricity
101 000	Hydrogen powered vehicles
866	GWh, electric car consumption (primary energy efficiency 2,5 times better)

Table 1. Volumes of energy sector infrastructure and fleet, resulting from the assumptions of the climate-neutral scenario.

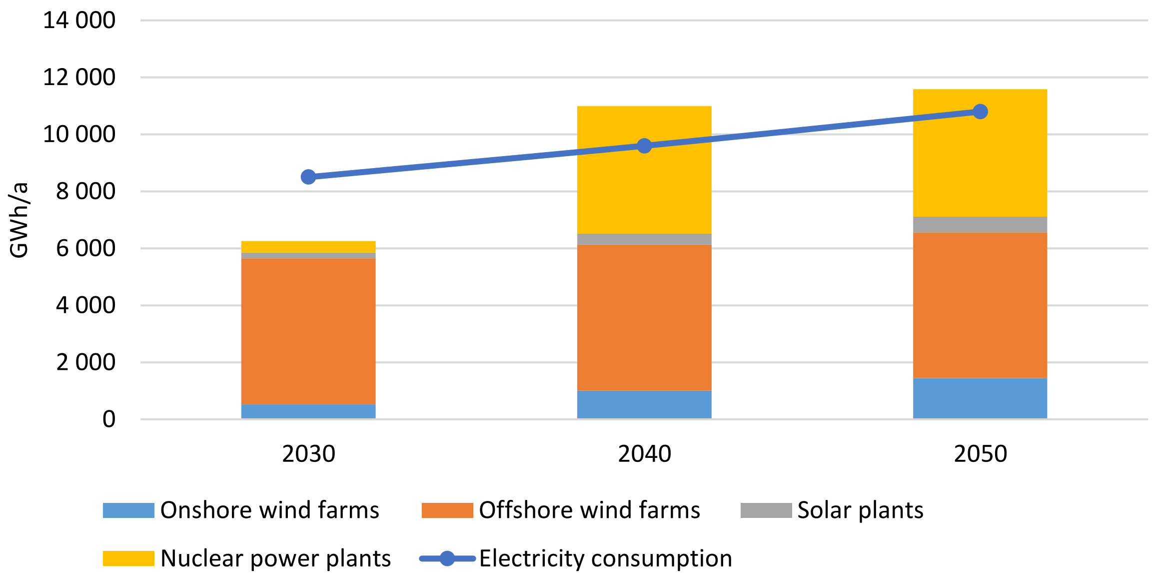


Figure 2. Carbon-free electricity generation from the assumptions of the climate-neutral scenario 2030-2050

The implementation of this scenario would cover the projected 10.8 TWh of electricity consumption estimated in the BENTE analysis from domestic capacities. Renewable energy with balancing capacity could cover about 8.6 TWh.

The scenario also identified the expected implementation period for each measure. Measures that are technologically and economically viable, ready to be used and address significant emission sources, need to be implemented immediately. The measures that are likely to require technological development or a more accurate assessment of regulatory and economic risks in the future, should be implemented in later decades. In the scenario, the expected change in specific emissions factors (or average GHG emissions) was calculated based on the rate of implementation of measures. As a result of the reduction in GHG emissions, the cost-effectiveness of some measures (e.g. energy savings in buildings) also began to decrease as the energy saved by these measures is expected to be cleaner in the future and therefore each unit of energy saved has a smaller GHG reduction effect. This, however, does not mean that these activities should be disregarded in the future due to the decreased savings potential, as they also encompass several co-benefits, such as improving indoor climate in buildings, helping to reduce the need to invest in new production capacities, bringing economic savings in fuel costs etc.

			2020	2030	2040	2050
Electricity	Primary energy emission factor for non-renewable energy sources	t CO_2ekv/MWh	0,36	0,36	0,36	0,36
	Average efficiency of conversion from primary energy to electricity		36%	36%	36%	36%
	Share of non-renewable energy sources in electricity generation		83%	50%	10%	0
	Average emission factor for electricity in the grid	t CO_2ekv/MWh	0,83	0,50	0,10	0
Heat	Primary energy emission factor for non-renewable energy sources	t CO_2ekv/MWh	0,22	0,20	0,20	0,20
	Average efficiency of conversion from primary energy to heat		80%	80%	80%	80%
	Percentage of heat generation from non-renewable sources		45%	37%	20%	7%
	Share of district heating in heat supplied to buildings		55%	60%	60%	60%
	Average specific emission factor for heat supplied to buildings	t CO_2ekv/MWh	0,12	0,09	0,05	0,02
Buildings (electricity and heat)	Average emission factor for total energy delivered to the building	t CO_2ekv/MWh	0,33	0,21	0,06	0,01
Fuels	Average primary energy specific emissions factor for liquid fuels (10% biofuels)	t CO_2ekv/MWh	0,24	0,24	0,24	0,24

Table 2. Changes in the estimate specific emissions factors and other energy system parameters for the 2020-2050 scenario

The volumes which need to be implemented and the investments that these volumes entail, are also calculated in the scenario. Some of these investments will be made any way due to regulatory pressures (EU Directives, Emissions Trading Scheme), while others require the development of regulatory frameworks, financial incentives, human capital and supporting investments favourable to research and development. This analysis does not prescribe which measures should be taken to ensure the achieving of the fulfilment of this scenario. Rather, it is designed to showcase the magnitude of the changes and investments needed to achieve climate neutrality and the socio-economic impact it entails. The next step for the government, is to discuss and agree upon with social partners on the key actions needed for ensuring the implementation of those activities in all areas. This is due to the lack of regulatory and financial incentives or knowledge and skills impede with the successful implementation of some measures.

Impact of investments on GHG emissions reduction

Reaching a climate-neutral Estonia (where net greenhouse gas emissions have been reduced to zero or below) by 2050 is technically feasible and, with strategically wise investments, profitable in the long term in all areas, both private, public and non-profit. Most of the measures analysed in the report are needed to meet the already agreed upon target of -80% GHG reduction. Thus, a fundamental acceleration of the pace of the implementation of activities is required. The existing measures are insufficient to not only reach climate neutrality by 2050 as described in this study, but also to reach the target of -80% GHG emissions by 2040.

In order to assess the feasibility of achieving net zero emissions, a baseline, which shows the likely emissions trajectory for 2050, was identified. For the development of a baseline, the Baltic Energy Technology Perspective Survey was used, supplemented by assessments by experts in the field and authors of the study at hand. If the measures in the analysis are implemented in full, the total emissions in 2050 are projected to reach of 2.25 Mt CO_2 equivalents, with energy sector contributing close to zero emissions. Investments in carbon capture / use (CCS / CCU) technologies are not included in the possible scenario, but indicative costs and possible solutions for these technologies are reflected in the work.

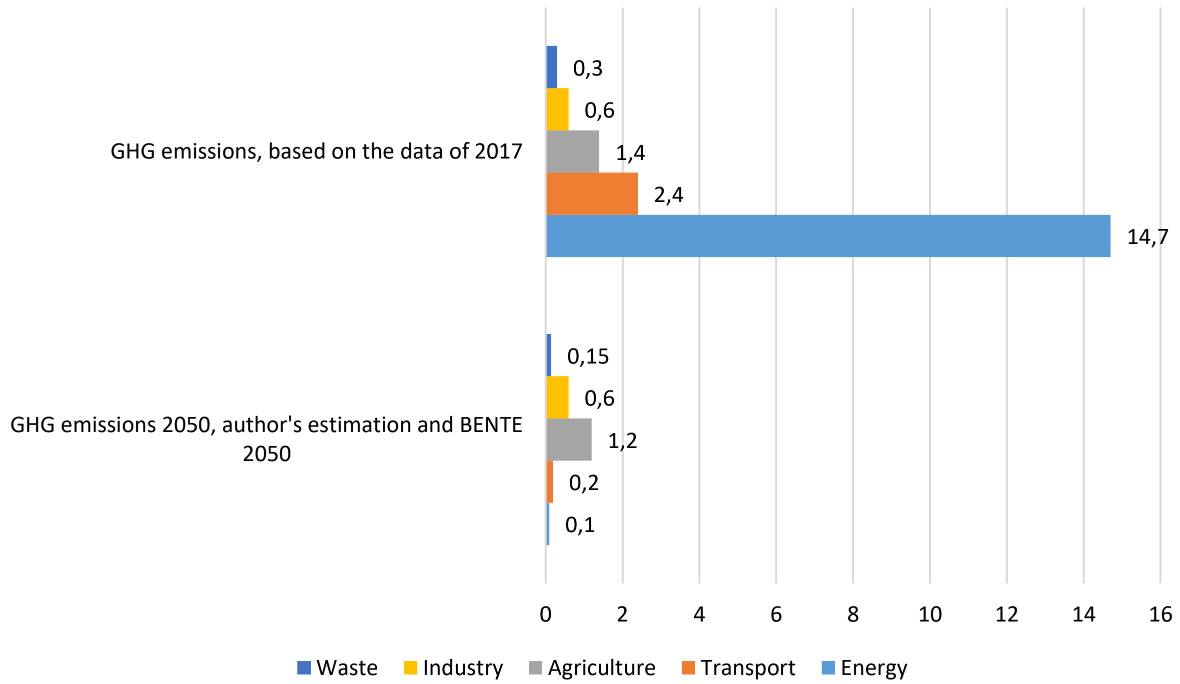


Figure 3. Reduction of GHG emissions required to achieve the objective of climate neutrality

In the year 2050, the emissions in the energy sector will originate from some low-emission production capacities, which are used to balance energy grids (e.g. gas-fired district heating boilers). In the transport sector, the emissions originate from heavy transport, shipping, maritime and agricultural machinery that have not been converted to run on alternative fuels. In agriculture, half of the emissions arise from livestock farming (animals, manure management) and the other half from fertilizer use. The emissions in the industrial sector originate mainly from processes (mainly the cement industry) and are projected to stay at the same level. The emissions in the waste management sector in 2050 will be decreased by half of 2017 emissions due to waste recycling and the reduction in waste volumes.

The LULUCF sector will be addressed as part of carbon sequestration. The main measures for capturing GHG emissions are afforestation, conversion of peat soils to natural grasslands and liming of soils. These measures can remove approximately 1.6 Mt of CO_2 equivalent of emissions. The remaining 0.65 Mt CO_2 equivalent will possibly be sequestered through strategic forestry policy. By fully implementing the afforestation measure and by regulating felling targets, it is possible to achieve net zero emissions by 2050, as the current data suggests that those measures combined would allow to remove approximately 4 Mt CO_2 equivalents in 2050. The strategic objectives in the forestry sector should in this case take into account that:

1. During the first two decades, felling volumes should decrease to about 10 million cubic meters per year;
2. During 2040-2050, annual felling rates should be around 8 million cubic meters per year;

According to the modelling, the total forest reserve would be decreased by 2050.

This does not take into account the carbon capture potential offered by CCS/CCU technologies available in 2050.

Figure 4 shows the dynamic reduction of GHG emissions in the period of 2020-2050. The emission factors have been calculated for each decade. Thus, the impact of the GHG emissions reduction investments made at the beginning of the period will decrease towards the end of the period. The volume of the LULUCF sector in the figure is the capturing of GHG emissions, i.e the sequestering effect of activities started in 2020 will become apparent towards the end of the period.

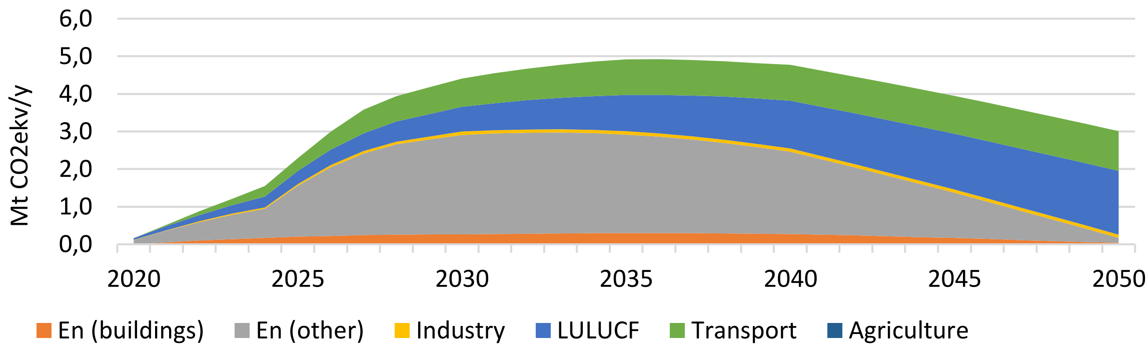


Figure 4. Reduction of GHG emissions over time by each sector.

GHG emission reductions are presented based on fixed point emission factors, hence the marginal cost curves present a mixture of measures, which can be combined with different policy options. At the request of the customer, the authors have replaced the fixed emission factors and the conventional marginal cost analysis with a more dynamic model that calculates the emissions factor at the beginning of each decade based on the activities and assumptions of the previous decade. The calculation model allows to use the static emission factors in parallel.

This analysis enables the effects of activities and the reduction of GHG emissions to be presented over time. As the initial assignment was to map the measures for reduction, the consumption curve has not been prepared on a similar basis, it is not possible to present a final graph showing the reduction of the consumption over time.

Figure 5 illustrates the GHG reduction potential of each activity and its associations with dynamic emission factors and cost-effectiveness. As emission factors are decreasing over time, activities with a higher GHG reduction potential should be launched earlier in the 2020-2050 period. The GHG reduction potentials shown in the figure are the sum of the annual GHG reductions over the analysed period.

The 2020-2030 period is characterized by a much larger investment volume than other periods. Investments into energy efficiency in the early phase brings rapid impacts and cost savings, since it is also reducing the need for investments in low-carbon energy sources. There are several areas with high energy saving potential in the buildings sector: residential buildings, offices, retail space, industrial buildings, farms, publicly owned buildings in different government domains. The potential for saving energy has also been mapped in the transport sector and in industrial processes.

Reducing the carbon intensity of energy carriers is a long-term process and should therefore start in the beginning of the 2020-2050 period. In the coming years, there is a need for the acceleration of the development of wind and solar energy systems, encouraging the uptake of EVs in transport sector, continuing the support for biomethane production and supporting the development of hydrogen technologies to further reduce the carbon intensity of energy carriers.

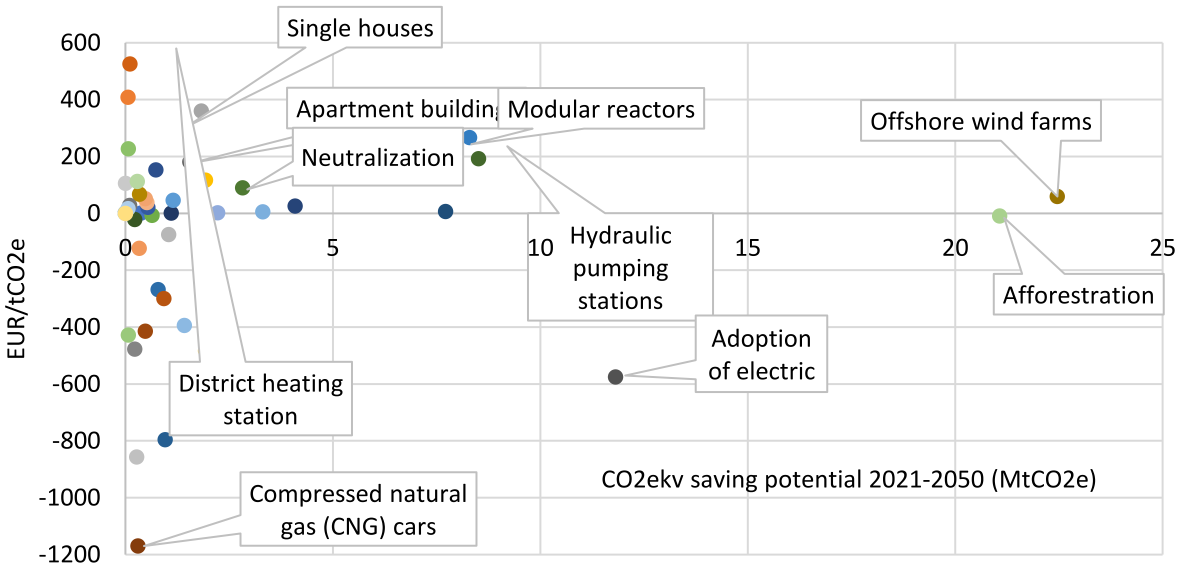


Figure 5. Cost-effectiveness of measures (y-axis) and cumulative GHG emission saving potential over the period 2020-2050 (x-axis). Measures of negative value generating gross social income (GNI).

Due to the time-consuming nature of creating the structural change in the transport sector, the greatest impact of GHG reductions can be achieved by taking early action, including steps towards reaching the set target of -80% GHG reduction by 2040. Given that around 700,000 vehicles will be in use in 2050, about 500,000 of them should electric, 100,000 hydrogen vehicles, and the rest should be with internal combustion engines that use biofuel. In 2018, there were about 50 thousand new vehicle registrations in Estonia, of which 26 thousand were new vehicles. Thus, about half of the yearly initial registrations of vehicles should be alternative-fuel vehicles. The widespread introduction of vehicles should be preceded by the establishment of the necessary refuelling infrastructure.

Regarding carbon sequestration, it is necessary to start research and implementation activities as soon as possible. In order to have an impact in 2050, strategic decisions need to be made at the beginning of the 2020-2050 period and implementation should be monitored throughout the period to ensure coherence with other public sector strategic plans.

The period of 2030-2050 is associated with much greater uncertainties, but it is possible to highlight some trends and choices that lie ahead.

Given the development of the Nordic-Baltic electricity market, climate neutral base load capacity and additional balancing capacity are likely to be needed in the future. Without the addition of balancing power (either in Estonia or the Baltic-Nordic region), it is most likely not possible to fully integrate the renewable energy capacities projected in the scenario. Co-operation and co-ordination between transmission system operators throughout the region is therefore essential to ensure the reliability of the electricity systems in the region (including very high levels of renewable electricity capacity) and efficient functioning of electricity markets. Based on the analysed activities, domestic electricity generation and consumption will produce and use 7.2 TWh of energy from natural energy sources (solar and wind) by 2050. This baseline is compensated by a pump-hydro storage plant with a capacity of 500 MW and an annual production of 1.5 TWh. The domestic energy consumption is expected to be 10.8 TWh, which means that 2.1 TWh (19.4%) of projected domestic consumption is not covered by these sources. Accordingly, the investment also foresees a possible construction of a modular reactor, but this can be generalized as a necessary investment in base load energy production, which doesn’t necessarily have to base on nuclear fuel.

In the second half of the period, in order to reduce the last few tons of GHG emissions, further action is needed in the transport, agricultural and industrial sectors. Although the measures have a smaller impact and are less cost-effective, they are still needed for achieving the goal of climate neutrality. It is also estimated that the instalment of some carbon capture technologies is required to avoid the cost of emitting GHGs.

Volume and distribution of investments

Analysing the socio-economic impacts of the measures in this study, were as important as analysing the impacts of investments on GHG emissions. Baseline data for each measure was collected to model the potential financial and GHG emission impact. The direct change in the cost and income (including investments) and the change in GHG (CO_2 equivalent) emissions from the implementation of the measure for the 2020-2050 period (for some measures up to 2060) was modelled. The measures’ impact on GDP and labour costs was analysed based on the National

Input-Output Framework. Impact on GDP and employment was either direct, indirect or induced (concomitant).

Based on the data available today and the assumptions made in the study, the total investments needed for the implementation of the measures is approximately EUR 17.3 billion. This volume assumes the full implementation of 85% of the measures, and a partial, or no implementation of the remaining 15%.

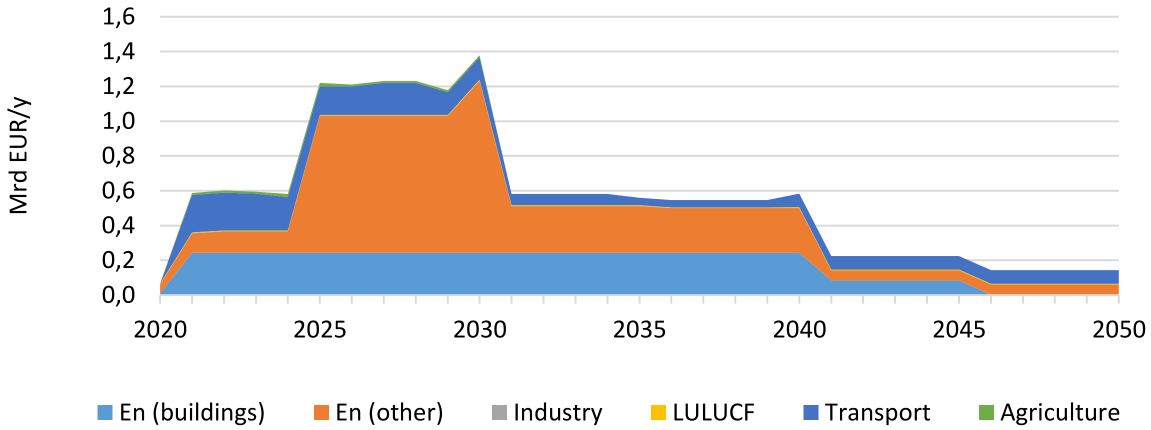


Figure 6. Yearly and sectoral investments, billion euros (61.8 million euros calculated for investments in 2020).

The perceived volume of the investments is not additional compared to the existing 80% reduction target. The achievement of the 80% reduction target requires a substantial investment in the energy sector, energy efficiency and transport sector between 2020 and 2030 and the period leading up to 2050, these necessary investments are already part of the total investment volume of EUR 17.3 billion.

Other assumptions and baselines may lead to a different estimation of the costs of the required measures. It should also be noted that both the cost of technologies and other relevant variables will change over the 30 year period, hence it is an indicative estimation which needs to be updated as data improves, using the modelling tool developed in the study.

In order to achieve the goal of climate neutrality, it is necessary that both the private and public sectors, including all ministries, local governments, sectors and all natural and legal persons contribute, and it requires changes in both levels of production and consumption. A total of 17.3 billion EUR is expected to be invested in the analysed measures, with the private sector investing the majority of approximately EUR 13.1 billion. Investments which fall under the public sector's responsibility amount to approximately EUR 4.2 billion. Combined, the annual private and public investments would amount to about 4% of GDP over the next decade (on average 982 million EUR per year) and decreasing thereafter to around 2% in 2031-2040 (on average 566 mln EUR per year) and less than 1% (on average 184 million EUR per year) in 2041-2050.

Based on the comments from the ministries and assumptions of the authors', it is conditionally possible to divide investments between the public sector and the private sector (Table 3.). The involvement of the public sector does not necessarily indicate the need for governmental support but means that the investment is made by a public sector organization, for example a local government investment into the reconstruction of a schoolhouse. Table 3 below summarizes and visualizes the proportional distribution and overall volume of the investments.

The largest investment needs lie within the power generation sector (offshore wind farms 3.9 billion EUR and modular reactors 2.2 billion EUR), with an approximate share of 90% arising from the private sector. Without taking into account these respective investments, the private sector's total investment volume would be 6.4 billion EUR and the proportions of investments between the public and private sector would shift to 40% and 60% respectively. It is important to bear in mind that the realization of these investments depends upon the establishment of an appropriate supporting regulatory and financial framework, without which the investments will not be made.

	Public sector (million EUR)	*Private sector (million EUR)*
Buildings	1 534	3 754
Energy	681	7 945
Transport	1 736	1 374
Industry (processes)	-	4
Agriculture	88	44
LULUCF	155	-
TOTAL	4 194	13 121
Share (%)	***24%***	***76%***

Table 3. Indicative breakdown of investments between public and private sectors.

In addition to creating additional jobs during the implementation of the measures, achieving the objective in the long term will also provide the opportunity to improve the competitiveness of the economy and restructure it in order to be better prepared for future developments.

Strategic investments in the next decade support innovation and the creation of new, high value-added jobs in low-carbon sectors and prevent the development of technical expertise bottlenecks (e.g. lack of necessary specialists) by contributing to the development of human capital.

Structural changes in the economy are a natural process, and the proposed (and other supporting) measures can be designed in a way to ensure long term positive impact on direct income and expenditure, GDP and employment.

Socio-economic impacts of the investments

Calculations of the socio-economic impact of the investments showed that the life-cycle weighted average marginal cost of the measures (reduction in ton CO_2 equivalent divided by net cost) is broadly negative, i.e. that revenues outweigh the costs. However, direct costs calculations show that (cash flow) costs are higher than revenues in the first decade of the period (2021-2050). This will change in the following decades when the operating income of the measures starts to outweigh the operating costs and investments, so all in all the revenues are higher than the costs.

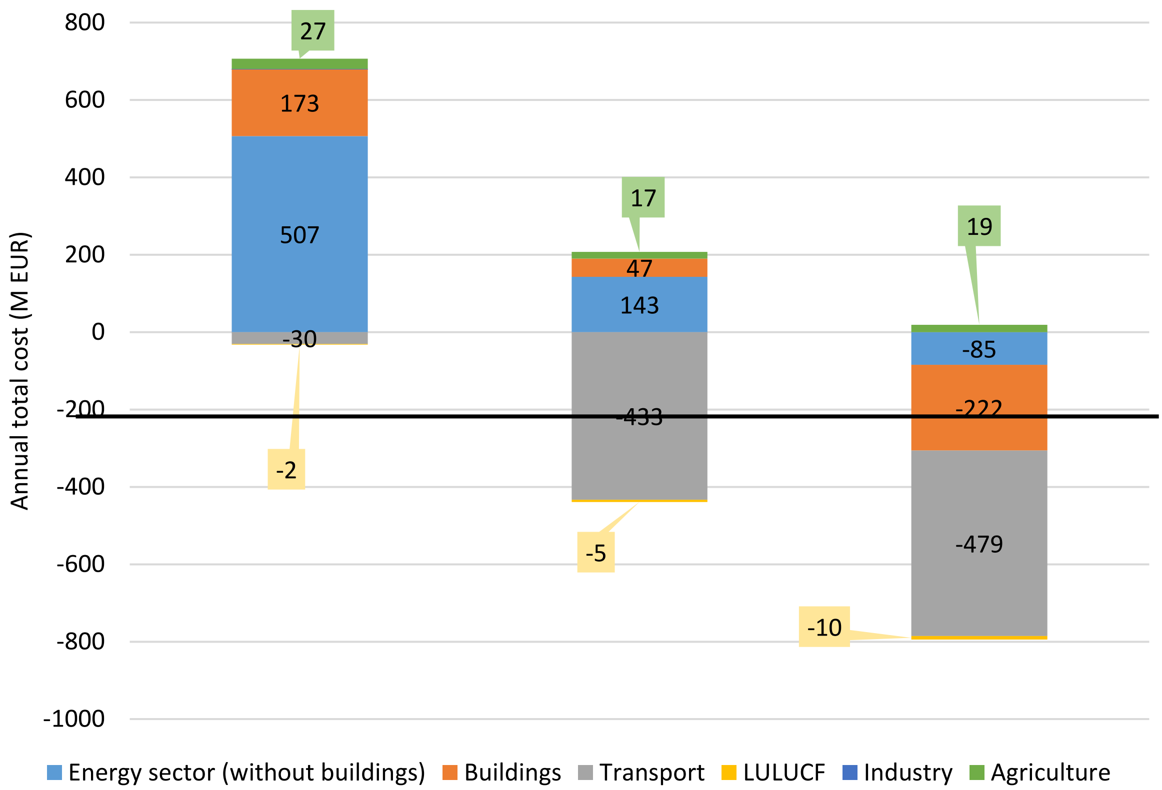


Figure 7. Total annual cost of measures (if '-' then total revenue) by sector and by decade.

As a result of the analysis, two types of activities were identified: activities that generate savings, e.g. activities that are self-profitable, and activities that entail additional costs. The cost of the measures changes as the price of carbon dioxide (CO_2) rises. As a result, activities considered as cost-effective, can become profitable. In the case of cost-effective measures where the driving force is the change in regulation, the public sector plays the key role.

Socio-economic impacts which arise from the implementation of the measures, cannot be automatically aggregated, since the effects of the measures are calculated independently, and the simultaneous application of the measures may create interactions and feedbacks which are difficult to calculate. However, the summarization of the results of the socio-economic impacts indicates the direction and extent of the possible effects.

In terms of GDP, the impact of the measures is predominantly negative (Figure 7), although the impact on Estonia's GDP is modest (ca 10%). The main contributor to GDP change is the reduction of carbon intensity in the transport sector, yet the associated potential reduction of tax revenues can also be considered as a risk for the government. Transport has a major impact on the GDP through the reduction of state tax incomes (excise duties in particular), and thus on total state revenues, which outweighs positive effects (such as the positive impact of increased purchasing power or use of local fuel).

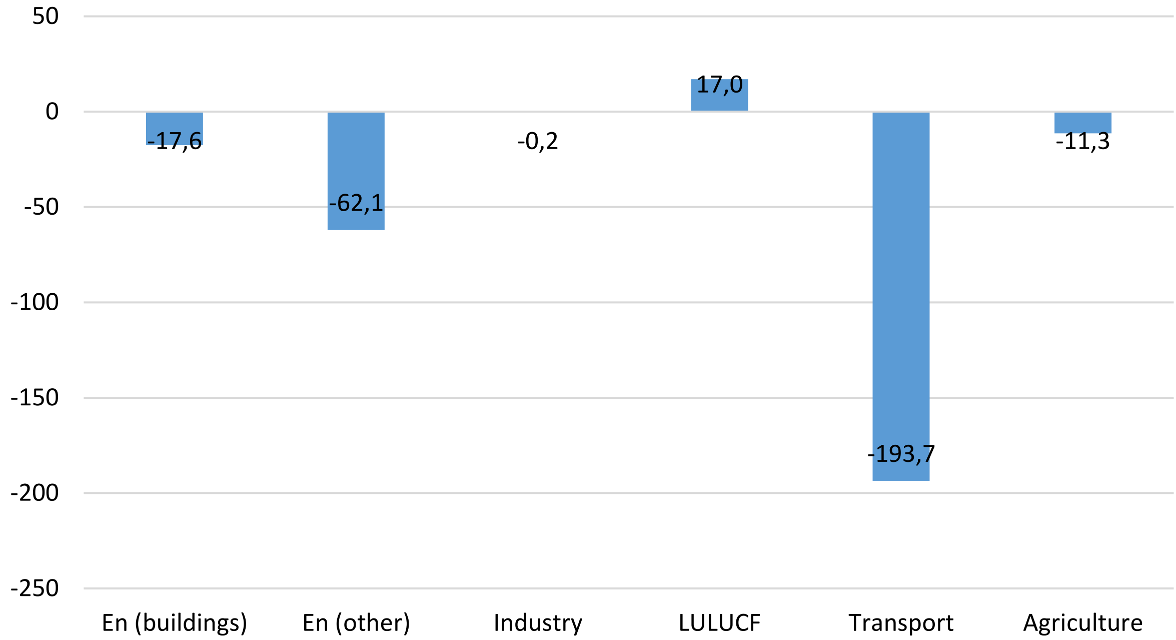


Figure 8. Average annual GDP change by economic activity, EUR million

The negative impact of energy efficiency in buildings on the GDP occurs through the reduction of costs and activities in the heating sector, which outweighs other, predominantly positive effects (investments, increase in purchasing power). In other energy sectors, the main source of negative impact is the decline in oil shale energy and the resulting economic impacts.

The impacts on employment can be divided to total impact (see Figure 8) and direct impact. The total impact was determined based on the direct, indirect and induced (derived) effects on the economy. In the calculations, employee compensation coefficients (estimated to be spent on labour costs from changes in output and induced final consumption) and the average wage in Estonia were used, as it is not possible to differentiate activities by calculating the total impact.

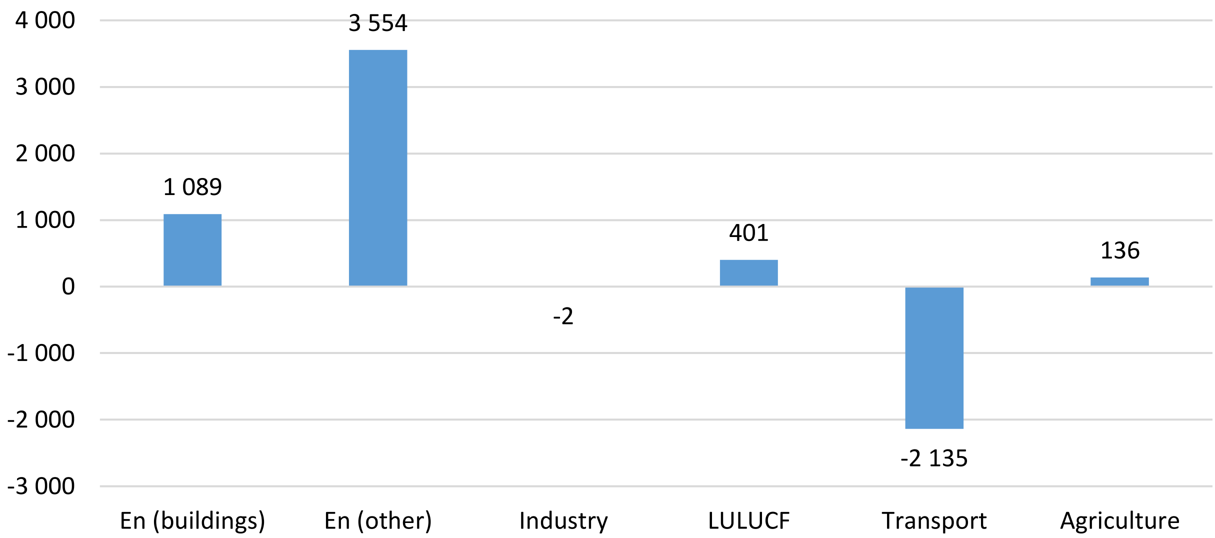


Figure 9. Jobs (total impact) annually by sector

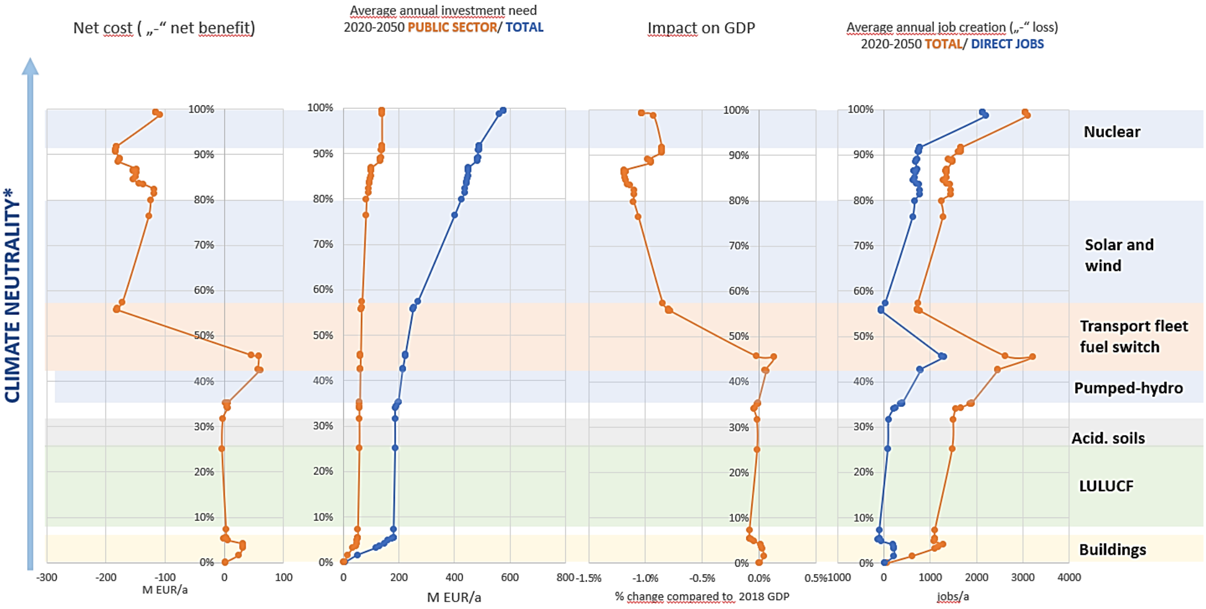
The short-term positive impact on employment occurs in the investment phase and is mostly related to construction, machinery and equipment installation, but also the retail trade (e.g. electric cars and other expensive vehicle sales) and IT solutions (new parking systems etc.). When investments lead to a reduction in the volume of activities (e.g. heating of buildings, fuel consumption, electricity generation, etc.), it will have a long-term negative impact on employment and GDP, which is a natural process associated with the shift towards capital-/technology-/knowledge-intensive economic activities. The measures analysed in this study are directly related to investments in the deployment of different technologies. However, international experience has shown that when investments into human capital development and research and development activities occur simultaneously, it is more likely to create high value-added knowledge-intensive jobs at a higher pace.

The impact on different regions is highly dependent on sector concentrations in the area. As an example, when a measure aims at reducing electricity production, it will consequently primarily affect the oil shale sector in Ida-Virumaa. However, as the production of renewable energy (wind, solar) increases, the regional impact distribution cannot be evaluated. Instead of increasing electricity imports (to replace oil shale electricity), the model assumes investments in on-site production to ensure energy security and security of supply close to current levels.

It is also difficult to assess the regional impact for sectors that more mobile. For example, if a building service is required to make an investment, the impact may not be regional. To a certain extent, the regional impact can also be assessed through the location of the implementation. For example, a district cooling measure is only feasible in Tallinn, Tartu and Pärnu, and the impact on employment should also mainly occur in these locations.

The permanence and duration of the impacts depend primarily on the nature of the action. Generally, the direct effect of the cessation of production (e.g. oil shale energy) is long-term. In the case of new production, the positive impact of the investment on employment is relatively short-term and the impact of investments made for further management of the production is long-term, depending on the life of the investment (maximum life expectancy up to 50 years).

Assessment of the cumulative impact of the measures



*Assuming 100% = 118 MtCO2e during 2021-2050

Figure 10. Cumulative impact of the measures on the different volumes to reach the climate target. The measures are ranked according to the authors' assumption based on the order of their implementation.

The assessment of the cumulative impact of measures provides an overview of the path to climate neutrality. In order to present the cumulative effect, the authors have assumed a sequence of measures that prioritizes the implementation of already existing and more tangible measures first, and measures with a longer realization period later. Accordingly, Figure 10 shows, that reducing the first 50% of greenhouse gases on the path towards climate neutrality is likely to have a marginal impact in terms of total costs and GDP, but a significant positive impact in terms of jobs. In order to achieve the first 50% reduction in GHG's, most of public sector investments are concentrated into the energy efficiency sector to develop supporting measures for building renovations, while the other measures in the early implementation category have low investment needs. The graph also shows that measures aimed at carbon-free electricity generation (solar plants, wind farms, modular reactors) and fuel switching measures in the transport sector (in particular the widespread introduction of electric cars) have the greatest impact on all indicators and GHG reductions.