PRELIMINARY CONTEXT ANALYSIS

WP 3.1 – Mitigation Strategy

ACTIVITY 7 – Preliminary Context Analysis

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1 Executive summary

In the framework of SECAP project, the following report is the first deliverable of Work Package 3.1 – General Data Implementation, it is called "Preliminary Context Analysis" and reviews the energy and the climate of the Interreg V-A Italy-Slovenia 2014-2020 programme area. The programme area consists of the Metropolitan City of Venice, the Friuli Venezia Giulia Region and five regions of western Slovenia (Gorenjska, Osrednjeslovenska, Primorsko-Notranjska, Obalno-Kraška, Goriška) as shown in Figure 1. The aim of this deliverable is to provide the reader with the basic information from the available literature to create a local mitigation and adaptation strategy, supporting the transition from SEAP to SECAP.

In chapter 2 the observed climate changes, the scenarios and the future projections for temperature and main climate parameters are described. The political commitments and actions related to energy and climate undertaken by the EU are shown in chapter 3, with a special focus to Italy and Slovenia carried out in chapter 4 and 5 respectively. We then deepened the energy and climate context in the project programme. The following aspects appear to be the most relevant.

The temperature of the Earth's surface is increasing resulting in strong repercussions on all the natural systems. The rapid change in the Earth's climate is caused by anthropogenic release of GHGs in the atmosphere mainly due to energy related activities. Substantial cuts in Green-House Gas (GHG) emissions over the next decades could limit temperature increase and reduce its impacts but it would require well-designed systematic and cross sectoral mitigation strategies, cooperative action and international collaboration. However, even in this case, the effects of temperature increase and climate change will be felt for years to come. Europe is predicted to be severely affected since the temperature is rising faster than the global average, and extreme weather events, primarily heat waves and extreme precipitation events, are occurring more and more often and are predicted to increase drastically in both number and intensity. There is, therefore, a strong need to implement local and context specific adaptation strategies.

The EU has been at the frontline of both climate change mitigation and adaptation. The latest EU climate and energy framework aims to reduce GHG emissions by 40% and increase the share of renewables and energy efficiency by 32% by 2030. In the long term, the aim is to reduce emissions by 95% by 2050. The main legislative instruments used to cut GHG emissions are the Emission Trading System (ETS) and the Emission Sharing Regulation (ESR), along with many other complementing initiatives such as the Covenant of Mayors for Climate and Energy. For what concerns adaptation, the EU has been successful in developing policies and programmes at national, regional, and local level, and imposed to its member states to develop adaptation strategies, funded adaptation projects, raised awareness, mobilized and supported cities in adopting local adaptation strategies.

In line with the EU directives, Italy and Slovenia are developing their energy and climate strategies. Italy has consumed 116 Mtoe of energy and emitted 433 $MtCO_{2-eq}$ in 2016, while Slovenia has consumed 6,7 Mtoe and emitted 17 $MtCO_{2-eq}$ in 2016. The transport, residential, and industry sectors were the main energy consumers in both countries, while GHG emissions derived 80% from energy related activities. The main objectives pursued to 2030 by both countries are the decarbonization of energy sources, exploitation of renewable resources, improvements in energy efficiency, and energy security. Both countries have experienced in recent years an increase of temperatures, a general diminution of rainfall and snowfall events, and an increase in the number of exceptional meteorological events. This trend is likely to increase in the next years. Italy will be most affected in the central and southern regions due to an increasing number and intensity of heat waves and droughts, and has develop its adaptation strategy, which will try to handle the main sectors that will be under increasing pressure such as water management, environmental degradation, agriculture and forestry, coastal management, and public health. Slovenia will experience significant warming and reduction in precipitation amounts, although this last projection is more uncertain due to the geography and morphology of the country. Although the country is still developing its adaptation strategy, several projects related to as water management, environmental degradation, agriculture and forestry, and public health are underway.

Going more specific in the energy and climate of the program area, the FVG region has consumed 2,9 Mtoe of energy in 2012 and emitted 12 $MtCO_2$ in 2010. The industry sector was the main energy consumer, followed by the residential and transport sectors. Regarding climate change, FVG has experienced an increase of +1,5 °C in the last fifty years, which is way more than the global average, and seen an increase of rainfalls in the west and a decrease of rainfalls in the east. There has been an increase in the number of heat waves and tropical nights, while the number of frost days decreased. There has been a diminution of snowfall events and a reduction of snow-covered bodies. Regarding sea temperature and salinity, there has not been a significant change. On the contrary, an increase of sea level was registered, reaching +20 cm since the year 1880. All the values are predicted to change significantly in the future depending on the RCP scenario causing considerable impacts. For mitigation, FVG has put efforts into pursuing energy efficiency, sustainable mobility, renewables, and raising of public awareness. Adaptation will consist of better spatial planning, flood prevention, water management, and public health.

The Metropolitan City of Venice has consumed 1,3 Mtoe of energy, mainly for the residential, transport, tertiary, and industry sector, and emitted 4,1 $MtCO_2$ in 2017. Regarding climate change, in the last 25 years a rise of 1,3 °C above the historical average has been detected, whereas precipitation was highly variable and unpredictable. Unfortunately, there is a lack of studies related to the observed climate change in this area as well as a lack of projections of temperature and precipitation. Mitigation seeks energy efficiency requalification, renewables, and urban mobility, whereas adaptation will consist in water management, environmental resilience, conservation, and valorisation.

Gorenjska, Osrednje Slovenska, Primorsko Notranjska, Obalno Kraška, Goriška are the regions in Slovenia part of the SECAP program area. There is specific data only for the Gorenjska region as the energy and environmental agencies collect information only at national scale. The Gorenjska region has consumed 0,3 Mtoe of energy in 2016, mainly in the industry, residential, and transport sector, and emitted 1 $MtCO_2$. The climate is expected to be on average 0,8 °C warmer in the next two decades, leading to more frequent heat waves, increase precipitation, extreme precipitation events, floods, and decrease in snowfall.

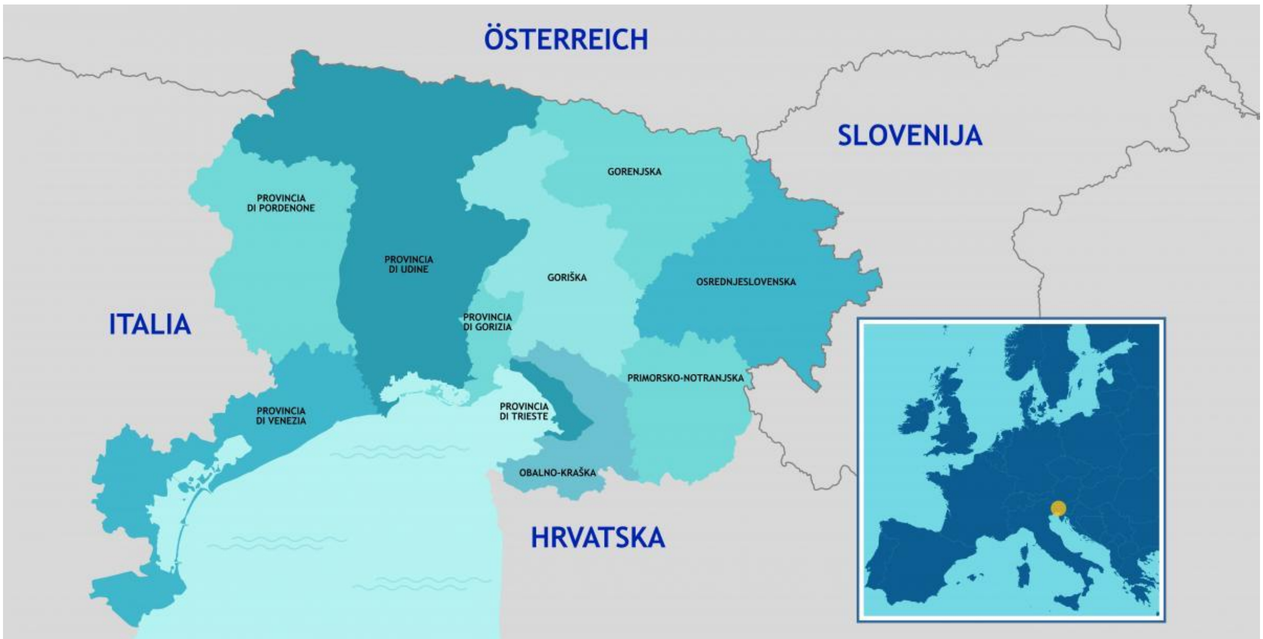


Figure 1. Map of the program area of project SECAP.

2 Climate change

2.1 Observed change and their causes

According to the 2014 Fifth Assessment Report of the Intergovernmental Panel on Climate Change [1], a review of the most recent and relevant climate change studies and world's most important and recognized document on this matter, the unequivocal changes in the climate system observed since 1950 are unprecedented over millennia. The temperature of the Earth surface has increased on average 0,85 °C since 1880 (Figure 2), with a noticeable spike in the last three decades. This temperature anomaly is having strong repercussions on the Earth's natural systems: oceans are warming, ice sheets are losing mass and the permafrost is disappearing. Global sea level has already risen by 0,19 m. Evaporation and precipitation have intensified in some areas, leading to extreme events such as floods and cyclones, whereas heat waves, droughts and wildfires have been observed in other areas. Many terrestrial, freshwater and marine species have shifted their geographical ranges, seasonal activities, migration patterns, abundance and species interaction. Many species have gone extinct. Almost all ecosystems are showing a high degree of vulnerability and exposure and are considered endangered [1].

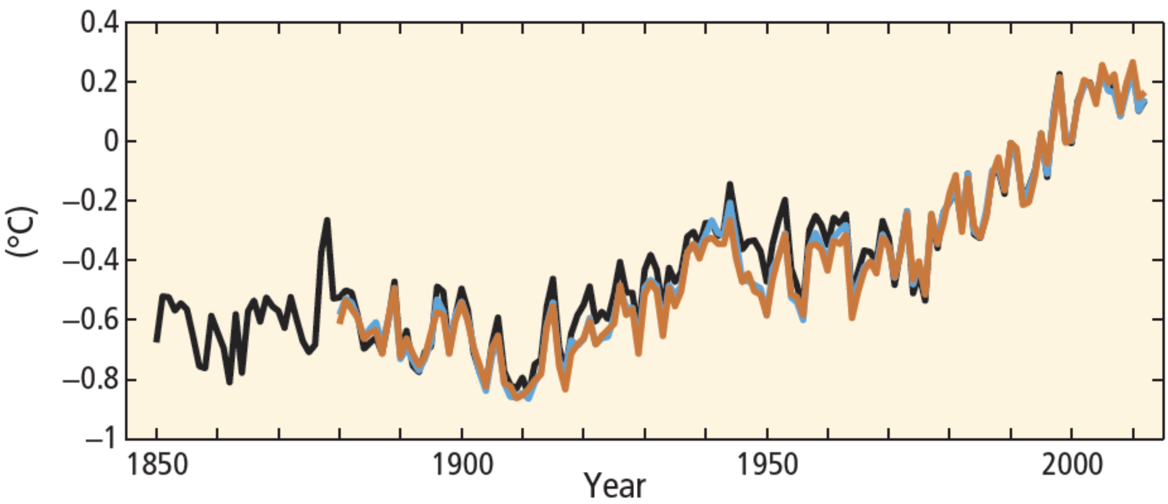


Figure 2. Global averaged combined land and ocean surface temperature anomaly [1].

The increase in surface temperature and climate change are caused by high concentrations of atmospheric GHG that trap solar radiation causing excessive warming. Anthropogenic GHG emissions, starting massively at the beginning of the industrial era, have increased significantly in the last decades (Figure 3) [1]. Concentration of the main GHG - carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) - are unprecedented in the last 800.000 years. Around 2.000 $GtCO_2$ have been released by human activity since 1850 (Figure 4), 40% of which is still present in the atmosphere (some 900 $GtCO_2$), while the rest is stored in plants and soil or absorbed by oceans (resulting in ocean acidification). Atmospheric concentration of CO_2-equivalent (CO_2-eq) have reached 415 ppm (parts per million) [1].

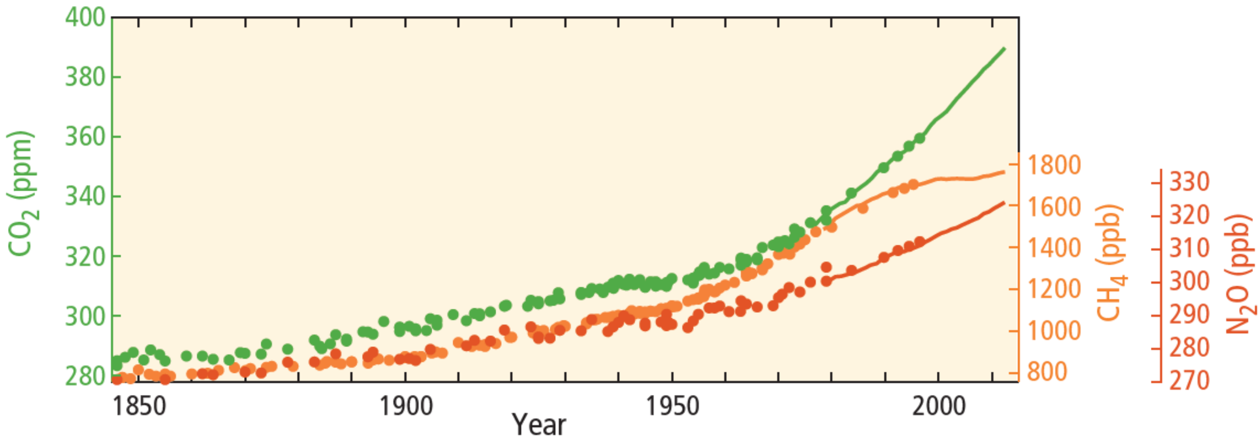


Figure 3. Global averaged GHG concentrations [1].

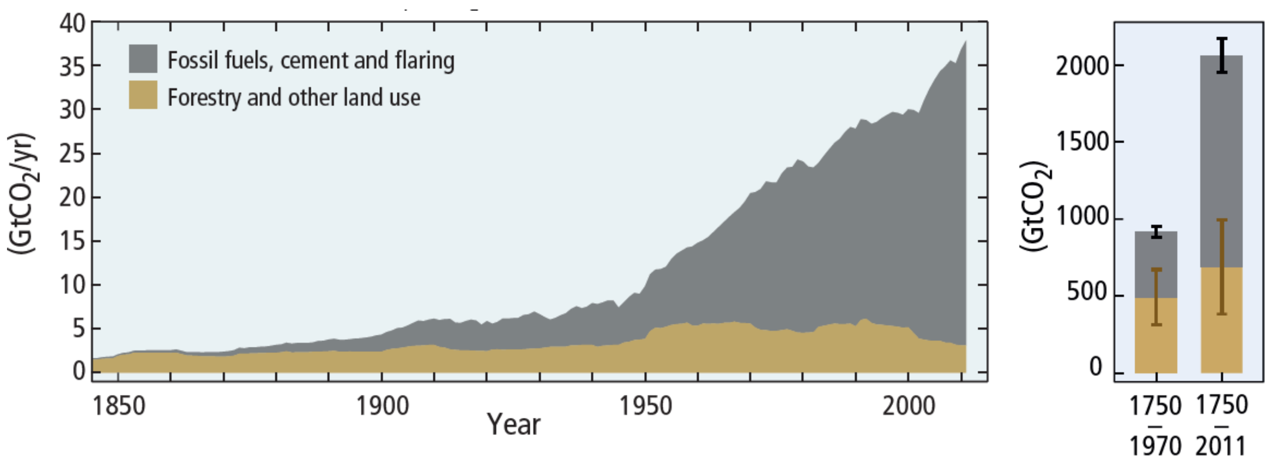


Figure 4. Global anthropogenic CO_2 emissions since 1850 (left); cumulative CO_2 emissions (right) [1]

2.2 Climate change scenarios, risks and impacts

Population growth, economic activity, lifestyle, energy consumptions, land use patterns, technology and climate policies are the most important drivers of GHG emission. The IPCC uses these drivers to create Representative Concentration Pathways (RCPs) and make projections of future GHG emissions, air pollution and land use. The RCPs include a mitigation scenario (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6.0) and a high emission scenario (RCP8.5) also defined as business as usual. These scenarios are useful in making predictions about possible surface temperature variations to the year 2100, as shown in Figure 5.

Assuming that there will be no unexpected natural events (such as a major volcanic eruption or change in solar irradiance), the IPCC predicts an increase in surface temperature by the end of the century (2081-2100) of 0,3 °C to 1,7 °C (RCP2.6) and 2.6 °C to 4,8 °C (RCP8.5) in comparison to the referent, 1986-2005 period, while the Artic region will warm more rapidly than the global average (Figure 6). These conditions will lead to fewer cold and more frequent and longer hot extremes, including intense heat waves. Concerning precipitations, the changes will not be uniform: according to RCP8.5, many mid-latitude dry and subtropical regions will experience a decrease in precipitation, leading to severe draughts and wildfires, whereas mid-latitude wet regions will see an increase in precipitation, extreme precipitation events, flooding and cyclones (Figure 6).

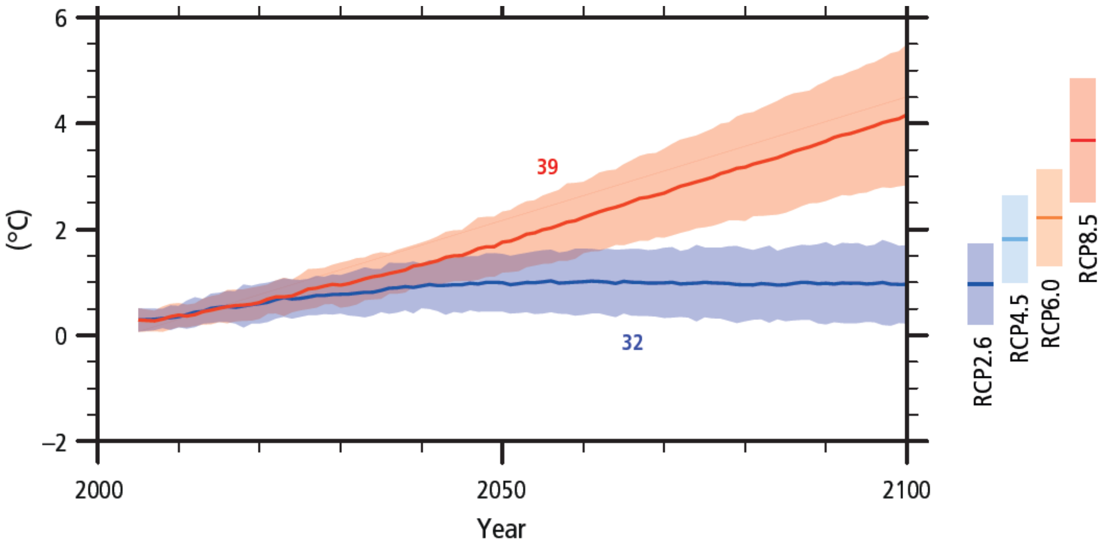


Figure 5. Global average surface temperature change relative to 1986-2005 period (left); mean over 2081-2100 (right) [1].

The oceans will continue to warm and could double in acidity. Global glacier volume (excluding Greenland and Antarctic ice sheets) could decrease by 85%, near surface permafrost by 81% and the Arctic Ocean could be ice free by mid-century. RCP8.5 estimates a rise in sea water level of more than 0,8 m [1].

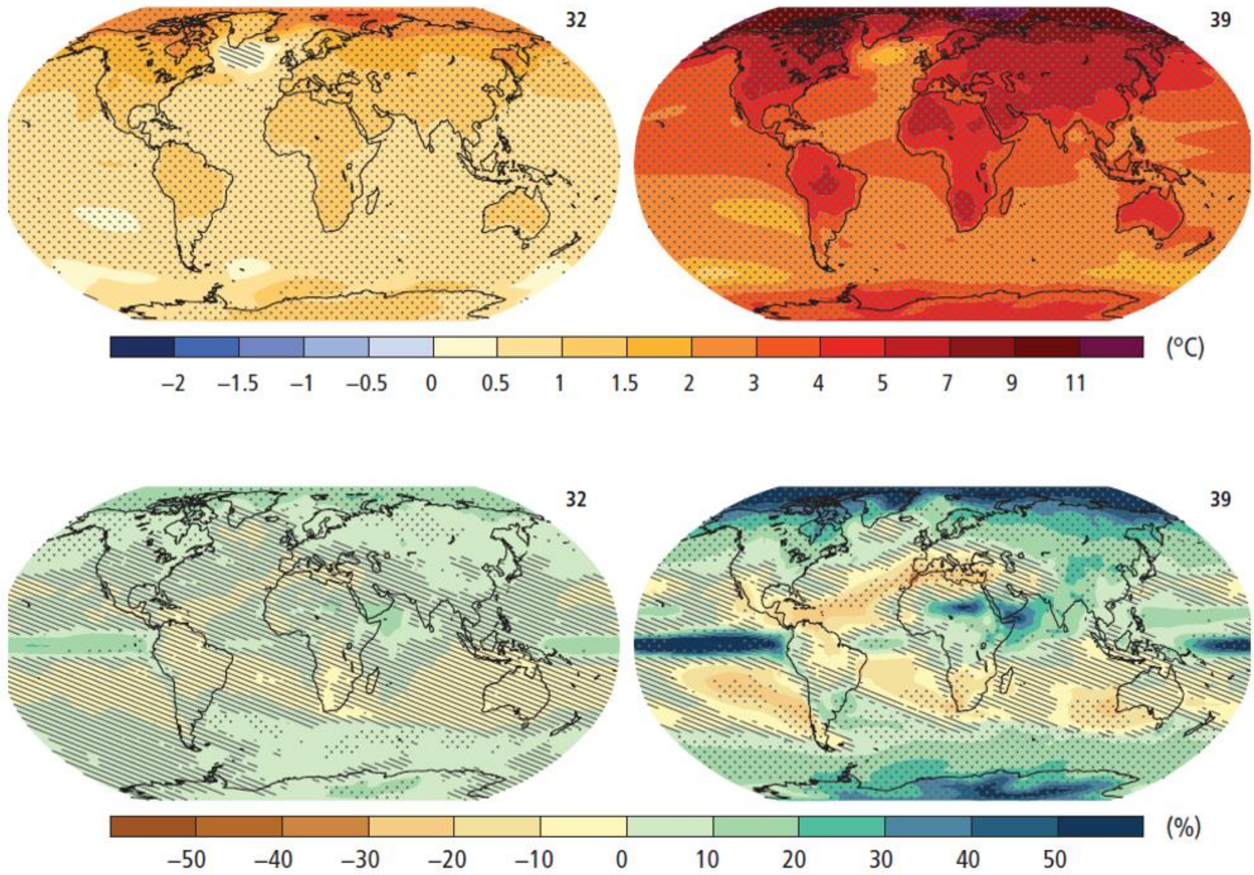


Figure 6. Change in average surface temperature (above) and average precipitation (below) for RCP2.6 (left) and RCP8.5 (right) to 2081-2100 in comparison to 1986-2005 period [1].

Climate change impacts will create severe challenges. We will face serious problems in guaranteeing food and water security. Global marine biodiversity and redistribution will radically change, and fisheries productivity with it. Wheat, rice and maize production is expected to be negatively impacted, especially in regions of water scarcity. Renewable surface water and groundwater in most dry subtropical regions will be reduced, intensifying competition for this resource. Health quality will decrease, especially in developing, low-income countries. In urban areas, people, assets, economies and ecosystems will have to endure air pollution, heat stress, droughts, water scarcity, but also extreme precipitation, flooding, landslides, and storm surges. People lacking basic infrastructure will be particularly at risk. As temperature increases, so does the aggregate economic loss. Although it is difficult to estimate the aggregated global economic impacts, it is expected that climate change will slow economic growth, make poverty reduction more difficult, create poverty traps, and increase food insecurity. People displacement will also increase [1].

2.3 Future pathways for mitigation and adaptation

Substantial cuts in GHG emission over the next decades can limit surface warming and reduce the impacts derived from climate change. In the *business as usual* scenario (RCP8.5), so without additional mitigation efforts, atmospheric concentrations of CO_2-eq will reach >1.000 ppm and temperature could consequently increase to +4,8 °C (up to +7,8 °C including climate uncertainty) by 2100 in comparison to the pre-industrial era. Vice versa, strong mitigation efforts could limit atmospheric concentrations of CO_2-eq to 450 ppm, and global warming below 2 °C relative to pre-industrial levels (Figure 7). This latter scenario can be achieved only if global GHG emission are reduced by 40% to 70% by 2050, and to near (or below) net carbon zero by 2100. Higher emissions than 500 ppm will have to rely on Carbon Dioxide Removal (CDR) technologies and afforestation if global warming is to be limited below 2 °C [1].

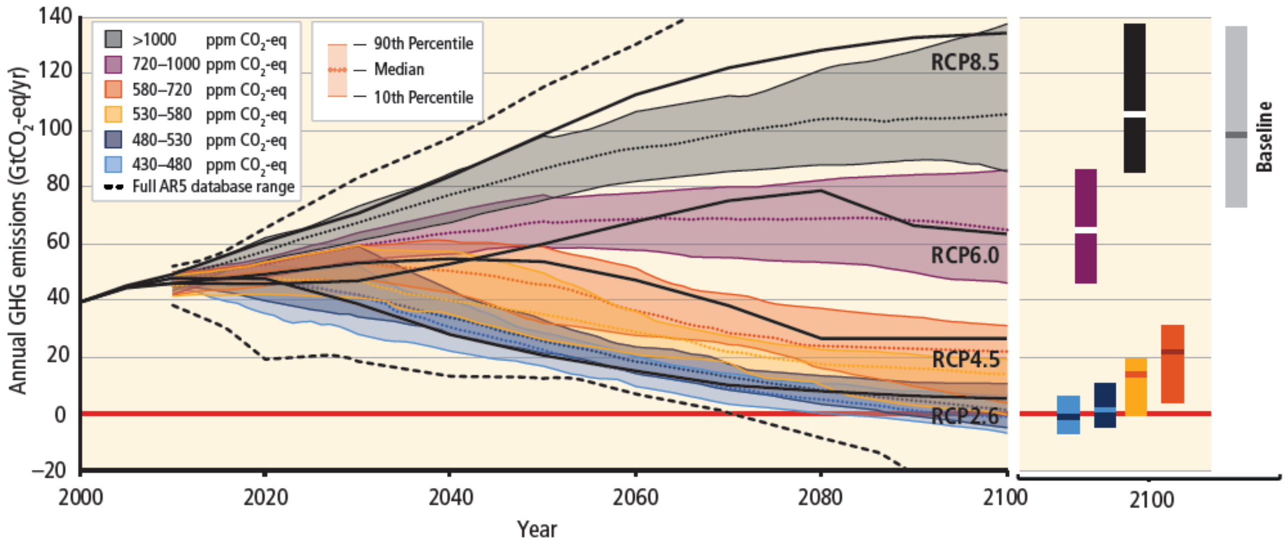


Figure 7. GHG emission pathways scenarios to 2100 [1].

Figure 8 shows the sectors that contribute the most to GHG emissions, and the baseline and mitigation scenarios to 2030, 2050 and 2100. Decarbonisation of electrical generation and improvements in energy efficiency will be crucial in reaching <450 ppm CO_2-eq goals. In comparison to today's levels, CO_2-dependent energy supply sector needs to decrease more than 90% by 2040-2070, and low carbon electricity (renewable, bioenergy and nuclear) needs to increase up to 80% by 2050. In the near-term, reduction in energy demand is an important factor of a cost-effective mitigation strategy, allowing for flexibility in adoption of mitigation actions. Apart from the energy sector, improvement in forestry management (reduction in deforestation and afforestation) and better agricultural practices (cropland and land management, and restoration or organic soil) will have a major role. Also, behaviour, lifestyle and culture have a considerable influence on both how people use energy and how land is managed, therefore changes in energy consumption patterns, energy savings, dietary change and reduction in food waste can significantly lower GHG emissions [1].

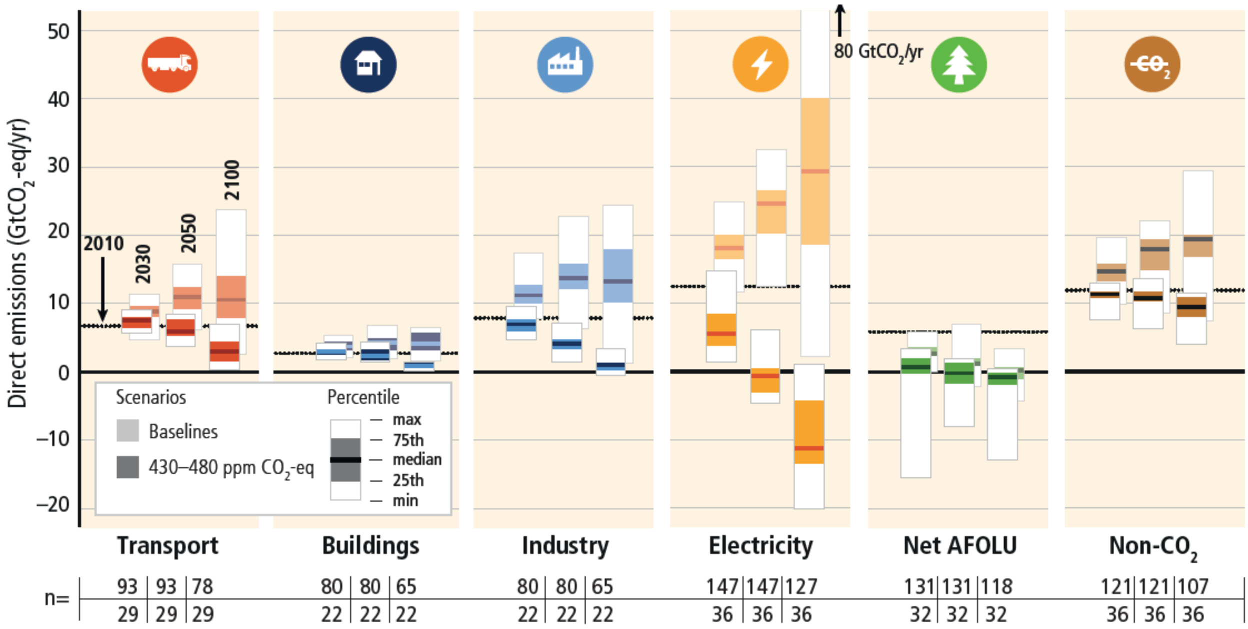


Figure 8. Direct CO_2 emissions by major sectors, and non-CO_2 emissions, for baseline and mitigation scenarios (AFOLU stands for “agriculture, forestry and other land use”) [1].

Finally, well-designed systematic and cross-sectoral mitigation strategies are more cost-effective in cutting emissions than dealing individually with each sector. However, mitigation can succeed only if done globally. As different countries will face different challenges and circumstances, and have different capabilities for mitigation, cooperative actions and international collaboration are required for an effective response.

However, to effectively combat climate change, mitigation measures need to be combined to adaptation practices. Adaptation is essential because even if we were to completely stop GHG emissions, the effects of temperature increase and climate change will be felt for years to come. Adaptation can contribute to the well-being of populations, the security of assets and the maintenance of ecosystem goods, functions and services. Adaptation is place- and context-specific and is achieved by reducing the vulnerability and exposure of people, assets and ecosystems to the changing climate. For an adaptation plan to be successful, adaptation measures must be included into the planning (including policy design) and decision-making process of a country, in order to promote development, disaster risk reduction, and build adaptive capacity. These measures must go in the direction of a country’s vision, approaches, circumstances and priorities, taking into consideration societal values, objectives and risk perception. It is also convenient to consider indigenous, local and traditional knowledge systems and practices, as it could potentially benefit the selection of the appropriate adaptive response. In addition, adaptation measures must be adopted both individually (citizen) and collectively (government). National governments can coordinate adaptation efforts regionally and locally (e.g. by protecting vulnerable groups, supporting economic diversification, providing information, policy and legal framework, and financial support), whereas citizens and private sectors can scale up adaptation of communities, households, civil society, manage risk information and financing. Adaptation options exist for all regions and sectors, although the potential and approaches vary significantly. Some adaptation examples are shown in Table 1. Importantly, there are multiple co-benefits, synergies and trade-offs between mitigation and adaptation responses, with some of them being: i) improved energy efficiency and cleaner energy systems which lead to better air quality, less climate altering gasses and more health benefits; ii) reduced energy and water consumption in urban areas through greening and water recycling; iii) sustainable agriculture and forestry iv) protection of ecosystems for carbon storage and other ecosystem services.

Unfortunately, there are also many barriers to adaptation, with the most common being limited financial or human resources, low degree of competence, uncertainty in climate predictions and projected impacts, different values or perceptions of risks, absence of appropriate leaders and advocates, limited research, observation and monitoring of climate indicators. These barriers can significantly increase the rate and magnitude of climate risks as poor planning and implementation, prioritizing short-term over long-term targets and lack of anticipation can result in maladaptation and increase the vulnerability and exposure of systems [1].

Overlapping Approaches	Category	Examples
Vulnerability & Exposure Reduction through development, planning & practices including many low-regrets measures	Human development	Improved access to education, nutrition, health facilities, energy, safe housing & settlement structures, & social support structures; Reduced gender inequality & marginalization in other forms.
	Poverty alleviation	Improved access to & control of local resources; Land tenure; Disaster risk reduction; Social safety nets & social protection; Insurance schemes.
	Livelihood security	Income, asset & livelihood diversification; Improved infrastructure; Access to technology & decision-making fora; Increased decision-making power; Changed cropping, livestock & aquaculture practices; Reliance on social networks.
	Disaster risk management	Early warning systems; Hazard & vulnerability mapping; Diversifying water resources; Improved drainage; Flood & cyclone shelters; Building codes & practices; Storm & wastewater management; Transport & road infrastructure improvements.
	Ecosystem management	Maintaining wetlands & urban green spaces; Coastal afforestation; Watershed & reservoir management; Reduction of other stressors on ecosystems & of habitat fragmentation; Maintenance of genetic diversity; Manipulation of disturbance regimes; Community-based natural resource management.
	Spatial or land-use planning	Provisioning of adequate housing, infrastructure & services; Managing development in flood prone & other high risk areas; Urban planning & upgrading programs; Land zoning laws; Easements; Protected areas.
Adaptation including incremental & transformational adjustments	Structural/physical	***Engineered & built-environment options***: Sea walls & coastal protection structures; Flood levees; Water storage; Improved drainage; Flood & cyclone shelters; Building codes & practices; Storm & wastewater management; Transport & road infrastructure improvements; Floating houses; Power plant & electricity grid adjustments.
		Technological options: New crop & animal varieties; Indigenous, traditional & local knowledge, technologies & methods; Efficient irrigation; Water-saving technologies; Desalinisation; Conservation agriculture; Food storage & preservation facilities; Hazard & vulnerability mapping & monitoring; Early warning systems; Building insulation; Mechanical & passive cooling; Technology development, transfer & diffusion.
		Ecosystem-based options: Ecological restoration; Soil conservation; Afforestation & reforestation; Mangrove conservation & replanting; Green infrastructure (e.g., shade trees, green roofs); Controlling overfishing; Fisheries co-management; Assisted species migration & dispersal; Ecological corridors; Seed banks, gene banks & other *ex situ* conservation; Community-based natural resource management.
		Services: Social safety nets & social protection; Food banks & distribution of food surplus; Municipal services including water & sanitation; Vaccination programs; Essential public health services; Enhanced emergency medical services.
	Institutional	***Economic options***: Financial incentives; Insurance; Catastrophe bonds; Payments for ecosystem services; Pricing water to encourage universal provision and careful use; Microfinance; Disaster contingency funds; Cash transfers; Public-private partnerships.
		Laws & regulations: Land zoning laws; Building standards & practices; Easements; Water regulations & agreements; Laws to support disaster risk reduction; Laws to encourage insurance purchasing; Defined property rights & land tenure security; Protected areas; Fishing quotas; Patent pools & technology transfer.
		National & government policies & programs: National & regional adaptation plans including mainstreaming; Sub-national & local adaptation plans; Economic diversification; Urban upgrading programs; Municipal water management programs; Disaster planning & preparedness; Integrated water resource management; Integrated coastal zone management; Ecosystem-based management; Community-based adaptation.
	Social	***Educational options***: Awareness raising & integrating into education; Gender equity in education; Extension services; Sharing indigenous, traditional & local knowledge; Participatory action research & social learning; Knowledge-sharing & learning platforms.
		Informational options: Hazard & vulnerability mapping; Early warning & response systems; Systematic monitoring & remote sensing; Climate services; Use of indigenous climate observations; Participatory scenario development; Integrated assessments.
		Behavioural options: Household preparation & evacuation planning; Migration; Soil & water conservation; Storm drain clearance; Livelihood diversification; Changed cropping, livestock & aquaculture practices; Reliance on social networks.
Transformation	Spheres of change	***Practical***: Social & technical innovations, behavioural shifts, or institutional & managerial changes that produce substantial shifts in outcomes.
		Political: Political, social, cultural & ecological decisions & actions consistent with reducing vulnerability & risk & supporting adaptation, mitigation & sustainable development.
		Personal: Individual & collective assumptions, beliefs, values & worldviews influencing climate-change responses.

Table 1. Adaptation practices in different social sectors [1].

3 European Union policies on mitigation and adaptation

3.1 The EU energy framework

Today, the EU collectively emits only 12% of total global GHG emissions [2], but ever since the issue of climate change arise, it has been at the frontline of mitigation and adaptation. In 2007, with the “20-20-20” initiative, the EU committed to reduce, by 2020, the total GHGs emissions by 20% (in comparison to 1990 levels), increase the share of renewables to 20%, and improve energy efficiency by 20% [3]. As part of this plan, the EU 2020 Climate and Energy Package was adopted in 2009. In October 2014. EU leaders agreed to revise the 2020 plan, and set the EU 2030 Climate and Energy Framework, with an ambitious goal to reduce, by 2030, GHG emissions by 40%, and increase the share of renewables and energy efficiency by 27%. These values were revised at the end of 2018 to 32% for renewables and 32,5% to energy efficiency with the Clean Energy for all Europeans Package [3]. This is the new energy rulebook central to implement the EU Energy Union, one of the key priorities of the 2030 Climate and Energy Framework. The rulebook was proposed in 2016, approved by the Council and European Parliament in 2018/early 2019, and set to enter in force by mid-2019. Member states will have between one to two years to turn these directives into national law. The EU Energy Union turns around five closely related and mutually reinforcing dimensions:

1. security, solidarity and trust;
2. an integrated internal energy market;
3. energy efficiency;
4. climate action and decarbonisation of the economy;
5. research, innovation and competitiveness.

These five dimensions support the diversification of the EU energy sources, suppliers and routes, and promotes solidarity and cooperation between the member states to ensure energy security in the EU; it removes barriers and builds the necessary infrastructure to enable the free flow of energy between EU borders; it improves energy efficiency and aims to reduce energy imports, lower emission and promote clean energy job opportunities and sustainable growth; it commits to renewables and supports research and innovation in low-carbon and clean energy technologies.

3.2 GHG emissions in the EU

According to the 2017 European Court of Auditors (ECA) Landscape Review – EU action on energy and climate change [2], the GHG emissions in the EU have seen an almost constant decline since

1990, reaching an all-time low of -22,4% in 2016 (compared to 1990), which decreased to -21,9% in 2017, but still within the 2020 targets (Figure 9). GHG emissions decreased in most sectors, except for domestic and international transport, with the largest reductions occurring in electricity and heat production, manufacturing industries, construction, and the residential sector.

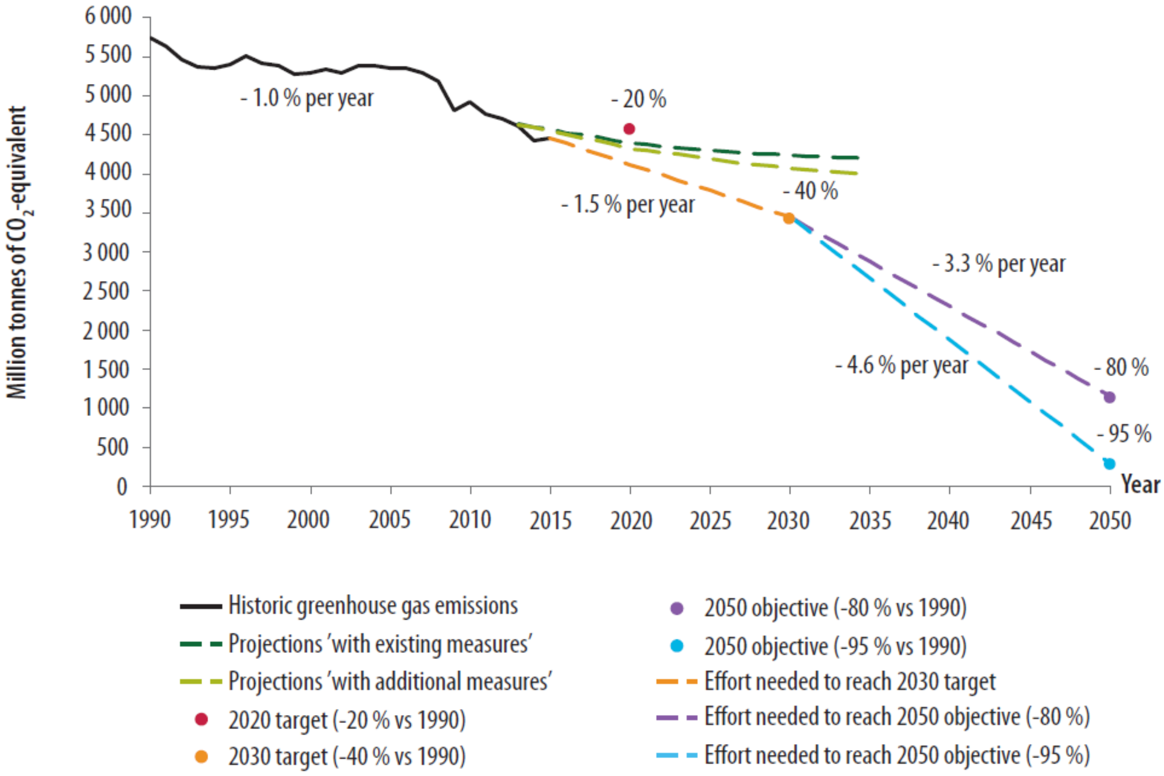


Figure 9. The EU GHG emissions since 1990 including the 2020, 2030 and 2050 objectives [2].

The main instruments used by the EU to reduce GHG emissions are the ETS and the Effort Sharing Decision [2]. The ETS sets a limit to the permitted annual GHG emissions per company/installation, a limit that decreases year by year, guaranteeing that total GHG emissions are constantly falling. The limit is set in form of allowances, credits that represent the right to emit one tonne of CO_2-eq. Within the annual limit, companies/installations can either receive, buy or sell emission allowances, creating a carbon trading system also known as “cap and trade”. Allowances can be auctioned by companies/installations that exceed the annual limit, or sold by the ones that stay under the emission cap. The annual emission limit follows a linear regression of -1,74% per year guaranteeing that the mitigation targets are met [2].

The core element of the ETS system is the price of carbon. As the emission limit increases, scarcity of the allowances drives up the price of carbon and creates a strong tendency for decarbonisation, energy efficiency or investments in low-carbon technologies (such as renewables). For this system to work, the price per allowance needs to be sufficiently high. In 2011 the Commission projected the price per allowance of 40 euro in 2020, 100 euro in 2030, and 250 euro in 2050 [2]. However, the price per allowance has fallen from 30 euro in 2008 to 5 euro in 2017, which is much lower than the Commission has projected. The reason for the decline in price was a surplus of available allowances (+1,8 billion of them) that exceeded the market demand. The oversupply was due to the 2008 economic recession, and to the fast growth of energy efficiency and renewable policies. To restore the market stability, the Commission has recently retracted 900 million allowances [2].

In addition to the ETS, the EU has adopted the Effort Sharing Decision (ESD) for some sectors that are not covered by the ETS [2]. These sectors include transport (except aviation and international shipping), agriculture and forestry, building, waste, and some industries. The ESD sets national emission targets based on GDP per capita. Countries that have a higher GDP per capita will have higher emission binding targets, while poorer countries will have lower binding targets. This to support the economic growth of poor countries that is often associated with increasing emissions rates. In 2018 the ESD has become ESR, which adopts the same GDP per capita criteria and sets the national binding targets to 2030. It is estimated that the ESR alone will cover 60% of total EU GHG emissions [2].

To monitor that objectives are met, the EU has created an internal emissions-reporting system that includes a compilation of member state GHG inventories, drawn up by the Commission, and quality checked by the European Environmental Agency in cooperation with Eurostat and the Commission Joint Research Centre. These inventories are reported annually to the UNFCCC and reviewed by international non-EU experts. A list GHGs emissions by member state is shown in Figure 10 for 2015 [2].

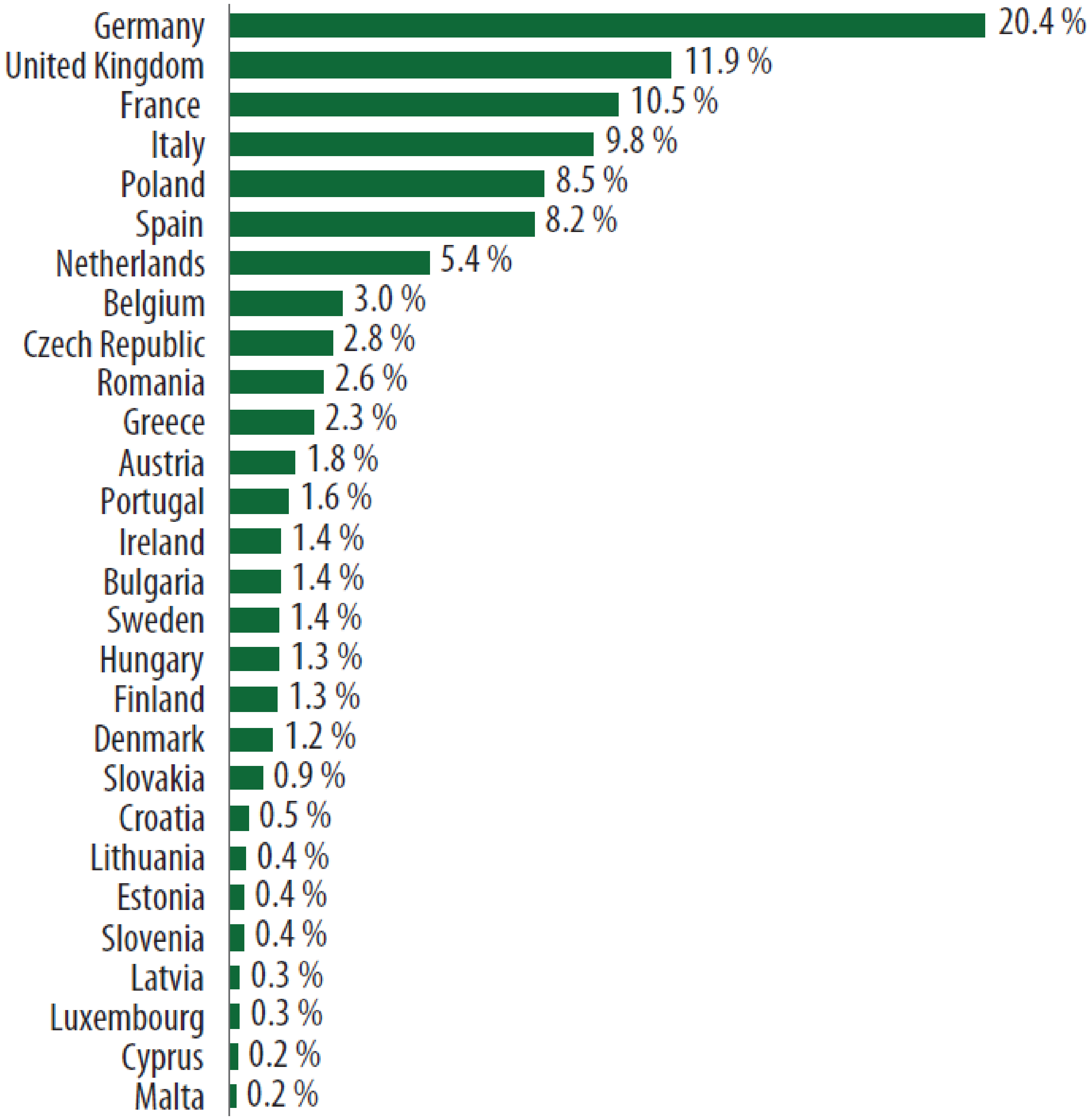


Figure 10. List of GHG emissions by EU member states in 2015 [2].

GHG emissions can either be classified by source or by sector (Figure 11) [2]. By source, in 2015, 79% of GHG emissions came from energy production and use, that includes electricity and heat generation, but also energy production in industry, buildings, transport and agriculture. The rest are indirect GHG emissions that come from agriculture (and forestry) and industrial processes, but also from waste management. By sector, 29% of GHG were emitted for energy supply, mainly from the generation of electricity and heat, which in the EU is produced primarily by the combustion of coal, gas and oil, but also from renewables and nuclear plants. Different member states have different energy production mixes and sources (Figure 12) [2] and are free to choose their own, provided that they respect the national emission limits. This also explains the uniformity in the challenges that different countries face to meet the reduction targets.

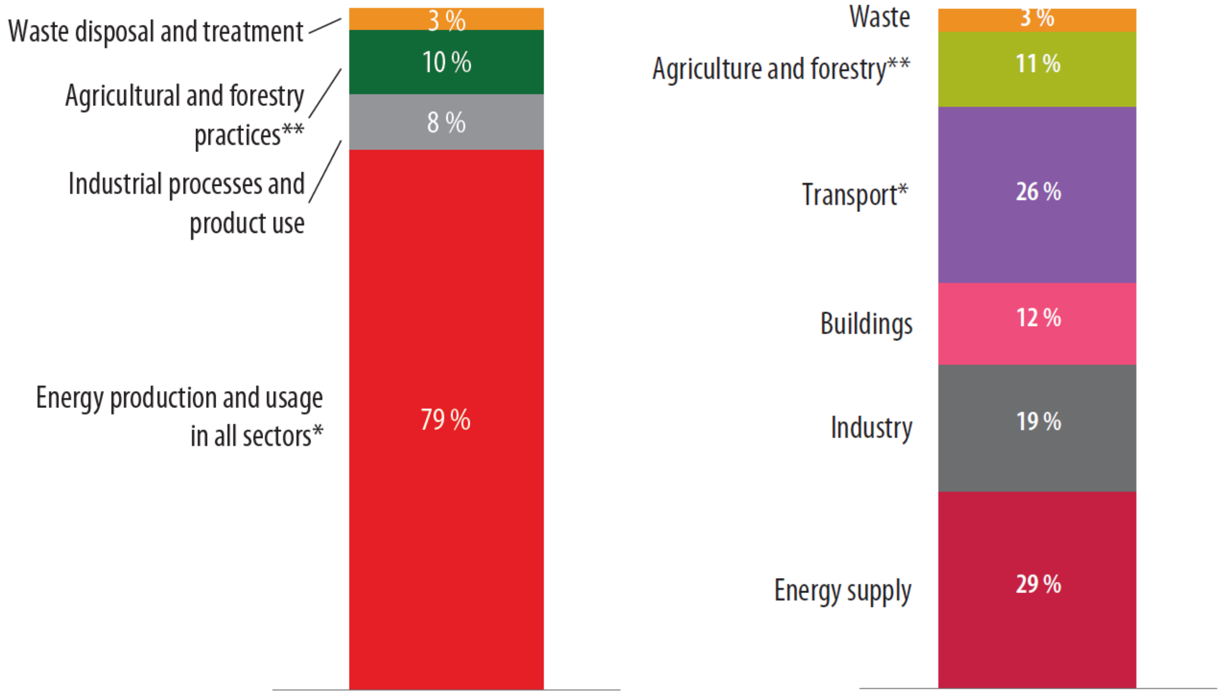


Figure 11. Total EU GHG emissions by source (left) and by sector (right) in 2015 [2].

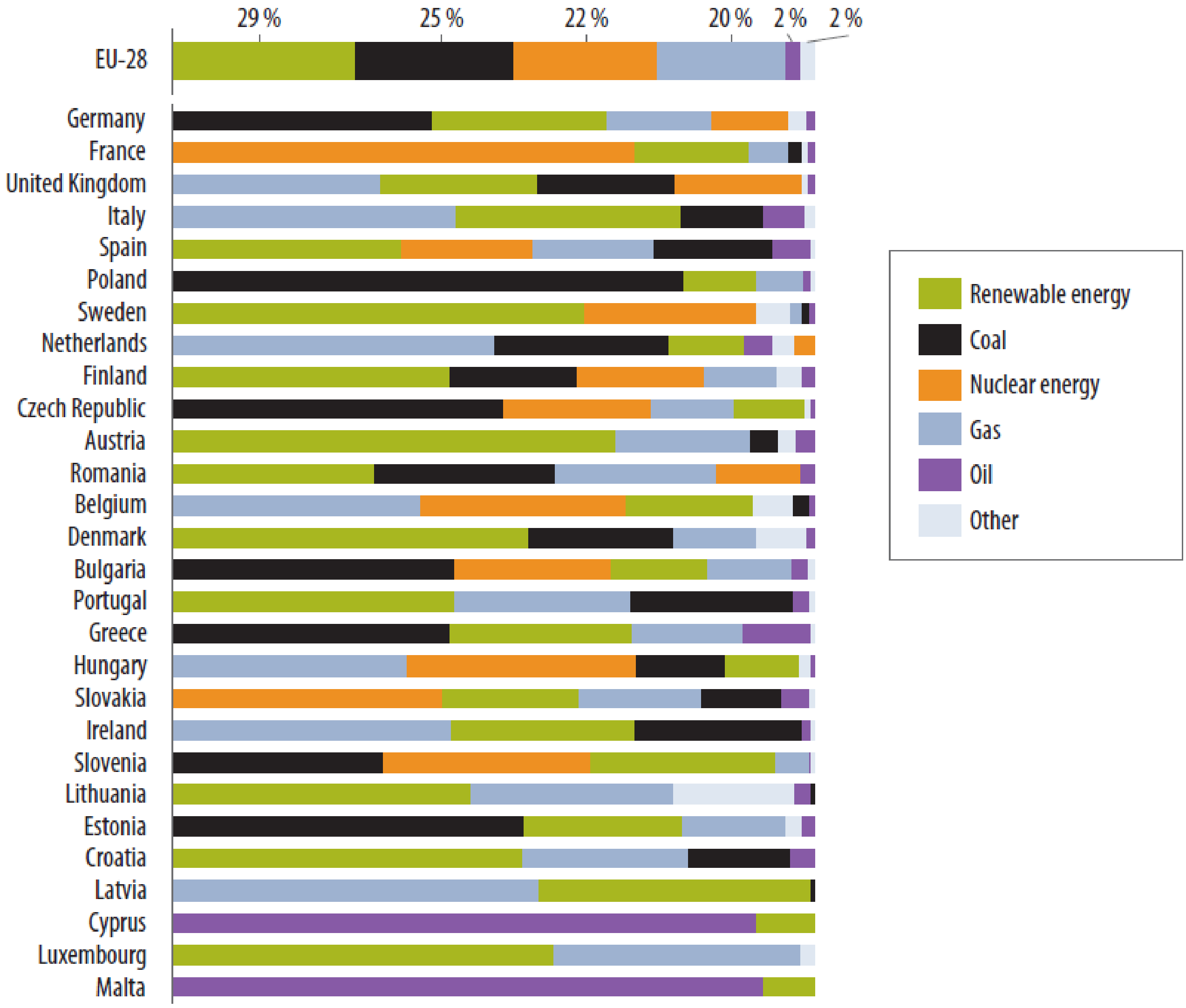


Figure 12. Energy mix by EU member state in 2015 [2]

Coal combustion, the process that emits the highest amounts of GHGs, has been steadily decreasing since the early 1950s, when 90% of electricity and heat generation was obtained from this energy source. Coal is an appealing energy source, primarily because of its widespread availability, low price, and easy utility, all factors that decrease a country's dependence on foreign energy imports. The situation has changed over the years, and in 2015 only 25% of energy came from coal (Figure 13) [2]. Similarly, the share of natural gas, a resource primarily used for production of heat, has experienced a sharp decline, with about 20% of share used in 2015 (Figure 13). The use of nuclear power has changed very little in the last decades. In 2015 it accounted for 22% of electricity and heat generation, but it is a technology that releases no carbon in the process. 47% of total low-carbon electricity came from nuclear, produced by 129 active nuclear reactors across the EU [2]. However, due to the high maintenance costs (related primarily to nuclear waste management) and associated risks, many member states will shut down a significant part of their reactors by 2025. For instance, Germany is planning to completely phase out from nuclear by 2022 and France will reduce its dependence from this source of energy. On the contrary, other member states such as Hungary, Czech Republic and the UK will be building new nuclear plants [2].

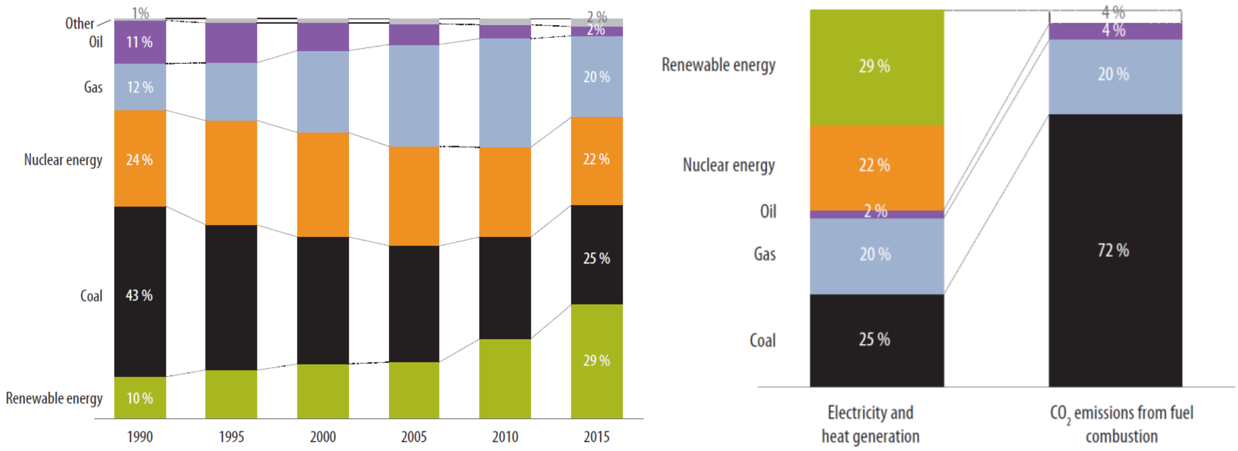


Figure 13. GHG emissions by energy source per year (left) and by main sectors in 2015 (right) [2].

In the last years a fast growth of renewables utilization has been observed (Figure 14) [2]. By 2020, 20% of the energy consumption should come from this energy source (32,5% by 2030), for both electricity and heat, and possibly for other sectors as well. In 2015, the EU has reached 16,7% of total renewable energy production (Figure 14) [2], which is still far from the aimed values. Fortunately, worldwide investments in renewables have produced, since 2009, a strong decrease in the price of these technologies (more than -85% for photovoltaics and more than -65% for wind energy) making them more affordable and competitive with traditional energy sources (Figure 14) [2].

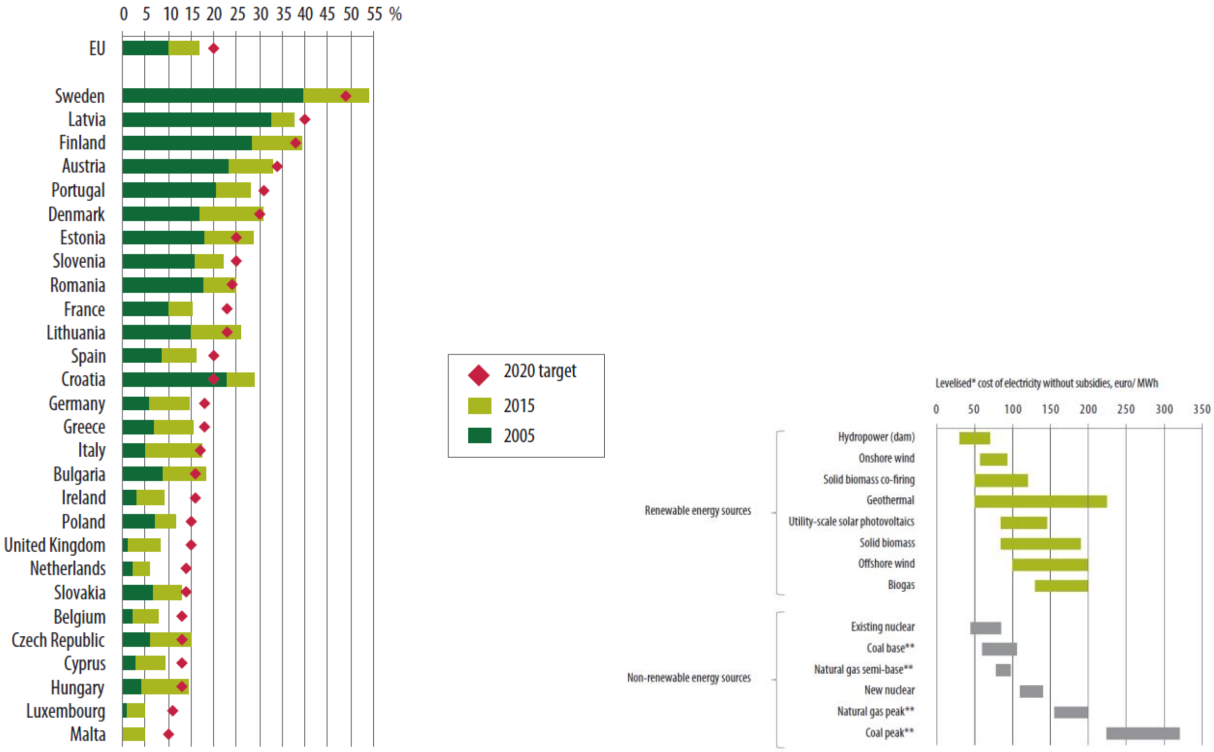


Figure 14. Percentage of energy coming from renewable sources by EU member state (left) and levelized cost of electricity (without subsidies) by energy source (right) [2].

The total GHG emitted by industries accounted for 19% of total EU GHG emissions in 2015 [2]. Around half of this comes from fossil fuel combustion, the remaining from industrial processes. The main reduction in this sector came at hand of the ETS (2/3 of the total), while the rest was covered by the ESD. This sector had also a big influence on energy efficiency improvements, since many of the big companies/installations are required to perform internal energy audits every few years [2].

Burning of natural gas for heating and cooking in buildings accounted for 12% of total EU GHG emissions [2]. In addition, considering that most of the energy supply (29% of emissions) is used by buildings. Interestingly, around 75% of buildings don't meet the EU energy efficiency standards. The EU has recently set strict rules for new public buildings that will have to respects a "nearly zero-energy standard" as of 2019. Apart from this, the EU has introduced energy-efficiency requirements and mandatory informative labelling on domestic products. It is estimated that these policies will deliver almost 10% of the energy efficiency by 2020 [2].

The transport sector accounts for 26% of total EU GHG emissions, 73% of which from road transport, mainly cars (Figure 15) [2]. This is the only sector where we have seen an increment in emissions in the last decades.

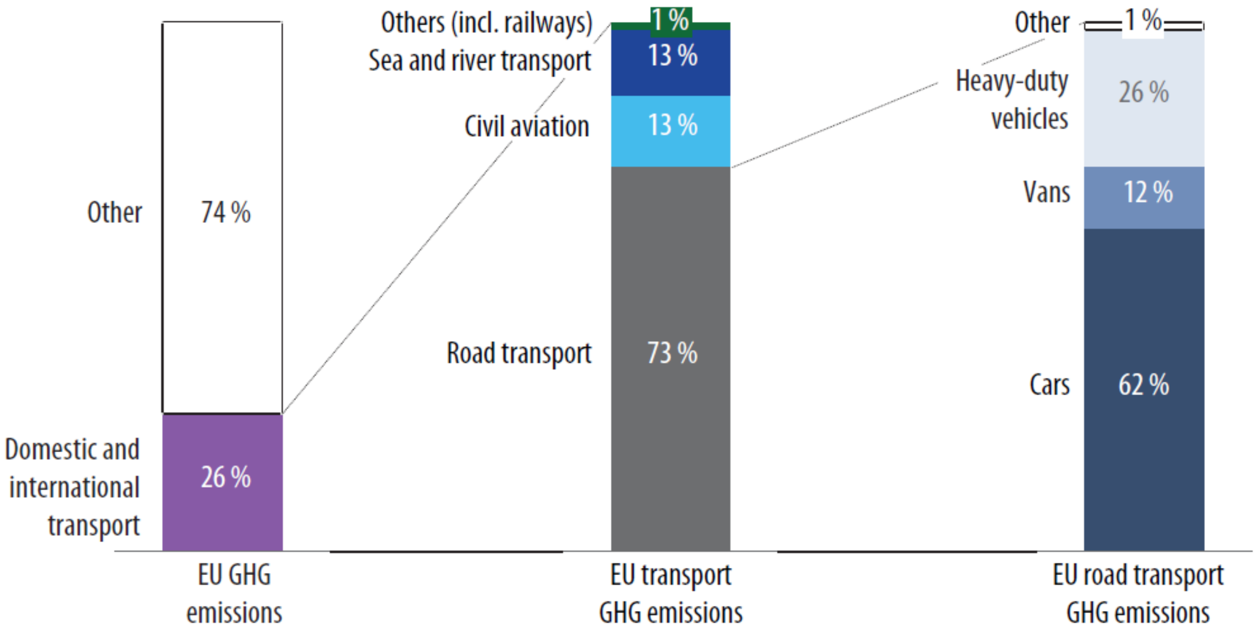


Figure 15. GHG emissions coming from the transport sector [2].

The EU has set emission standards for cars and vans. By 2020, emissions from new cars must not exceed 95 grams per km (-40% lower than in 2007), whereas vans will have to consume under 147 g/km (-19% from 2012) [2]. This will not be the case for heavy-duty vehicles – lorries, buses and coaches, which account for 14% of the total EU fleet, and emit 26% of road transport GHGs. In this subsector, just an activity of monitoring will be performed [2].

Aviation produced 3,4% of GHG emissions, 3,1% of which from flights between the EEA and non-EEA, the rest inside the EEA zone [2]. This way of transport is predicted to drastically increase, more than 70% by 2020 in comparison to 2005 levels. Emissions from flights within the EEA are covered by the ETS since 2012 [2]. On the contrary, international flights are covered by an agreement reached by the International Civil Aviation Organization (ICAO) in 2016, which implies that large airline companies must acquire international carbon credits to cover some of their emissions.

Maritime and inland waterways transport emitted 3,3% of EU GHG in 2015, mostly from international shipping between EU and non-EU ports [2]. International maritime transport covers 2,1% of global GHG emissions, with a 5-fold predicted increase in this subsector by 2050. Even if the exact fuel consumption of ships is known, this subsector is not currently regulated internationally, while in the EU an activity of monitoring and reporting has recently started, which may be the first step into reducing emissions. Water and rail transport release much less GHG per passenger or per tonne of freight than any other mean of transport (Figure 16). The EU supports and provides funding measures for the use of this transport system [2].Still, 76% of freight is currently moved by road.

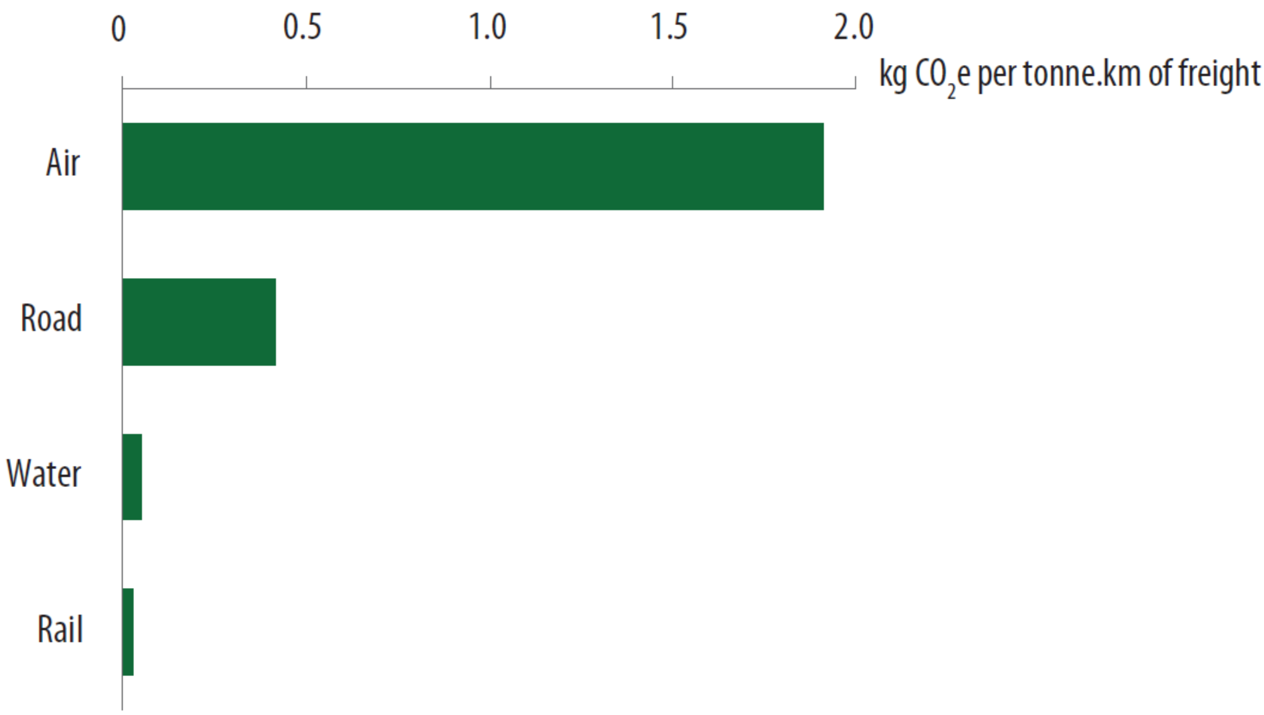


Figure 16. GHG emissions per tonne of freight by transport method [2].

The EU supports the use of renewable fuels, mostly biofuels and electricity. By 2020, 10% of the energy used in transport must come from renewable sources [2]. Development of infrastructure and policies for recharging and refuelling will be required across the member states. In addition, the use of low-carbon fuels, such as hydrogen or liquid petroleum gas will be encouraged. Currently, 70% of renewables used in transport are biofuels, mainly agricultural or forestry products, or industrial waste [2]. Biofuels are considered environmentally friendly because the carbon that is emitted during the combustion process was previously absorbed from the atmosphere when the biomass was being grown. This is true as long as the cumulative emissions of the life cycle of the biofuel (cultivation, transportation, transformation, feedstock or land change) don't exceed the amount of carbon captured from the atmosphere. Provided that these conditions are met, biofuels are an excellent substitute to traditional fuels. Indeed huge investments generated high revenues starting from the 2000s but then dropped a decade later as a huge debate prompted the EU to set sustainability criteria, setting the conditions biofuels must fulfil to enter in the 10% of renewable transport share [2].

Agriculture accounted for 11% of GHG emissions in 2015 (Figure 17), which is a 20% decrease since 1990 [2]. This improvement was due to better farm-management practices. The main GHGs coming out from this sector are CH_4 and CO_2, gasses that are released by the digestive system of livestock or by soil management.

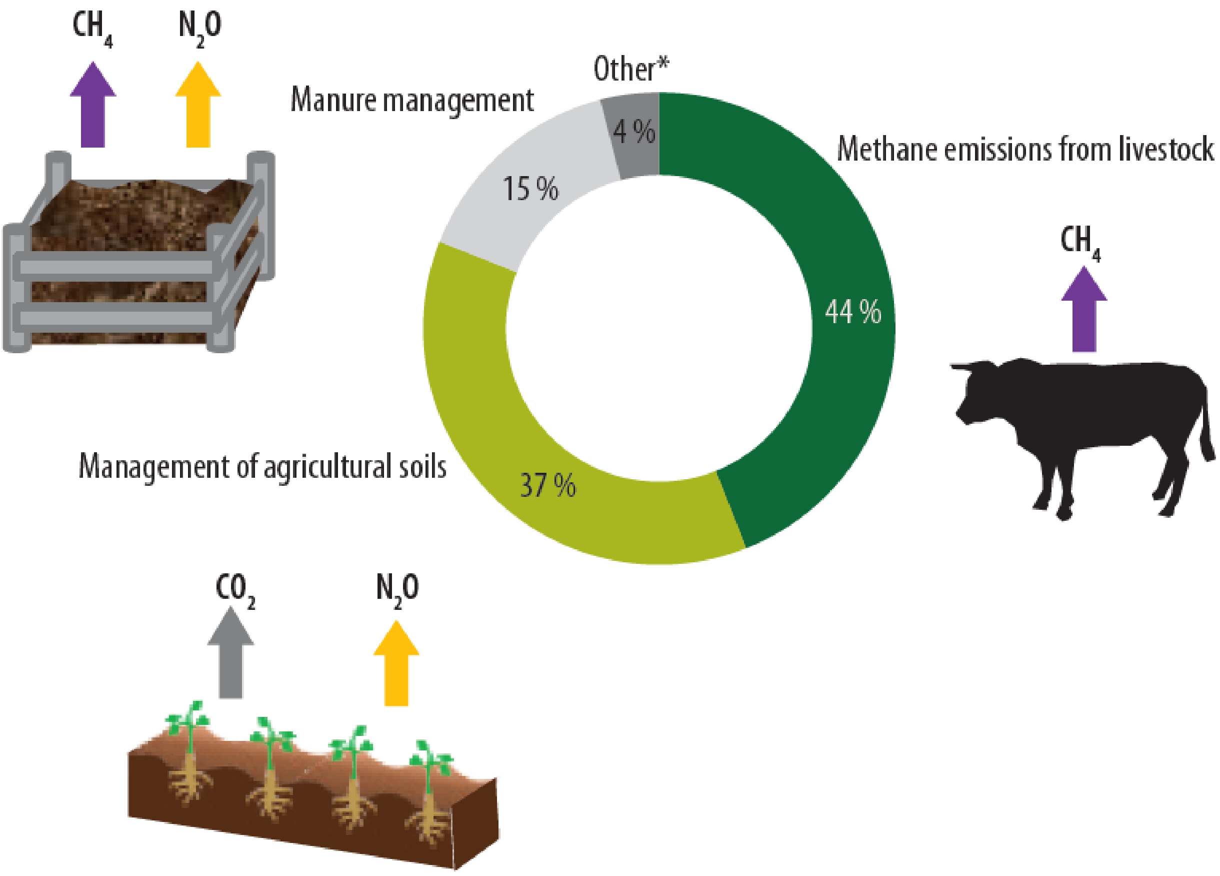


Figure 17. GHG emissions from agriculture [2].

A more efficient use of fertilisers or different cattle breeding techniques could hugely reduce GHG emissions in this sector, but since these solutions are costly, it is estimated that the contribution in GHG reduction will be only moderate. However, soil and vegetation could have a huge carbon storage potential. In 2015, an estimated 7% of EU GHG emissions have been absorbed by land (of the growth of forests and grassland mainly), and it has been suggested to add the emission reductions of this process in the ESR for 2030 [2].

Waste and waste management accounted for 3% of total EU GHG emissions in 2015. This is a 42% reduction from 1990 levels [2]. Changes in waste management, brought mostly by legislation, cut direct emission from landfill as well as indirect emissions by reducing waste or by recycling materials (which would otherwise be extracted or processed) from sectors such as energy supply, agriculture, manufacturing and transport.

3.3 Climate change in Europe

This chapter reviews the observed and projected climate change in Europe, as well as the impacts that might occur in different sectors according to the IPCC AR5 [4]. The report divides Europe in five distinct climate areas: Atlantic, Alpine, Southern, Northern and Continental (Figure 18). Most of the following research material comes from EU member states, as result of targeted funding and directives from the European Commission. Thus, in most of Europe, there has been a significant response to climate change, in terms of research, but also adaptation, with a vast majority of policies developed at international, national and local level, all of which can be found on the European Climate Adaptation Platform (Climate-ADAPT) catalogue.

Talking about non-climate trends first, European countries, although very different both demographically and economically, have seen a constant social and wealth growth in the last decades. Health and welfare have improved, mortality rates diminished, and populations have increased. Europe is one of the largest food and fiber supplier, as agriculture is one of the main sectors, and occupies large part of the land area in the continent (up to 35% of land area in some western countries) [4]. An intensification in the use of land came after 1945, when agricultural productivity increased significantly, bringing also negative effects on several land proprieties, such as reduced carbon sequestration, compromised nutrient cycling, soil degradation, water quality decrease, pollution, and eutrophication. In some southern countries more than 80% of water abstraction goes for agricultural practices. Soil degradation is a big problem, especially in the Mediterranean and Central-Eastern countries, in combination with fires and draughts is causing desertification in many regions. Urban development is increasing, especially in Eastern European countries, and will probably have a major impact on environmental quality [4].

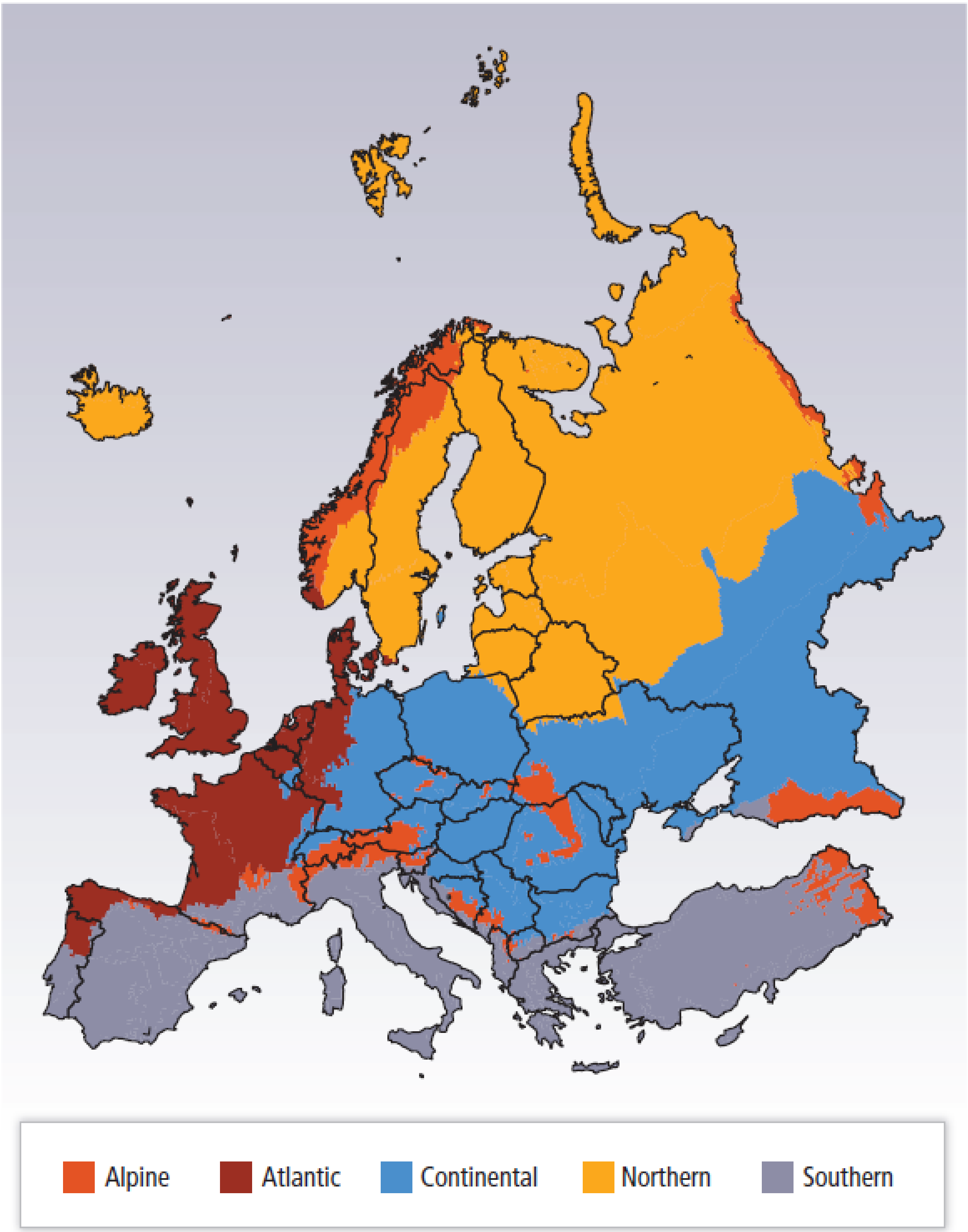


Figure 18. Classification of areas with similar climatic zone in Europe [4].

About climate trends, temperature has been increasing in Europe and has reached +1,3° average land surface temperature in comparison to 1850-1899 values [4]. Since 1950, high-temperature extremes (hot days, tropical nights, and heat waves) have become more frequent, while low-temperature extremes (cold spells and frost days) have become less frequent. Annual precipitation has increased in Northern Europe and decreased in Southern Europe, while mean wind speeds have diminished generally. Sea level has risen [4].

In its AR5, the IPCC shows future projections for temperature and rainfall in Europe based on different emissions scenarios (RCPs) and timescales [5]. It is expected that even in the most optimistic scenario, the RCP2.6, the climate in Europe will be much different from the one of today. It is generally agreed that warming will occur across all Europe, with strongest warming projected in the Southern region in summer, and Northern region in winter [4]. Precipitation will further decrease in Southern Europe, and increase in Northern Europe, especially in winter, whereas it is not yet agreed what will happen to the Continental region. Alpine regions will see less snow and more rain [4]. There will also be a marked increase in heat waves (Figure 19) and heavy precipitation (Figure 20), the latter most likely to occur in the Northern and Continental region. Wind speeds are projected to increase in the Central and Northern Region. Sea levels will follow global trends, which predicts a rise of 0,8 m by the end of the century in the worst scenario, accompanied with floods and strong storm surges along most of European coastlines [4]. Climate change will affect streamflow and river basins, although it is difficult to predict to what extent, and floods will be difficult to predict. Similarly, the analysis of draughts is uncertain, although it is commonly accepted that the Southern and Central region will be mostly affected [4].

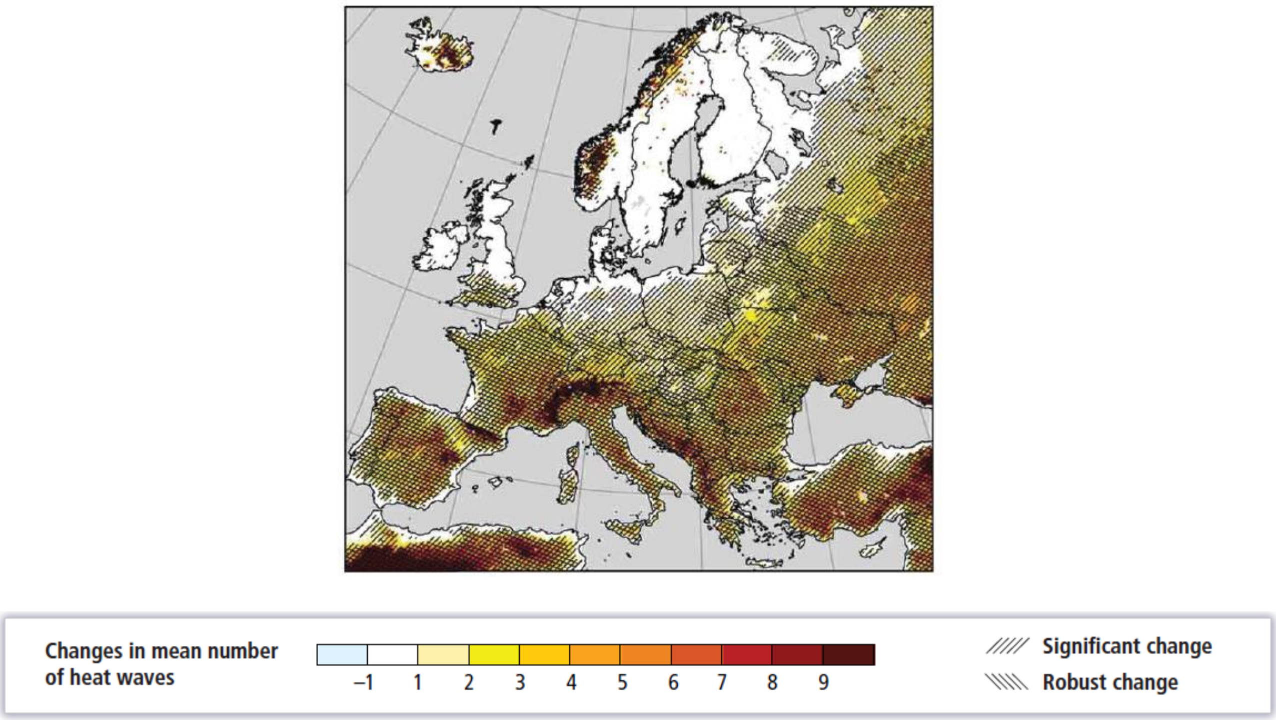


Figure 19. Changes in the mean number of heat waves in summer 2081-2100 compared to 1971-2000 according to the RCP8.5 in Europe [4].

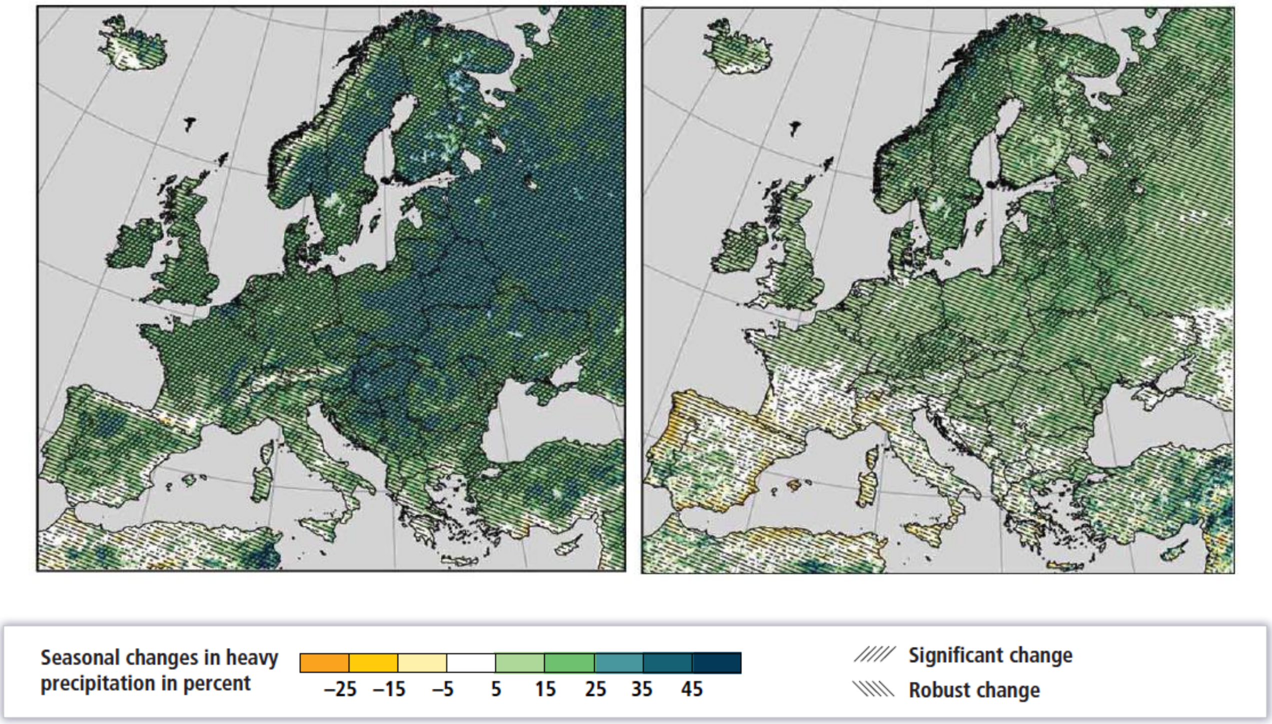


Figure 20. Changes in heavy precipitation in winter (left) and summer (right) to 2081-2100 compared to 1971-2000 period according to the RCP8.5 in Europe [4].

3.4 The EU climate framework

In 2005, the EU has suggested the introduction of adaptation measures and adopted the “White Paper” in 2009, from which derives the **EU adaptation strategy** [6], released in 2013.

The strategy has set eight objectives:

1. Encourage member states to adopt adaptation strategies
2. Provide LIFE programmes of funding to support capacity building and adaptation actions
3. Introduce adaptation in the Covenant of Mayors
4. Bridge the knowledge gap
5. Develop a platform to share adaptation practices (Climate-ADAPT)
6. Enable the climate proofing of agricultural, cohesion and fishery policies
7. Support more resilient infrastructure
8. Promote insurance and finances for investments in adaptation measures

According to the 2018 Report from the Commission to the European Parliament and the Council on the Implementation of the EU Strategy on Adaptation to Climate Change [7], although not all objectives have been entirely fulfilled, a substantial progress has been made. As of 2018, 25 member states have adopted national adaptation strategies. LIFE has funded 60 projects related to adaptation (184 million euros in total), the Commission has introduced adaptation in the

Covenant of Mayors, raised awareness, mobilized and supported cities in adopting local adaptation strategies. Knowledge about adaptation has substantially accumulated, and the adaptation sharing platform Climate-ADAPT has become more informative. Also, a clear progress has been made in developing adequate adaptation policies and programmes. The EU structural and investment funds have allocated totally 453 billion euros for the 2014-2020 period. The strategy is broadly coherent with other EU national, regional and local policies. In addition, the EU macro-regional strategies and the Covenant of Mayors helped to tackle some transboundary climate issues between countries that have similar climatic areas or share the same climate risks and thus can adopt similar adaptation measures. In respect to international policies, the EU must report to the UNFCC progresses and actions made and redefine its policies and targets if necessary.

Always according to this report [7], some improvements could be brought by a better exchange of information between the scientific community and decision makers, better integration of various adaptation actions by research and methodology exchanges, integration of the international dimension in adaptation, monitoring actions at all governance levels, and increasing the number of local adaptation strategies. The strategy should also deliver more in areas such as disaster risk reduction, maritime and fishery policies, in developing tools for investors and insurers, in driving private investments, and adopting more ecosystem-based adaptation measures. Despite, the EU adaptation strategy has been highly successful and added value to national, regional and local adaptation efforts while remaining cost-effective. The strategy was a reference point and a policy instrument that has successfully brought attention on stakeholders and decision makers on the need to prepare for climate hazards.

It is considered [7] that the changes in the climate in Europe have already impacted ecosystems, economic sectors, human health and well-being. Estimates of total economic losses due to climate change since 1980 amount to 436 billion euros, distributed unequally between member states as shown in Figure 21, and could increase 10 folds by the end of the century under the *business as usual* scenario (Figure 22).

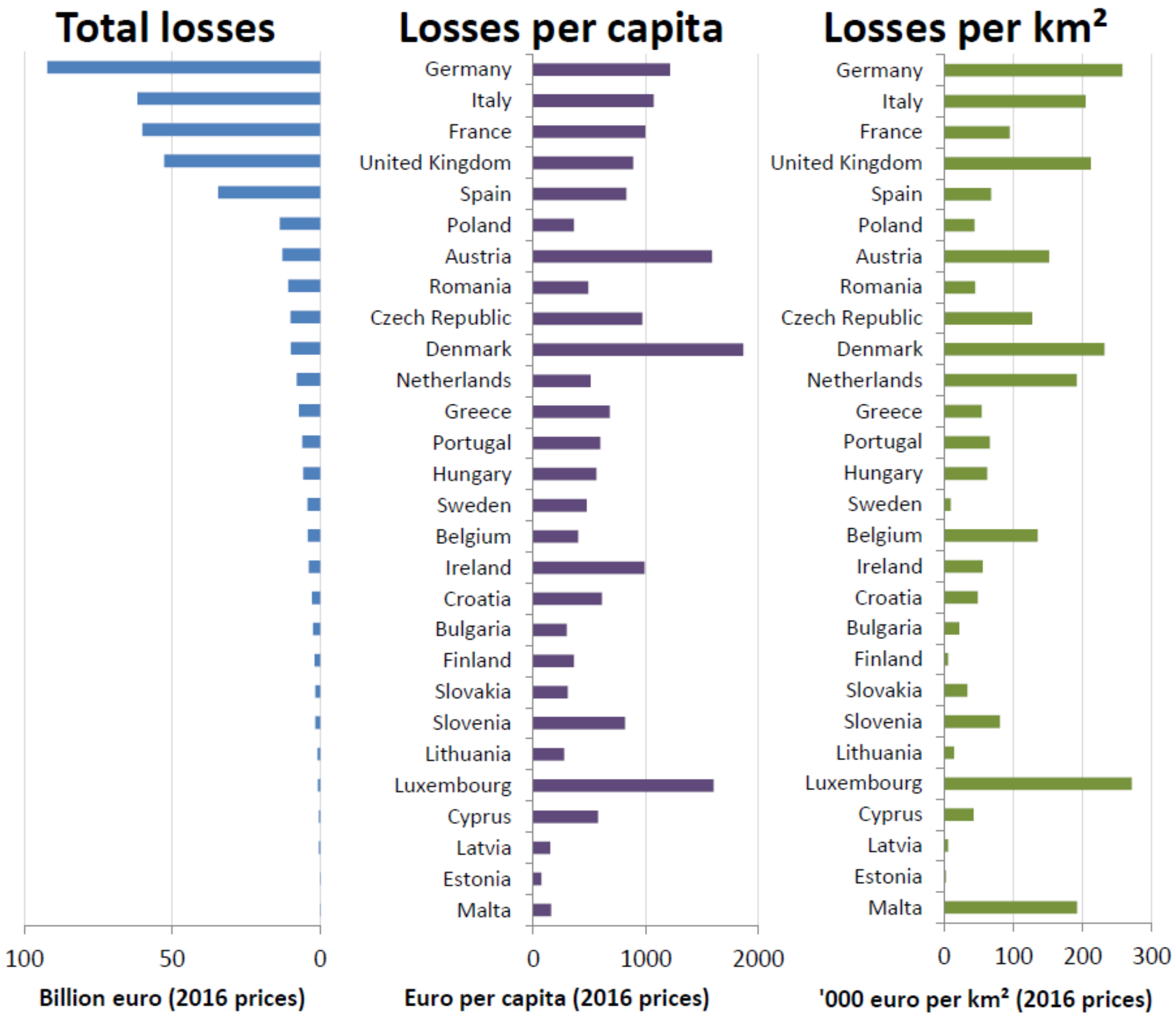


Figure 21. Economic losses in billions of euros by EU member states [7].

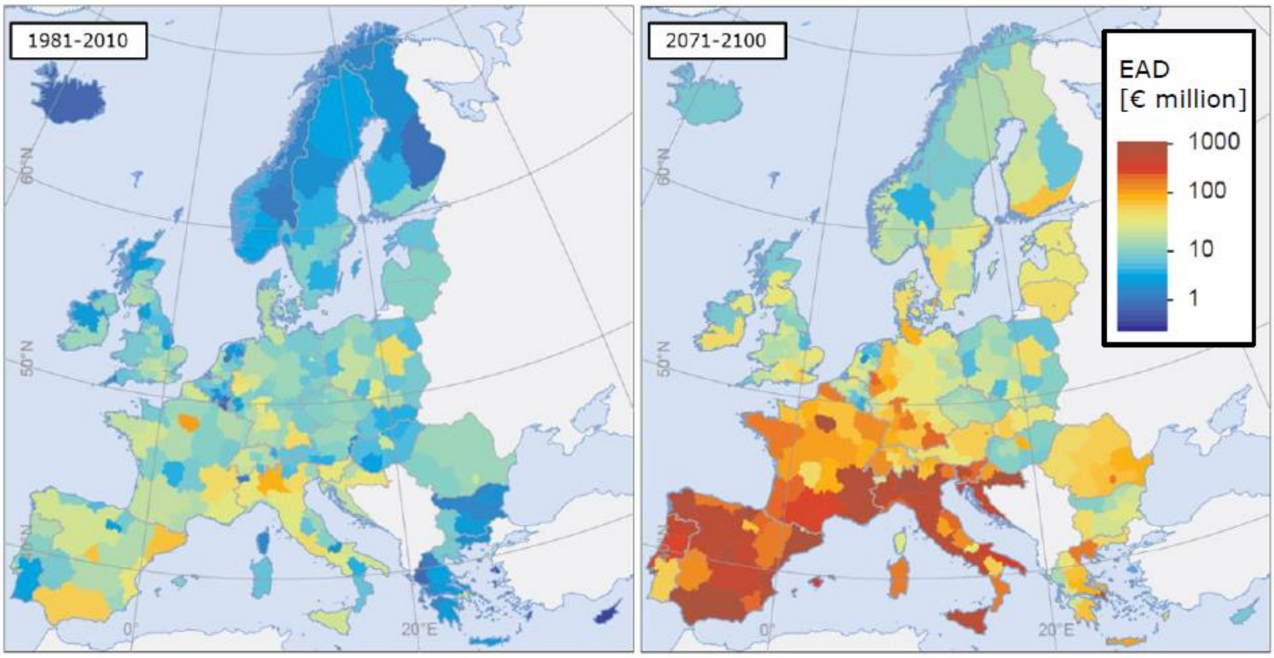


Figure 22. Projected economic losses in millions of euros distributed by regions in the EU [7].

These graphs and maps reserve an important observation: climate impacts will not be distributed equally across member state and Southern regions will suffer more than others. Besides, evidence is accumulating on Europe's vulnerability beyond its borders, through trade, international financial flows, migration and security. As climate change affects negatively the GDP of several EU trading partners, so does the EU financial dependence from these countries. Figure 23 shows which are the regions and countries the EU is economically most dependent of, and what could be the future economic losses for the EU if these countries are more or less severely affected by climate change.

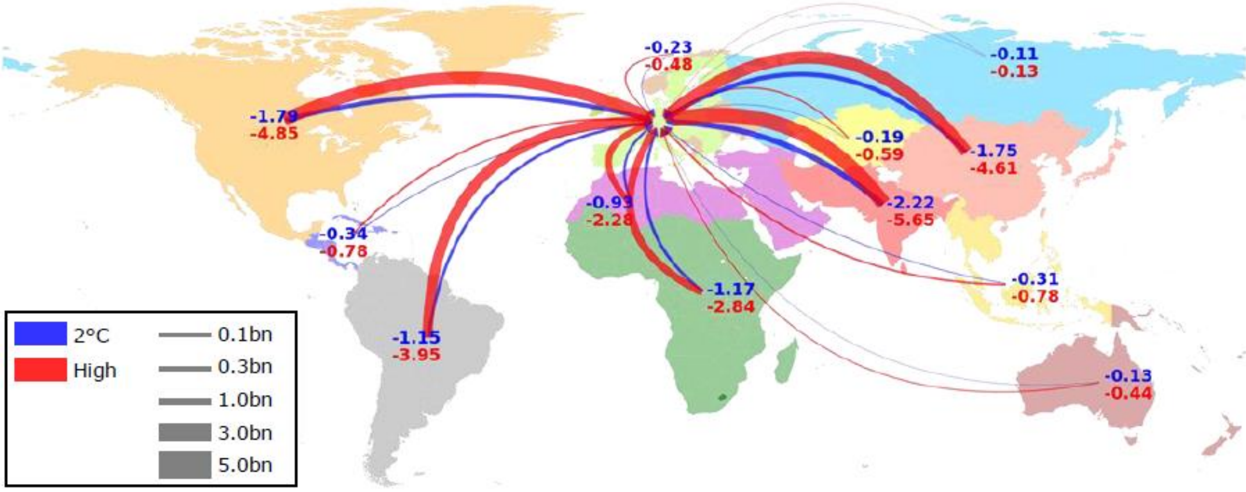


Figure 23. The EU economic relationships from trading partners worldwide and potential economic losses due to climate change [7].

3.5 The Covenant of Mayors

The Covenant of Mayors for Climate and Energy is an initiative launched in 2008 by the European Commission that aims to support local authorities in implementing sustainable climate and energy policies [8]. Recognizing the importance of a bottom-up approach in the fight against climate change, with this movement the European Commission sets the ground for local governments to pursue their own mitigation and adaptation policies and actions. The Covenant of Mayors represents a voluntary commitment of signatory municipalities to meet the EU mitigation (-40% of CO_2 emissions by 2030) and adaptation objectives [8]. When it was first launched, The Covenant of Mayors endorsed local authorities to develop sustainable energy policies targeting the EU 20% CO_2 emissions cuts by 2020 [8]. Later on, supported by the EU adaptation strategy and taking example of the Covenant of Mayors, the European Commission launched the Mayor Adapt in 2014, an initiative that aimed to support local authorities in setting adaptation actions to fight climate change [8]. Finally, in October 2015, the Covenant of Mayors and the Mayor Adapt merged into the Covenant of Mayors for Climate and Energy, a movement that aims to make cities decarbonised and resilient, with a constant access to sustainable, affordable and secure energy [8]. Taking into account the immense diversity that different local authorities face in meeting the mitigation and adaptation objectives, the Covenant of Mayors (supported by the Joint Research Centre) has develop a unique platform for data compilation and reporting called **Sustainable Energy and Climate Action Plan (SECAP)** [9]. This is a excel template that signatory parties can download from the Covenant of Mayors website and use to collect, analyse and manage data in a structured and systematic manner. When the local authority signs the Covenant of Mayors, it commits to fill the SECAP template within two years, and report the progresses made every two years [9]. The SECAP includes a long-term strategy, an emission inventory, mitigation actions, an adaptation scoreboard, a climate risk & vulnerability assessment, and adaptation actions (Table 2) [9]. Before the SECAP submission, the document must be first approved by the Municipal Council and then quality controlled by the JRC, on behalf of the European Commission [9]. From the submission date, every two years, the municipality agrees to monitor and report the progresses made by filling the monitoring template (Table 3)[9].

Since 2008, 9.847 municipalities in 59 countries have signed the Covenant of Mayors, which covers more than 315 million inhabitants. 6.418 municipalities have submitted their action plans with the 2020 objectives, which was followed by 2.296 monitoring reports. 1.032 municipalities have moved to the 2030 objectives. The majority of the signatory parties are small cities with less than 10.000 inhabitants, followed by medium size cities with less than 250,000 inhabitants, and only a very small percentage are large cities. Some countries like Italy and Spain have more than 1,000 cities signatories. In 2017, the Covenant of Mayors has brought -23% of GHG emissions, -14% of total energy consumption, 4 times more renewable energy sources and 3 times more local renewable energy production [10].

	SECAP	Monitoring
Strategy	Dedicated to the vision, the overall CO_2 emissions reduction target(s), the adaptation goals, the attribution of staff and financial capacities and the involvement of stakeholders and citizens.	Dedicated to any changes to the overall strategy, updated figures on the attribution of staff and financial capacities and identification of barriers to the implementation of actions.
Emission Inventories	Dedicated to the amount of final energy consumption and associated CO_2 emissions by energy carrier and by sector in the base year.	Dedicated to the amount of final energy consumption and associated CO_2 emissions by energy carrier and by sector in the monitoring year – the main objective is to monitor the evolution of CO_2 emissions over time.
Mitigation Actions	Dedicated to the list of key mitigation actions to put the overall strategy into action, together with time frames, assigned responsibilities, allocated budgets and estimated impacts.	Dedicated to monitor the implementation status of the key mitigation actions. At least three implemented or ongoing actions have to be submitted as Benchmarks of Excellence.
Scoreboard	Dedicated to understanding the areas of the adaptation cycle in which the signatory has made progress.	Dedicated to monitoring progress against the six steps of the adaptation cycle and creating an overall picture of the signatory's adaptation efforts.
Risks and Vulnerabilities	Dedicated to the climate vulnerabilities, hazards as well as the impacts and assessments thereof.	Dedicated capturing the information that has been gathered to date on the climate vulnerabilities, hazards, in addition to impacts, which are broken down by sector
Adaptation Actions	Dedicated to the Action Plan(s) and individual (key) actions, including various relevant parameters (i.e. sector, timeframe, stakeholders and cost).	Dedicated to tracking the Action Plan(s) and individual actions taken over time to meet goals increase resilience to identified climate impacts.

Table 2. SECAP overview of actions [9].

	Registration stage	SECAP	Monitoring Action Reporting	Monitoring Full Reporting
	Year 0	Within 2 years	Within 4 years	Within 6 years
Strategy	×	✓	✓	✓
Emission Inventories	×	✓ (BEI)	×	✓ (MEI)
Mitigation Actions	×	✓	✓ (min. 3 Benchmarks)	✓
Adaptation Scoreboard	✓	✓	✓	✓
Risks and Vulnerabilities	×	✓	✓	✓
Adaptation Actions	×	×	✓ (min. 3 Benchmarks)	✓

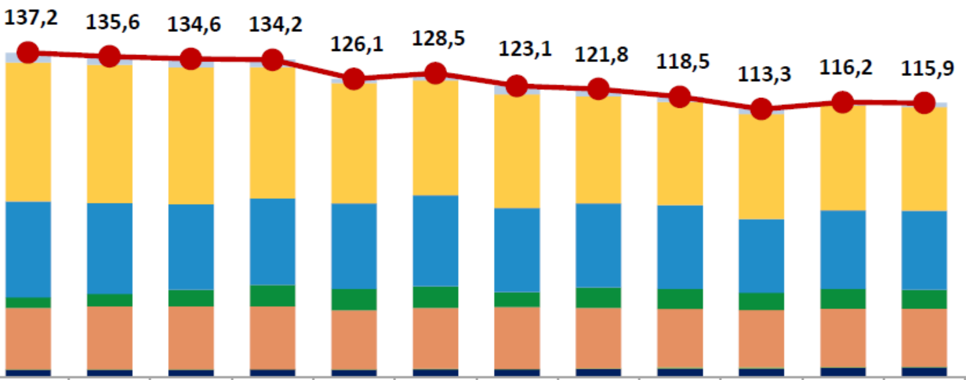
Legend: ✓ Mandatory | × Optional

Table 3. SECAP timelines [9].

4 Italy and program area: energy and climate

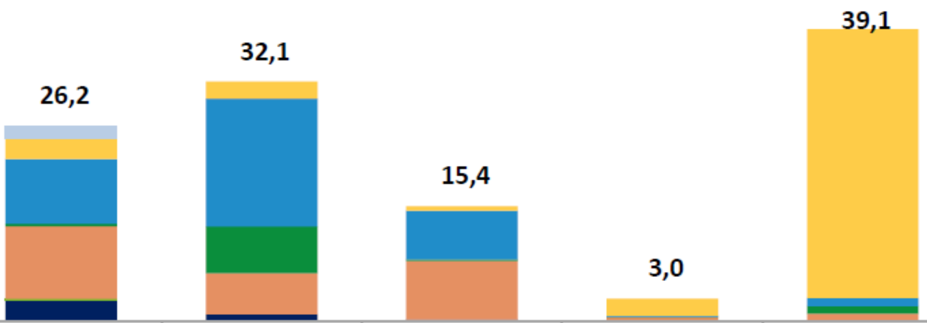
4.1 Energy consumption, GHG emissions, objectives, politics and measures

According to the proposed Italian Integrated National Plan for Energy and Climate (2019) [11] from the Ministry of the Environment, Land and Sea (MATTM), the final energy consumption in Italy in 2016 was 116 Mtoe (Figure 24).It can be noted that energy efficiency has been significantly increasing in the last 10 years, and the energy mix has changed. In terms of energy consumption by sector, the main energy consumptions came from the residential sector (41%), followed by transport (34%) and industry (22%) (Figure 25) [11].



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Solidi fossili	4,0	3,7	3,6	3,2	1,8	2,9	3,4	3,1	2,2	2,1	1,5	1,8
Petrolio	59,0	58,4	57,9	55,6	50,9	48,7	48,3	45,2	43,8	44,3	44,3	43,8
Gas	40,6	38,5	36,2	36,6	36,1	38,5	35,5	35,7	35,4	31,2	33,2	33,5
Rinnovabili	4,5	5,3	7,1	9,0	9,2	9,1	6,5	8,6	8,5	7,5	8,4	8,0
Energia elettrica	25,9	26,6	26,6	26,6	24,9	25,7	26,0	25,5	24,7	24,2	24,7	24,6
Rifiuti non rinnovabili	0,1	0,1	0,1	0,1	0,1	0,2	0,2	0,3	0,3	0,3	0,3	0,3
Calore cogenerato	3,1	3,1	3,1	3,2	3,1	3,3	3,2	3,4	3,7	3,7	3,9	4,0
Totale	137,2	135,6	134,6	134,2	126,1	128,5	123,1	121,8	118,5	113,3	116,2	115,9

Figure 24. Energy consumption in Mtoe in Italy since 2005 [11].



	Industria	Residenziale	Terziario	Agricoltura	Trasporti
	26,2	32,1	15,4	3,0	39,1
Solidi fossili	1,8	-	-	-	-
Petrolio	2,7	2,3	0,6	2,3	36,0
Gas	8,6	17,1	6,5	0,1	1,1
Rinnovabili	0,4	6,3	0,2	0,1	1,0
Energia elettrica	9,7	5,5	7,9	0,5	1,0
Rifiuti non rinnovabili	0,3	-	-	-	-
Calore cogenerato	2,7	0,9	0,2	-	-

Figure 25. Energy consumption in Mtoe by sector in Italy in 2016 [11].

Regarding GHG emissions, the Italian Third Biennial Report to the UNFCC (2017) [12] by the Institute for Environmental Protection and Research (ISPRA), describes the entity and composition of GHG emissions during the 1990 – 2015 period. This study highlights that Italy has been reducing its total GHG emissions during the studied period for a total of -16% [12]. The share of emissions in the different sectors remained the same during the reporting period. The sector that relates to the production and supply of energy was the largest contributor, about 82% in 2015, followed by industrial processes and agriculture, each accounting for about 7% of total emissions, and other emission sources for the remaining percentage. CO_2 is largely the most emitted GHG and displayed a remarkable reduction during the analyzed period of about 18% (Figure 26) [12].

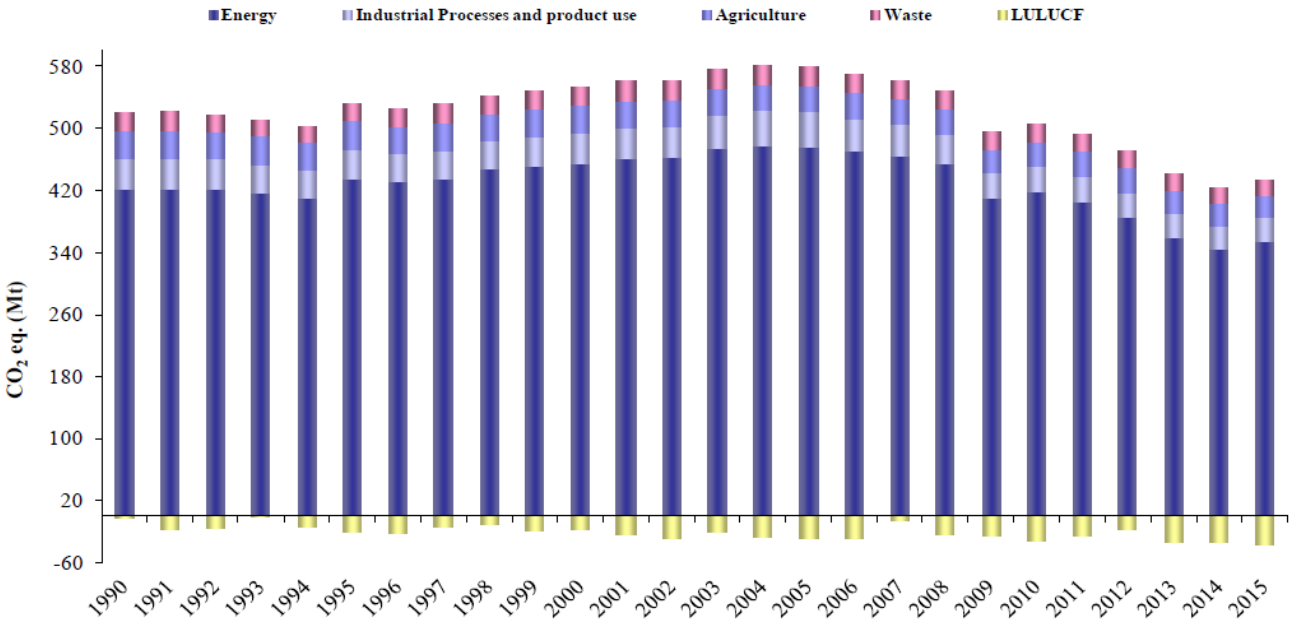


Figure 26. Trend of total GHG emissions in Italy [12].

Regarding the trend reported in Figure 26, it should be specified that, the 2008 economic recession has had a remarkable influence on the total emission rates, especially in the energy and industrial process sectors. Also, an increment in the use of renewables and advances in energy efficiency has brought a significant decrease to emissions rates. Regarding the transport sector, GHG emissions showed an increase in the 1990 - 2015 period equal to 3%, due to an increase in goods and passengers' movements. After a peak in 2007, emissions from the transport sector showed a decrease (-18 % from 2007 to 2015) mainly explained by the economic crisis contributing to the reduction of movements and by the growing presence in the market of low energy consumption vehicles. Emissions from energy industries showed a reduction of 24% in 2015 with respect to 1990, in spite of an increase in the thermoelectric energy production and electric energy consumption [12].

To obtain the future trends of GHG emissions, this document considers two main scenarios. The first one, namely With Measures scenario (from now on WM), takes into account the evolution of the national energy system and it considers only policies in force on December 31st, 2014 and minimal standards for building efficiency measure which was adopted in June 2015. For this scenario, the base year for the projections is 2015. The other one, namely With Additional

Measures scenario (from now on WAM), also considers the objectives and measures included in the National Energy Strategy document, published in 2017 [12]. From these two scenarios, five cases were developed by applying different models of population growth. The results of total GHG emissions are reported in Figure 27, being the results until 2015 the inventory data as submitted to the UNFCCC in 2017. From 2015 on, the points show a general trend of reduction of GHG emissions for all the cases except for the WM-BR1 one, which brings a slight increase compared to 2015's values. This general reduction of emissions is estimated to be due to an increased efficiency of electricity generation, a reduced fuel consumption in the transport sector due to high prices, and a remarkable reduction of energy consumption in the industrial sector thanks to structural changes in production processes [12].

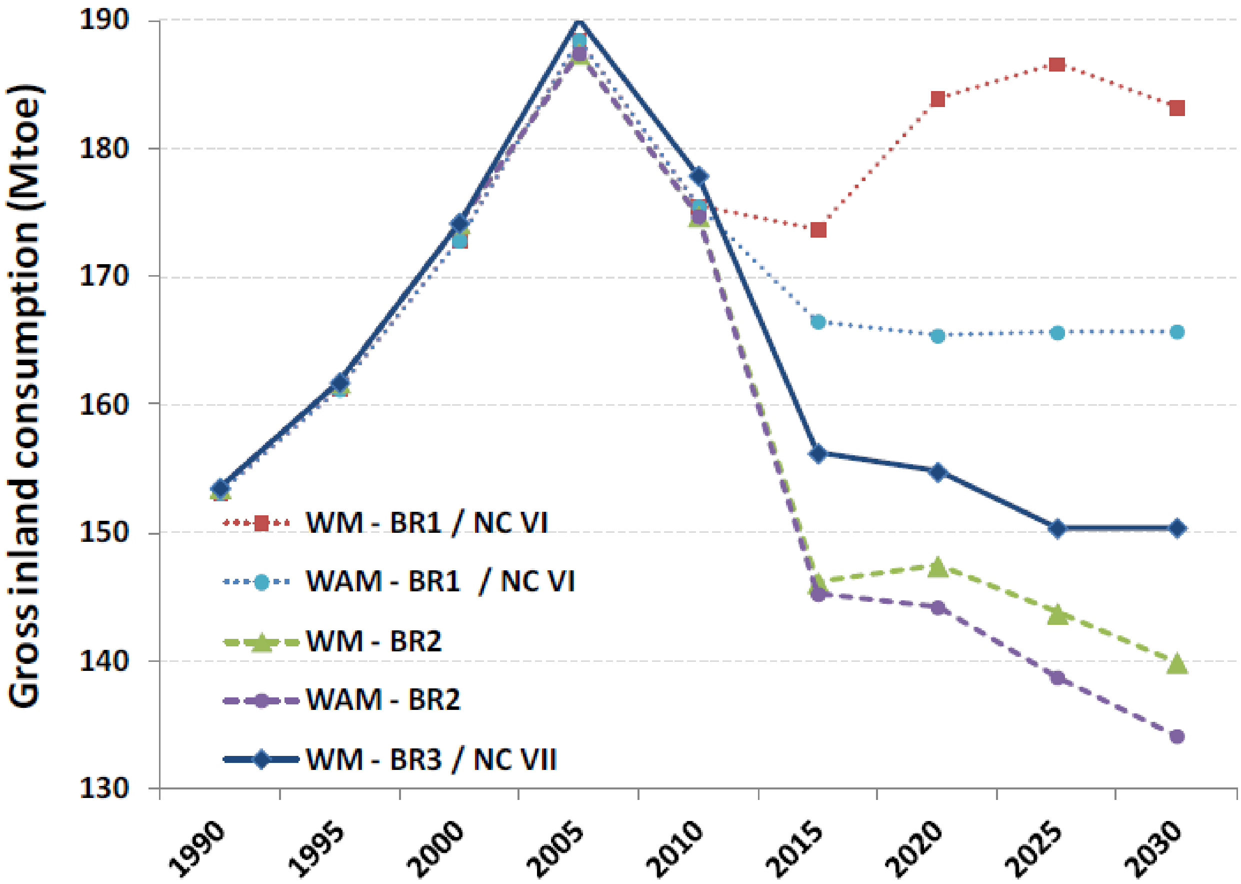


Figure 27. Actual and predicted GHG emissions in Italy [12].

Because of the energy sector being the most influenced and influential sector in the context of climate change, great attention has been posed on the objectives, politics and measures to be adopted to enhance its performances and to reduce its impacts on the climate. Following this purpose, the National Energy Strategy [13] was drafted in 2017, a document that describes which kind of objectives and actions will be pursued to obtain the aforementioned objectives. As reported in the document [13], the main objectives to be pursued are:

- **de-carbonization**: the objective is to obtain an acceleration in the closing process of the coal plants by 2025;
- **exploitation of renewable resources**: the aim is to increase the quote of renewable resources used from 17,5% (in 2015) to 28% (in 2030); more specifically electric renewable from 33,5% to 55%, thermal renewable from 19,2% to 30% and transport renewable from 6,4% to 21%;
- **energy efficiency**: the aim is to obtain a reduction of final energy consumption of about 10 Mtoe/year in 2030 compared to the actual trends;
- **energy security**: the aim is to manage the variability and peak demands of natural gas fluxes considering the political situation of countries from which Italy imports its natural gas and to extend the quantity and quality of renewable sources for electricity by including new actors and by making markets and infrastructures more smart, flexible and resilient.

The National Energy Strategy established a starting point that led to the creation of another document in 2019: The Italian Integrated National Plan for Energy and Climate. If the 2017 document focused more on the analysis of the actual situation and on the definition of the objectives, the 2019 one focuses mainly on the determination of the politics and measures to be actuated in order to accomplish these objectives.

The first two objectives are strictly linked because the main way to reduce coal consumption is to exploit renewable resources; three sectors are essential in this scenario: electricity production, building heating and cooling, and transports [11]. About electricity, the Italian politics aims to increase electricity production from natural gas exploitation by creating new power plants for about 3 GW of power and by creating new accumulation systems for another 3 GW in southern-central Italy and Sicily [11]. Moreover, focusing on the particular situation of Sardinia, a new electric connection with Sicily and the peninsula is planned, coupled with the creation of new natural gas generation or alternatively new storage capacity for electricity for about 400 MWh [11]. Finally, a great improvement in the use of both wind and solar power plants is planned through the creation of new generators and the revamping and repowering of existing ones using newer and more performant technologies while exploiting locations that already proved to be suitable for this kind of power generation [11]. Regarding buildings heating and cooling, which alone consists of about 50 % of total energy usage, there are already measures applied such as tax deductions for energy efficiency interventions, the stimulation of high-efficiency co-generators usage and obligation about renewable resources integration in buildings refurbishment [11].

Regarding transports sector, the Italian politics strongly focus on the introduction of biofuels within 2022, like bio-methane and the ones made from used oils and animal fat. This will also lead to the gradual substitution of older vehicles with newer and more efficient ones, thus obtaining also a reduction of 6% of GHG emission due to transports by 2020 [11].

In order to obtain the expected reduction of 10 Mtoe/year within 2030 (compared to the actual trend), Italy has already set a pool of politics and measures which will be strengthened in the years to come [11]. These politics include the usage of White Certificates and Thermal Accounts, the aforementioned tax deductions for energy refurbishment of existing buildings and for the recovery of the existing buildings heritage and the National Energy Efficiency Fund [11].

The White Certificates system is a regime of primary energy saving imposed to the electricity and natural gas energy distributors having more than 50.000 customers. These Certificates are negotiable titles that attest the achievement of energy saving in the final energy usage through interventions and energy efficiency improvement projects and reward the distributors through economic support if the objectives are reached [11]. The Thermal Account system is primary focused on interventions conducted in the residential sector by the public administration or private investors. This incentive is almost totally focused on the substitution of older and less efficient plants with new and more performant ones [11]. The tax deductions for energy refurbishment interventions were introduced in Italy in 2007 and are still active; they consist of reduction in Irpes and Ires taxes for every actor, private or a business, which aims to improve energy efficiency of residential and service industry buildings [11]. Finally, the National Energy Efficiency Fund aims to sustain energy efficiency improvements led by businesses and public administration on buildings, plants and productive processes, through the promotion of teamwork between financial institutions and private investors based on adequate risk sharing [11]. The sustainable interventions are the ones aiming to reduce energy consumption of industrial processes, the creation of district heating and cooling and to the improvement of public services and structures. It has been estimated that the Fund can generate energy improvement investments for an amount of 800 milion euro, by investing 150 milion euro, so having a leverage effect of 5.5 [11].

Another important objective is focusing on maintaining energy security standards in gas, oil and electricity sectors [11]. About gas, there are mainly three planned interventions. The first one is the review of the Italian existing Natural Gas Preventive Action and Natural Gas Emergency Plan following the ordinances reported in the Safety Regulation of 2017. The second one is the adjustment of transport and storage gas system and the third is the diversification of supplying sources using LNG (Liquefied Natural Gas). Although the final purpose of all the measures to be taken is to nullify the fossil fuel consumption, the energy production based on these fuels must be maintained efficient and secure until the transition to renewable resources is complete. In this context, marginal refineries are to be converted in bio-refineries to satisfy the increasing demand of bio fuels, a new production chain is to be created to ensure raw material for the bio-refineries and old industrial sites will be reconverted to new productive investments in order to maintain the current occupational level [11]. Finally, regarding the electric sector, many interventions are planned to ensure the system's security. First of all, a review of the National Plan for Electric System Security is set to guarantee the best management of the system in case of emergency. Another important measure is to improve the system resiliency in order to adapt to the increasing number of extreme meteorological events of the near future [11]. Finally, the continuous technological improvement constitute a fundamental aspect for the security of electric system because it will be more and more important to adapt the system to the prospected climate changes, to the different resources to be exploited and to the management problems to come [11].

4.2 Climate, observed climate changes, scenarios, risks, impacts and adaptation measures

The climate in Italy is characterized by its morphology and geographical position. On the north it prevails a humid climate, whereas on the south it is prevalent an arid one. It is strongly influenced by the Mediterranean Sea that circumvents the peninsula and has a huge thermal capacity. In addition to the Mediterranean atmospheric fluxes, Italy is interested by atmospheric currents coming from the west, particularly from the Atlantic Ocean but these are also mitigated by the Mediterranean Sea. Furthermore, the cold air masses coming from the north are stopped by the Alpine and Apennine mountains reefs.

Regarding the temperatures and precipitation, Figure 28 summarizes the main values on an annual average in Italy. The temperature means indicate similar values along the entire littorals with the exception of the islands of Sardinia and Sicily, and generally the southern coasts, where values are significantly higher. Along the Apennine reefs, the temperature is cooler, with values similar to those found inland on the north. The Alpine regions are much cooler instead. For what concerns precipitation, the Alpine and Apennine regions, and the south-western regions experience much more rain in comparison to the remaining littorals and the north-central regions. The islands and south-eastern regions are, on the contrary, very arid.

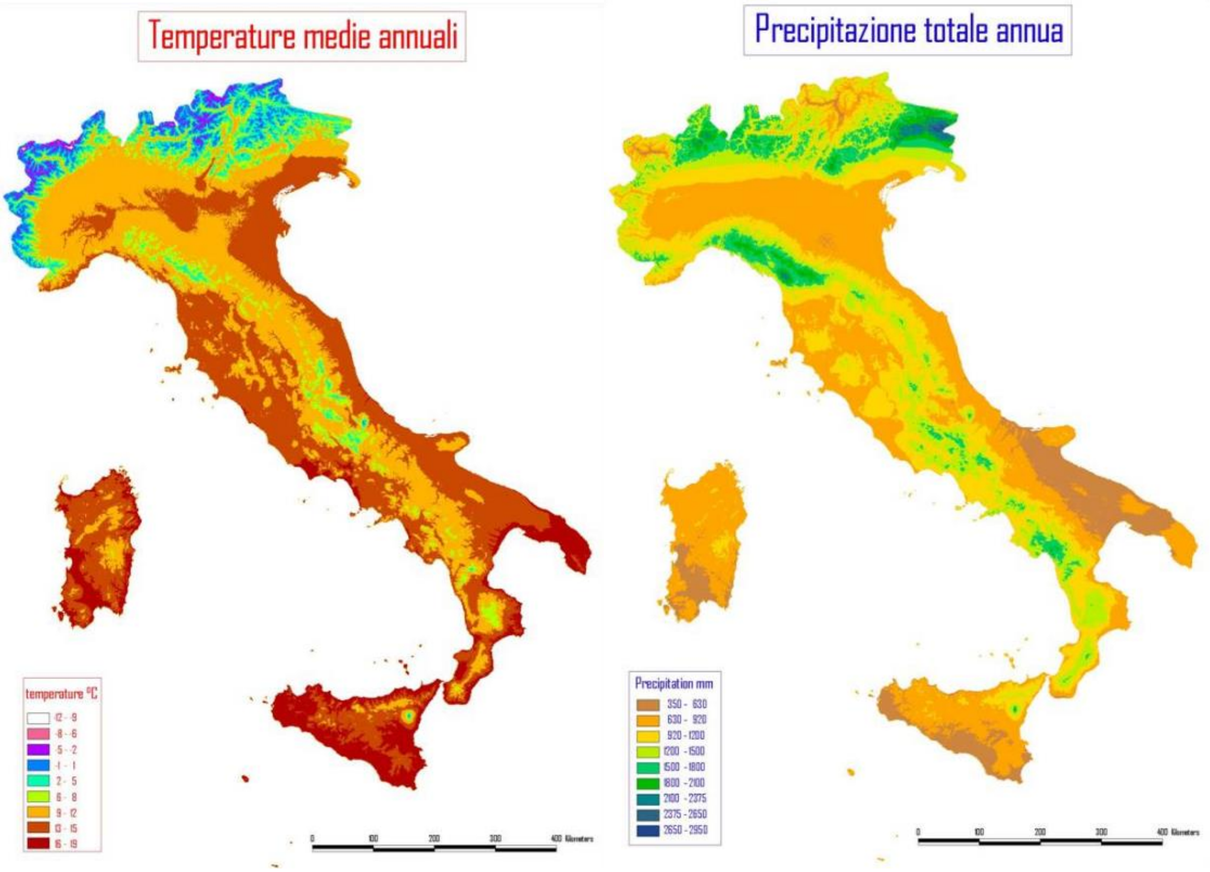


Figure 28. Annual mean temperatures (left) and precipitations (right) in Italy [14].

Recent studies have highlighted significant changes in the Italian climate over the last hundred years. The most important documents about this scope for Italian territory are the National Strategy for Climate Change Adaptation (2015) [15] and the National Plan for Climate Change Adaptation (2017) [16] (still in stage of approval). The observed changes affect all the climatic aspects, although at different rates on each one. The most important variation recorded is temperature. In fact, the mean value of temperature has been constantly increasing in Italy over time; moreover, this trend is becoming more and more evident and it has been demonstrated to be speeding up in the last thirty years. Rainfall and snowfall are slightly reducing, with a ratio of 1% per decade and there is a diminution in the number of moderate events, counterbalanced by an increasing number of extreme ones. This has led to a modification of water distribution and availability and to a general loss of snow accumulations, snow permanence, and permafrost.

Many studies have been carried out to evaluate the future impacts of climate change on the Italian environment. The National Strategy for Climate Change Adaptation [15] identified the main climate evolutions in one hundred years as:

- Exceptional temperature increase (especially in summer season);
- General diminution of rainfall and snowfall events;

- Increasing number of exceptional meteorological events.

The National Strategy for Climate Change Adaptation was developed in order to create a National Plan for Climate Change Adaptation. These two documents evaluated the effects of climate change on several natural and anthropic environments and their interactions on each other. The climatic anomalies reported in these documents are based on the difference between two timespans, each one 30 years in length. One future period, 2021 – 2050, and one reference period, 1961 – 1990, are considered in the analysis [15], [16].

The model used to predict future climate changes is the COSMO-CLM model [15] modified through the CMCC-CM model [15] and considers two possible scenarios: RCP4.5 and RCP8.5. The two selected scenarios are the most commonly used in simulations because they represent medium and high-emissions scenarios respectively, corresponding to an increment of mean global temperature under 2 °C and 4 °C respectively. To perform the analysis, the National Plan first evaluated the following pool of relevant climatic parameters during the reference period for all the Italian territory (Table 4) [16].

Parameter	Symbol	Description	Unit of measure
Mean yearly temperature	T_{mean}	Yearly mean of daily mean temperature	*(°C)*
Days with intense rainfall	R20	Yearly mean number of days having more than 20mm of daily rainfall	*(Days/year)*
Frost days	FD	Yearly mean number of days having minimum temperature below 0 °C	*(Days/year)*
Summer days	SU95p	Yearly mean number of days having maximum temperature over 29.2 °C (equal to the 95TH percentile of maximum temperature distribution observed through E-OBS)	*(Days/year)*
Winter cumulated rainfall	WP	Cumulated rainfall in winter months (December, January, February)	*(mm)*
Summer cumulated rainfall	SP	Cumulated rainfall in summer months (June, July, August)	*(mm)*

Table 4. Climatic parameters considered in the definition of the macro-regions [16].

After having defined and detected the analysis parameters, the document divides the Italian territory in climatic macro-regions, defined as parts of territory with similar climatic conditions detected during the reference period. Because of this approach, six macro-regions were created (Figure 29) [16], characterized by the mean value and the standard deviation of the climatic parameters reported in Table 5 [16].

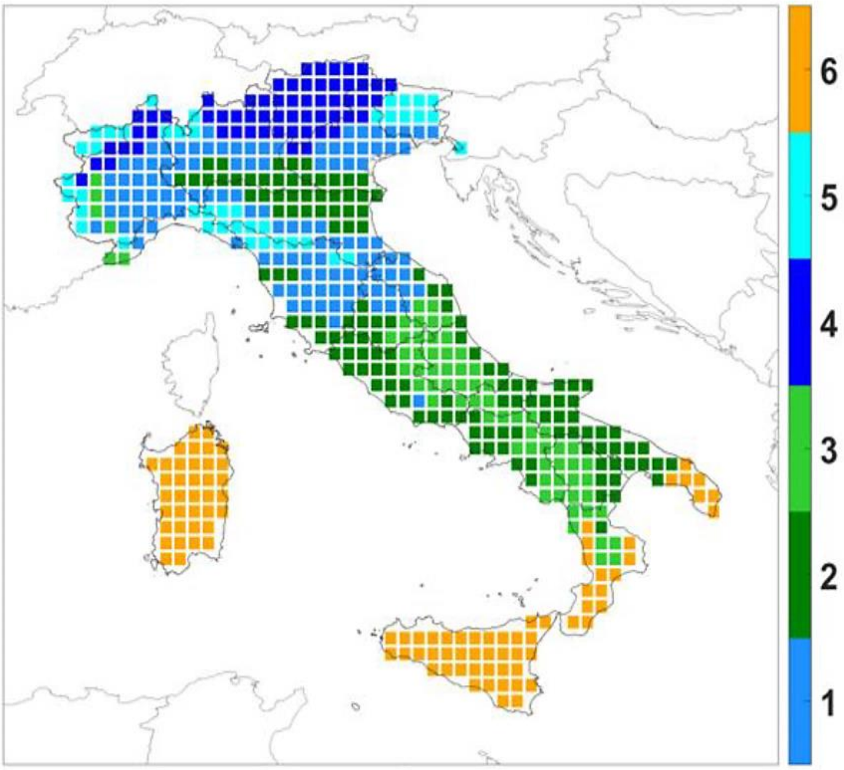


Figure 29. Italian climatic macro-regions [16].

	Macro-region	T_{mean} (˚C)	R20 (days/year)	FD (days/year)	SU95p (days/year)	WP (mm)	SP (mm)
1	Alps foothills and northern Apennines	13 (+-0.6)	10 (+-2)	51 (+-13)	34 (+-12)	187 (+-61)	168 (+-47)
2	Po Valley, coastal areas of southern-central Italy	14.6 (+-0.7)	4 (+-1)	25 (+-9)	50 (+-13)	148 (+-55)	85 (+-30)
3	Southern-central Apennines	12.2 (+-0.5)	4 (+-1)	35 (+-12)	15 (+-8)	182 (+-55)	76 (+-28)
4	Alps	5.7 (+-0.6)	10 (+-3)	152 (+-9)	1 (+-1)	143 (+-47)	286 (+-56)
5	Northern-central Italy	8.3 (+-0.6)	21 (+-12)	112 (+-12)	8 (+-5)	321 (+-89)	279 (+-56)
6	Islands and far south Italy	16 (+-0.6)	3 (+-1)	2 (+-2)	35 (+-11)	179 (+-61)	21 (+-13)

Table 5. Mean values and standard deviations of climatic parameters for each macro-region [16].

After defining the macro-regions and their parameter values, the study measured the future climatic anomalies by computing the difference between the reference values and the ones simulated for the period 2021 – 2050. In order to identify zones with homogeneous climatic anomalies, these differences were grouped in homogeneous categories defined as "cluster of anomalies" (data not shown), identified for both RCP4.5 and RCP8.5 scenarios. Once having settled the macro-regions and the anomalies clusters, the document defines some homogeneous climatic areas, defined as parts of the macro-regions that in future will face similar climatic issues identified by the intersection of macro-regions and clusters (Figure 30 and Figure 31).

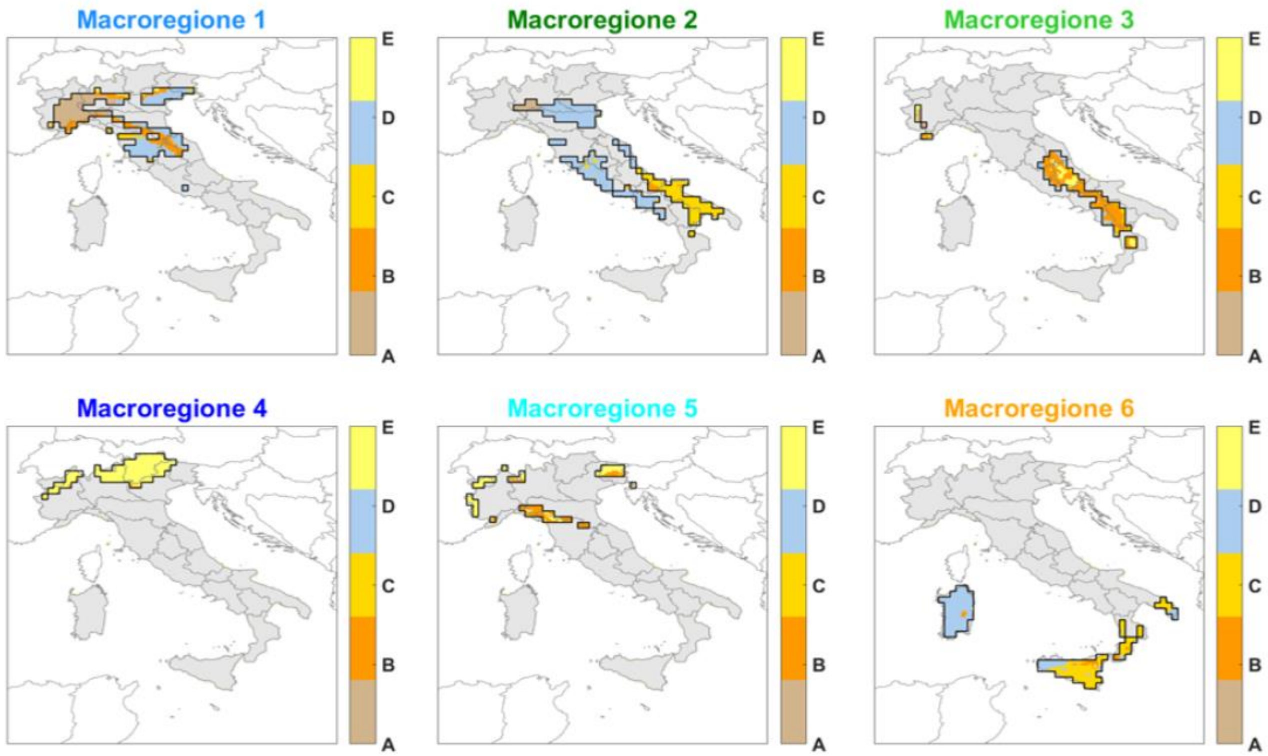


Figure 30. Homogeneous climatic areas, RCP4.5 scenario [16].

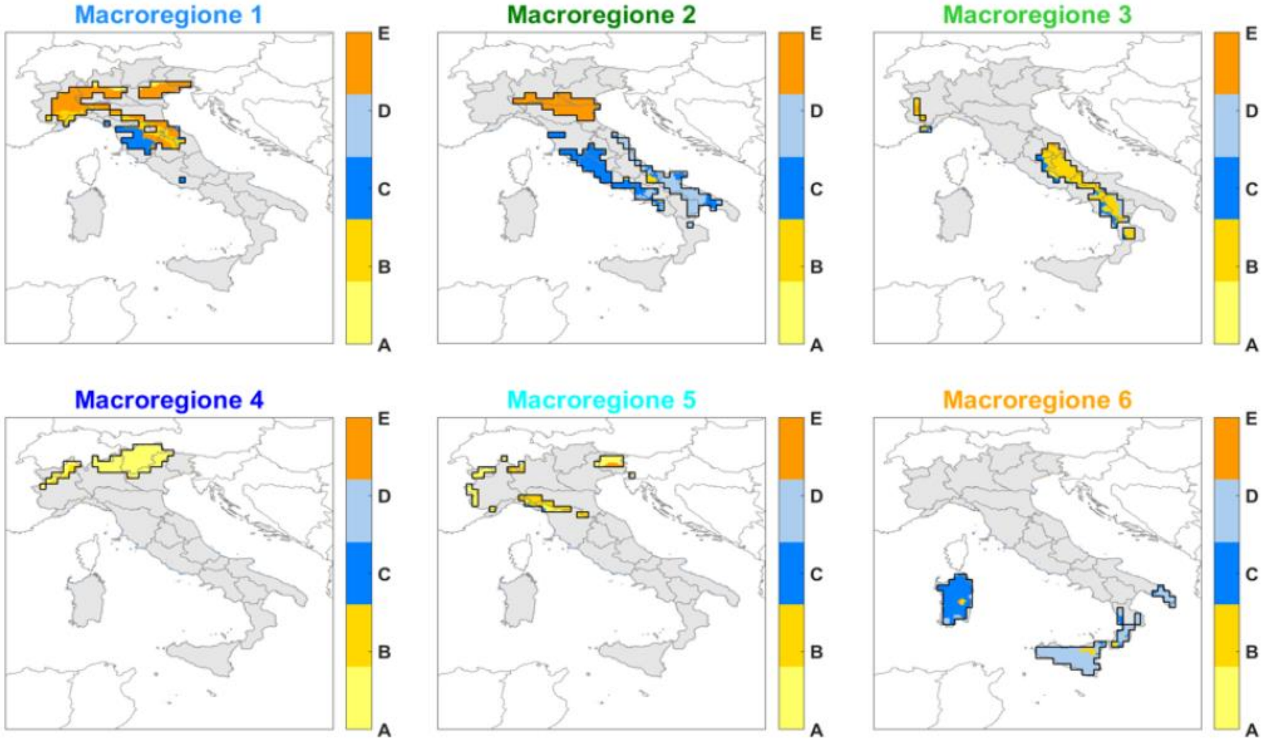


Figure 31. Homogeneous climatic areas, RCP8.5 scenario [16].

Through the definition of the homogeneous climatic areas (H.C.A) within each macro-region is possible to identify the main climate changes that will occur in the future in each of these regions. By analyzing the RCP4.5 and RCP8.5 scenarios, the following features are detected for each macro-region (from now on M.R.):

- M.R. 1 (RCP4.5:1A, 1B, 1D H.C.A; RCP8.5: 1B, 1C, 1E H.C.A): for all the region, the RCP4.5 expects a relevant diminution of both summer rainfall and frost days; the RCP8.5 sees a relevant diminution of summer rainfall and an increase of winter ones, with an exception of Tuscany, in which rainfall in all seasons is expected to increase. Also, a reduction of frost days is noticed, more relevant than the RCP4.5 scenario;
- M.R. 2 (RCP4.5: 2A, 2C, 2D H.C.A, RCP8.5: 2C, 2D, 2E H.C.A): the RCP4.5 shows that the Tyrrhenian side and most of the Po Valley will mainly be affected by an increase in winter rainfalls and by a reduction of summer ones. Instead, the western part of the Po Valley and the Adriatic side will be affected by a general reduction in both winter and summer rainfalls. Finally, an increase in summer days is expected; for what concerns the RCP8.5, the Po Valley will face a reduction in summer precipitation and a significant increase in winter precipitation; the remaining areas of M.R. 2 are characterized by an overall increase

in normal and extreme precipitation phenomena. In general, there is a significant increase in summer days, as in the RCP4.5 scenario.

- M.R. 3 (RCP4.5: 3B, 3E H.C.A; RCP8.5: 3B, 3C, 3D H.C.A): the RCP4.5 predicts that the southern and central Apennines will be characterized by a notable reduction in summer rainfalls, as well as by less winter rainfalls in the inner parts of the regions, and by an overall reduction of frost days in all the region; the RCP8.5 shows that the southern and central Apennines will generally see a reduction in summer precipitation, while for the outermost areas there will be an increase in summer precipitation and extreme precipitation phenomena (greater than in RCP4.5);
- M.R. 4 (RCP4.5: 4E; RCP8.5: 4A): the RCP4.5 expects a homogeneous behavior in all the region, featuring a reduction of extreme events, frost days and snow accumulation; the RCP8.5 indicates a reduction of summer rainfalls and an increase of winter ones; a reduction of frost days and snow accumulation is also expected, similarly as in RCP4.5;
- M.R. 5 (RCP4.5: 5B, 5E; RCP8.5: 5A): the RCP4.5 sees a remarkable reduction of rainfalls and frost days in all the region; the RCP8.5 expects that the region will experience a remarkable reduction of summer rainfalls and an increase of winter ones;
- M.R. 6 (RCP4.5: 6C, 6D H.C.A; RCP8.5: 6C, 6D): the RCP4.5 predicts a reduction of summer rainfalls and a slight increase of summer days for all the region. In addition, Sicily and Sardinia will be affected by an increase in winter rainfalls. On the contrary, the RCP8.5 sees a remarkable increase of extreme events and of summer rainfalls, opposing the results of RCP4.5.

In order to set up the adaptation measures, the National Strategy for Climate Change Adaptation developed a description of the major impacts of climate change on relevant environments in Italy and developed a pool of adaptation measures to be applied to each one of said environments [15]. Because of the huge pool of measures reported in the document and of the synthetic nature of this report, not all the solutions are reported below; moreover, because this part of the Plan is a list of measures, the ones reported here will also be described in list form, although divided in the various environments described below:

- **Quality and quantity of water sources:** Italy is historically subject to water shortage due to the nature of the territory and has already developed strategies to handle the effects of climatic change; however, infrastructural and management deficiencies are present and could lead to a reduction in exploiting the available resources. The state of water resources does not present, in general, serious problems in terms of overall availability on an annual basis, but rather in terms of uneven availability over time and space, and management criticalities. These issues are then expected to become more and more important over time because of climate change effects. Planning and coordination to stabilize water availability expectations will be required, such as an optimized demand management. Specific financial aid, aimed at interventions that ensure water availability over the years and increase its efficiency of use, will be created, such as incentives for low intensity water use products and technologies for the use of poor-quality water (grey water). Also, a financing and modernization plan for water facilities and infrastructures will be set up.

- **Desertification, environmental degradation and droughts:** the areas most susceptible to drought and desertification effects constitute 30% of Italian territory. Prospected trends developed by the recent studies show an increasing trend of drought events, leading to remarkable erosion, fire risk and water stress of the soil. These effects will be even more evident in the southern regions like Sicily, Puglia, Molise and Basilicata. A plan of protection and restoration of wetlands to counteract the phenomenon of salinization of soils and groundwater in coastal areas will be actuated. Monitoring of the degradation phenomena of the territory on a national scale will give valuable information to the integration of the fight against land degradation and desertification in all related plans and policies. Activation of planning and implementation actions of land and soil protection against degradation and recovery of degraded areas will help to increase environment resiliency.
- **Hydrogeological instability:** the expected effects of climate change on this sector are heterogeneous because of the different cause-effect reaction that each basin could have; in fact, the same climate change produces different effects, related to the different characteristics of the natural environment involved. If many effects are mostly unpredictable, there are some main changes that will be common in many basins: the spring floods will become more burdensome and the lack of water will increase the risk of landslides. Development of advanced systems for gathering information on a local scale on the conditions of riverbeds and slopes will help to improve the monitoring of the territory and the production of updated databases. This will lead to an improvement in forecasting and alert systems, and a better exploitation of the information provided by advanced monitoring systems and networks. It will be fundamental to favor the maintenance and safety of structures, infrastructures and buildings of strategic importance for the safety of the territory and of people. Definition of a monitoring plan

for assessing the status of buildings, structures and strategic infrastructures, including school complexes located in the areas most at risk will also play a crucial role.

- **Terrestrial ecosystems:** global climate change will most likely have an impact on the physiology, behavior and life cycle of many animal and plant species. In Italy already common are effects like the anticipated blooming of many plants and a modified timing of animal migrations. Moreover, modifications on the geographic distribution of animal and plants have already been detected. The Alps, Apennines and Mediterranean areas are the most threatened zones and the ones that have already suffered the most important impacts. Until now, the initiatives inherent to climate change are mostly focused on research and monitoring of the ongoing situation. However, in order to ease the effects of climate change on these ecosystems, an integrated plan to manage the heritage of biodiversity and to lead mitigation interventions is strongly needed.
- **Marine ecosystems:** climate change will greatly impact marine ecosystems by inducing variability on all the marine natural processes, like increasing the stratification of water masses and inducing the alteration in the distribution of plankton and marine species. All of these will lead to important alteration of the fishing practice, of the marine trophic network and to the establishment of natural conditions favorable for non-native species. Moreover, because of the geographic position of the Mediterranean Sea and of the strong anthropic presence along the coastlines, an exacerbation of eutrophication has already been detected. In order to increase the resilience of the marine ecosystems, it is necessary to improve their quality status, to preserve the biodiversity and to reconstitute the impoverished fish stocks.
- **Inland and transitional waters ecosystems:** inland waters ecosystems are heavily burdened by anthropic pressure that causes the loss of biological components, of natural habitats and a decline of natural conditions. Climate change will act on these already compromised environments, characterized by a high grade of vulnerability. Glaciers recession is causing the loss of glacial waterways and important variations of the hydrologic regimes of alpine waterways. Generally, the rivers ecosystem in Italy will present an intensification of extreme events, like draughts and floods, thus altering the normal biologic components of that environment. Regarding mountain lakes, which are heavily influenced by glaciers quality status, tourism and water withdrawals, they will present incomplete shuffling of water masses and persistence of thermal stratification. These would lead to deep water anoxia and loss of valuable fish species like salmons. Moreover, minor precipitations and major heating could lead to a progressive narrowing of the lake basins. This latter effect will be even more evident in central and southern

Italy, where many lakes like the Trasimeno lake could disappear in the next decades. Finally, ponds, pools, swamps are small and isolated ecosystems that represent important biodiversity reservoirs; however, environments are very vulnerable to climate change and could lose a great part of their natural heritage in the near future.

- **People's health:** climate change will surely influence the incidence of diseases: eradicated illnesses will come back due to mutated environmental conditions, and physical and psychological disorders related to the high temperatures will also peak. Another important impact will be the increased costs for public health because of the expenses needed to have an effective environmental monitoring and epidemiological surveillance. Sessions of training of non-health workers on climate-sensitive risks will be fundamental to guarantee first aid to the people. Monitoring of heat islands in the urban settlements will help to improve safety measures to protect the weakest parts of the population. The definition of the roles of public bodies for controlling insect vectors of diseases and the development of information systems and update protocol on contaminants and pollutants will represent important instruments.
- **Forests:** forests constitute 29% of the Italian territory and have a fundamental role in protecting the soil from hydrogeological instability. Impact of climate change will cause alterations on growth and productivity rates of forests, on the species composition and will also generate altitudinal and latitudinal shifts of forest habitats. This will lead to a loss of biodiversity, augmented fire risk and hydrogeological instability. Promoting and strengthening actions related to innovation, research, education and training will create new generations more aware of natural issues. Infrastructures for protection will be created to protect and conserve biodiversity and wildlife. Modernization and automatization with high environmental efficiency for a sustainable and efficient use of forest resources, through the use of innovative and sustainable techniques and equipment, will help to keep forests in a good status. Active forest management to increase resilience and fire prevention and other natural hazards such as restoration of forests damaged by fires, natural disasters and catastrophic events will be set up.
- **Agriculture:** agriculture is one of the most susceptible sectors when talking about climate changes because it strongly depends on the natural environment. Generally, climate change will cause a diminution of cultivable surface, agricultural yield and an increase of parasites. Animals will also be affected by both direct (forage and water quality and availability) and indirect effects (increased heat stress during summer season) of climate change. It has been estimated that because of agricultural yield reduction, a negative impact on GDP of about 0,7% and 1,9% could happen because of an increase in

temperature of 2 °C to 4 °C respectively. Research for adaptation and mitigation solutions for the agricultural sector will be promoted. Restoration of agricultural production potential damaged by natural disasters and catastrophic events and introduction of adequate prevention measures will be set up as well. Crop diversification is an agricultural practice beneficial for the climate and the environment. Diversification of production activities and investments in tangible fixed assets for improving the efficiency of the networks and water saving will play a fundamental role in conserving the biodiversity and soil productivity.

- **Sea fishing:** climate change will mainly aggravate the pre-existing critical issues like overfishing, variation of the geographical distribution of species and demographical explosion of alien species. It has been estimated that most of the coastal fish species will move into deeper layers of the sea or towards north by about 70 km to counterbalance the increasing surface water temperature. Finally, the predicted marine water pH reduction will have a marked effect on the species having calcified parts, like clams. An improvement of the knowledge of marine species more sensitive to climate change will make fishermen more aware of the impacts of climate change, thus strengthening awareness on the subject. Blocking or reducing the annual fishing effort of the Italian fleet, through catching limits and disposal of obsolete ships will help reduce overfishing and sea pollution. Another important role will be played by the planned incentives for conversion to more sustainable fishing systems and a reduction of energy consumption for fishing.
- **Aquaculture:** Italy is the third European aquaculture producer, after France and Spain, and the second in the Mediterranean Sea after Egypt. About a thousand productive settlements generate the 50 % of national fish production. The main problem about aquaculture is that all the settlements are located in the heavily vulnerable ecosystems of the lagoons and coastlines of the Adriatic Sea. Many consequences of climate change like rising of sea level and sea surface temperature, water acidification and intensification of extreme events could lead to fish production alteration and to less availability of suitable sites for aquaculture. Actually, only a monitoring of the sites is present, with no adaptation measures developed so far.
- **Energy:** because of the general increase of temperature, less energy will be required to heat the buildings and more energy to cool them. In southern-European countries like Italy, however, cooling load increase will overcome heating load reduction, leading to a general increase in energy consumption. Moreover, there will be great peaks of demand during the summer season, probably leading to black-outs. Installation of monitoring

systems will be fundamental. Replacing fossil fuels used by traditional thermoelectric power plants, from coal and fuel oil to natural gas, will greatly reduce GHG emissions. Adaptation interventions of existing buildings and "climate proofing" for new buildings, such as rationalization, planning and reduction of consumption in the summer period will help to reduce energy consumption for both buildings heating and cooling. Strengthening the control and monitoring of water supply variability and the introduction of economic incentives for the development of new storage capacity will counterbalance the water availability issues predicted to come.

- **Coastal areas:** the simulations of extreme events do not show an evident intensification or attenuation of marine storms. Almost 80% of all existing beaches are eroding due to the rise in sea level and the action of waves generated by the wind, and because of unsustainable uses of the coastal territory and of hinterland, and due to the reduction of the solid material coming from rivers. Incentives for the abandonment of areas exposed to sea level rise will reduce economic and social losses due to this phenomenon. The creation and management of non-buildable areas and the installation of fixed and/or mobile barriers, united with the re-naturalization of coastal areas and the promotion of natural reconstruction of coral structures will establish a s protection of the coast from the effects of the rising sea, the action of erosion and storm events.
- **Tourism:** Italy is one of the favorite destinations for international tourism. In fact, it ranks fifth in number of international arrivals worldwide; however, tourism is strongly exposed to the negative consequences of climate change because the development of tourist activities requires favorable climatic conditions and because the changed physical conditions of the destinations may indirectly diminish attractiveness for tourism. Assessments on the costs of impacts on the tourism sector in Italy in 2050 indicate losses ranging from 0,25 % to 1,05 % of GDP. Diversification of touristic offer and seasonal adjustment will help to keep the actual levels of arrivals in Italy, counterbalancing the negative effects of climate changes. About ski tourism, the use of artificial snowmaking facilities will be restricted to the existing ones only and their gradual disposal in favor of more sustainable snow-keeping practices will reduce anthropic impact on mountains. Systems for monitoring the sustainability (environmental, social and economic) of the tourism destination and the reforestation of urban areas and the creation of green spaces within cities will respectively grant sustainability and more attraction for tourism.
- **Urban settlements:** the urban settlements host the preponderant part of the Italian population (94% in 2001) and at the same time they are the main culprits and the main "victims" of climate change. It is very likely that the magnitude, duration, frequency and

intensity of heat waves and extreme precipitation events in Italy urban settlements may be more intense and concentrated in short periods. Climate change will tend to accentuate critical issues already present in urban settlements and because of the complete artificial nature of this environment, all the resilience must be guaranteed by human actions. Encouraging scientific research on the nature and magnitude of climate change in an urban context and risk assessment will be the base to create new politics and measures to protect people and buildings from extreme weather events. Preparation of alert systems accompanied by constant improvements of forecasting models, with active stakeholder participation will play a great role as well. Encouraging scientific research on climate adaptation of existing settlements, and the experimentation in the building sector, through promoting experimental adaptation interventions in peripheral areas, suburbs, historic centers and public spaces, will be the base to create low-impact settlements in the near future.

- **Cultural heritage:** being extremely rich in terms of cultural heritage, Italy has to pose great attention on its conservation and to the effect that climate change could have on it. The main activity is to identify the climatic parameters that cause decay for both outside (architectural and archeological heritage) and inside (museums, churches, etc.) locations. Moreover, it is very important to correctly identify the materials that constitute the valuable goods and their response to external influences caused by the climatic behavior. To obtain a good resilience of the cultural heritage, priority should be given to maintenance interventions rather than restoration ones. It is then necessary to promote a pool of long-term financing strategies for maintenance plans.
- **Transport and infrastructures:** the transport sector is fundamental to keep a functioning society because it allows the displacement of people, goods and services. Climate change will have a great effect on this sector: infrastructures will suffer more damage than nowadays and also the traffic patterns will be influenced by the changing conditions. Talking about infrastructures, the increasing temperatures will lead to an augmented vulnerability of roads and railways during the hot days but, on the other hand, to diminished problems due to low temperatures during winter season. Rainfalls variation will lead to increased soil instability, threatening infrastructures placed on unstable soils. Finally, floods will surely affect the structures located near waterways while the raising sea level could heavily damage ports, docks and other infrastructures placed along the coastlines. In order to prevent such issues, an optimization of the existing networks should be carried on instead of building new and impactful roads, also to prevent soil consumption that further increases hydrogeological instability. Moreover, an adaptation

of the structures to improve their efficiency standard and their resilience to climate change should be conducted. This should lead to organic Mobility Plans and to the creation of a network of climate-proof infrastructures.

- **Industries and dangerous infrastructures:** although not being considered much vulnerable to the effects of climate change, the industrial sector will surely have to face the impacts of the predicted increased number of extreme events. Managers of industries and dangerous infrastructures have to consider that climate change could become a risk for their activity; adaptation costs could be important, but costs derived from a missing an adaptation action could be even greater. Regarding new infrastructures, to obtain resilience the effects of climate change should be considered since the design phase. Instead, on already built infrastructures, the identification of the most vulnerable environments should be carried on, coupled with a continuous monitoring system. Following this, management and adaptation measures should be developed.

4.3 Friuli Venezia Giulia

4.3.1 Territory and demographics

According to the 2015 Environmental Evaluation Study [17], fundamental part of the Energetic plan for FVG [18] (analyzed later), and produced by the Autonomous Region Friuli Venezia Giulia (RAFVG), the territory of the FVG region presents four main types of environment based on altimetry: mountains, plains, inland hills and coastal hills (Figure 32) [17]. The regional landscape is fragile because of past seismic events, of its particular orography and of human interventions, with the latter leading to hydrogeological instability. However, the region displays also a great biodiversity and different landscapes even presenting, despite its small extension, seven different types of landscape (Figure 32) [17]. The Alps develop in the north-east part of the region, protecting hills and plains from the excesses of the continental climate; valleys are tight and mountains slopes are steep and covered by woods. The hydrographic network is torrential and present a pending layout, and remarkable sediment transport [17].

In the foothills most part of the territory is covered by woods and the hydrographic network presents a pattern similar to the mountains one, although displaying fewer pendant flows. The hills are located in the Collio zone and in the morainic zone of the Tagliamento river. There is also a presence of small and medium size flows and a presence of small lakes [17].

The hydrographic network of high plains is instead crossed by large rivers and endowed in a rich system of irrigation ditches and canals, often of artificial nature, this because the underlying gravelly mattress does not retain water. In the low plains, the hydrographic network is very dense, rich in water and present a substantially constant flow. Across the Friuli plain land reclamation, irrigation systems, land reorganization and containment of water bodies abound. In the lower Friuli plain, the reclamation works have stiffened long stretches of water bodies, as well as drained wetlands and cleared plain woods. The line of the resurgences determines the division between the two plains [17].

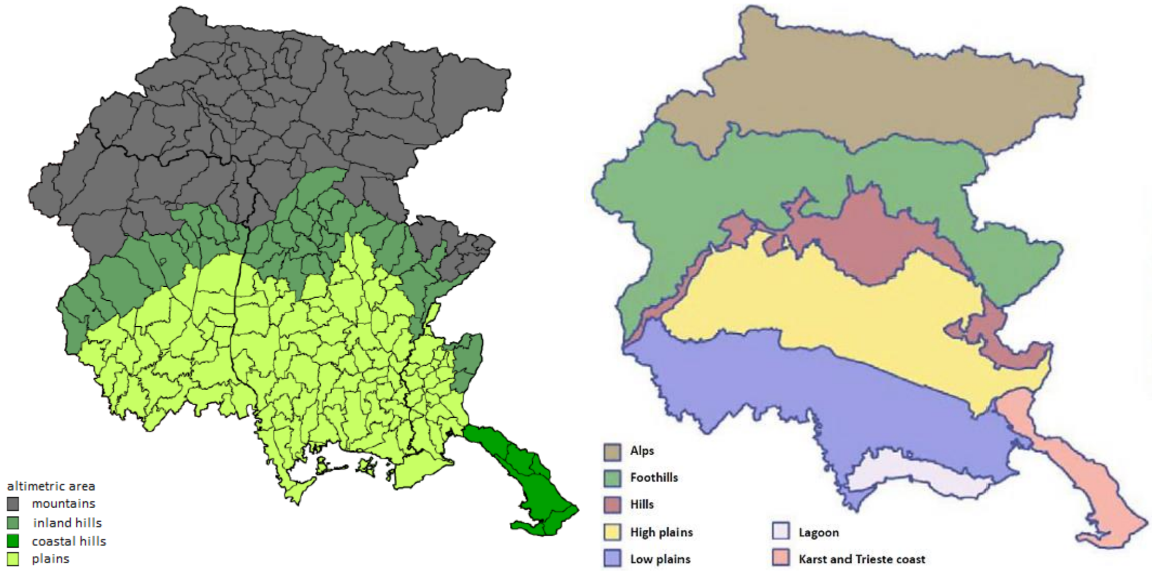


Figure 32. Territory altimetric distribution (left) and landscape types (right) in FVG [17].

There are two lagoons in the region morphologically distinguishable, Marano and Grado. The Marano lagoon is the most ancient, characterized by shallow waters (about a meter), crossed by natural canals formed by the mouths of the resurgence rivers (Stella, Turgnano, Cormor, Zellina and Corno). The lagoon of Grado is younger and less deep than that of Marano. Both lagoons are rigidly confined and protected by coastal cords subject to erosion, with few port mouths and continuous excavation of canals and water management according to the needs of human activities (fishing valleys, recreational boating and industry).

Finally, the Karst is distinguished by a set of surface and underground morphological forms determined by the dissolution processes of the limestones and by the total absence of a hydrographic network, apart from the Ospo and the Rosandra streams in the east and emerging Karst waters, lakes and springs, in the Gorizia area. The Trieste coastline is characterized by cliffs, where the Karst plateau flows with an average drop of 200 meters of rock directly on the sea [17].

Administratively the region constitutes a border area, confining with two different nations, Austria and Slovenia, and is divided in four ex provinces: Trieste, Udine, Pordenone and Gorizia (Figure 33) [17]. Population in the FVG region was registered to be 1.215.220 at the end of 2018. As it can be seen in Figure 33, three major settlements can be identified in the region, corresponding to Trieste, Udine and Pordenone. Urbanization shows a capillary pattern in all plains area, becoming rarefied in the mountains, with a behavior following valleys morphology. However, all the mountain area is affected by a depopulation effect and by an abandonment of agro-pastoral activities. The main activity is represented by ski tourism that is greatly affecting the natural environment because of the impactful ski-lifts and snow-making facilities. Also the foothills present a very low population density, such as the mountains area. The hills area instead presents many urban settlements located on the slopes of the hills and often characterized by the presence of historical buildings like castles. At the base of the hills is present a continuous urbanized strip. The plains are characterized by many anthropic settlements and national and international roads and energy infrastructures, which fragment the natural territory, reducing the natural quality and creating isolated and weak ecosystems. The landscape of the Karst and the coast is very varied. From the rural villages of the Karst to the Trieste conurbation, with advanced tertiary settlements and a large industrial and port area. The Karst plateau of Trieste has recently undergone many excavations due to large-scale traffic interventions. The area of Trieste and Gorizia also has very clear traces belonging to the Second World War as well as strong economic relations with Eastern Europe [17].

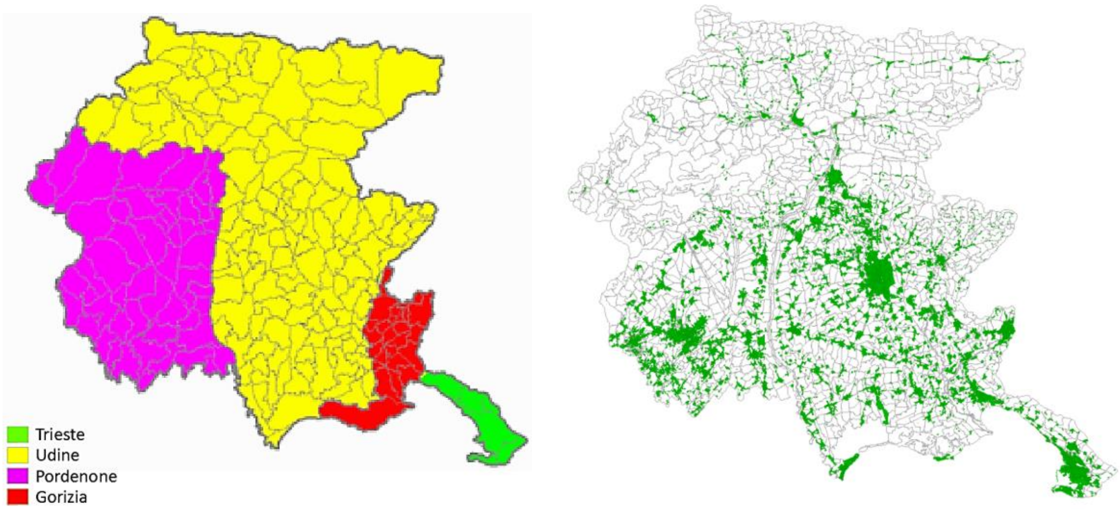


Figure 33. FVG ex provinces (left) and urban settlements distribution (right) [17].

Population shows a distribution that place a percentage of 5,4% of the people in mountains area, the plains contains the 59,1% of the total, while the hills (both coastal and inland ones) host the remaining 35,5%. Population density in FVG is 153,6 ab/km^2, value markedly smaller than the national one, of about 201,2 ab/km^2. Population mean age is registered to be of about 46,2 years, a value greater than the national one, showing an increasing trend (following the national pattern); Trieste is the oldest province, followed by Gorizia, Udine and Pordenone [17].

4.3.2 Energy consumption and baseline emissions

The energy sector in FVG is analyzed in the Energetic Plan for FVG (2015) [18]. According to this document, in 2008 (latest official data available), FVG imported most of its energy vectors, primarily natural gas (2.248 ktoe), oil (1.539 ktoe), and coal (691 ktoe), and produced internally just a very small amount of energy from renewables (316 ktoe), for a total of 4.465 ktoe of gross energy available (4.850 ktoe including renewable energy). Out of this amount, 2.226 ktoe (mainly coal and gas) were used for electricity generation which generated 1.311 ktoe of electrical energy. Considering internal losses and storage, the net total energy available was 3.352 ktoe and the final energy consumption was 3.339 ktoe. More recent measurements, related just to the final energy consumptions in FVG, were made also for the year 2012 [18]. According to these measurements, the final energy consumptions in FVG in 2012 amounted to 2.853 ktoe, with industry being the most energy demanding sector (1.194 ktoe), followed by the civil (583 ktoe), transport (579 ktoe), and tertiary (469 ktoe) sectors. Table 6 compares 2008 and 2012 final energy consumption in FVG. It can be noted that there has been a reduction of 15% in the final energy consumption since 2008.

	Agriculture	Industry	Transport	Civil	Tertiary	Total
2008	47	1.438	710	622	520	**3.339**
2012	27	1.194	579	583	469	**2.853**

Table 6. Final energy consumption in ktoe in FVG in 2008 and 2012 [18].

The consumption of coal for electricity production is estimated to increase, in particular due to the lower cost of electricity production deriving from this energy vector in comparison to natural gas. On the contrary, the use of natural gas is expected to decrease in FVG region in almost all activities. Regarding the transport sector, in the FVG region the most widely used energy vector is diesel and, starting from 2015, its increasing trend should stabilize both for heavy vehicles and those dedicated to public transport. The use of gasoline is predicted to substantially decline while the use of electric and natural gas vehicles is negligible. The use of wood in the region is estimated to grow substantially. In particular, domestic consumption of wood for heating purposes is expected to grow rapidly; the use of wood biomass for the production of electricity and heat is also growing [18]. For what concerns renewables, it is foreseen a decrease in energy production from hydroelectric plants (the main source of renewables in FVG), counterbalanced by a significant growth in energy coming from woody biomass and geothermal energy, and from photovoltaic that, as of 2030, is given as the second renewable energy source in the region, not far from the hydroelectric energy production [18]. Wind power and biogas, although slightly upwards since 2005, are still destined to remain marginal in terms of overall energy input.

The total GHG emissions in FVG are shown in Figure 34. CO_2 was the major GHG released, around 12 $MtCO_2$ in 2010. The main processes responsible for CO_2 emissions were energy production, followed by industry and transport sectors.

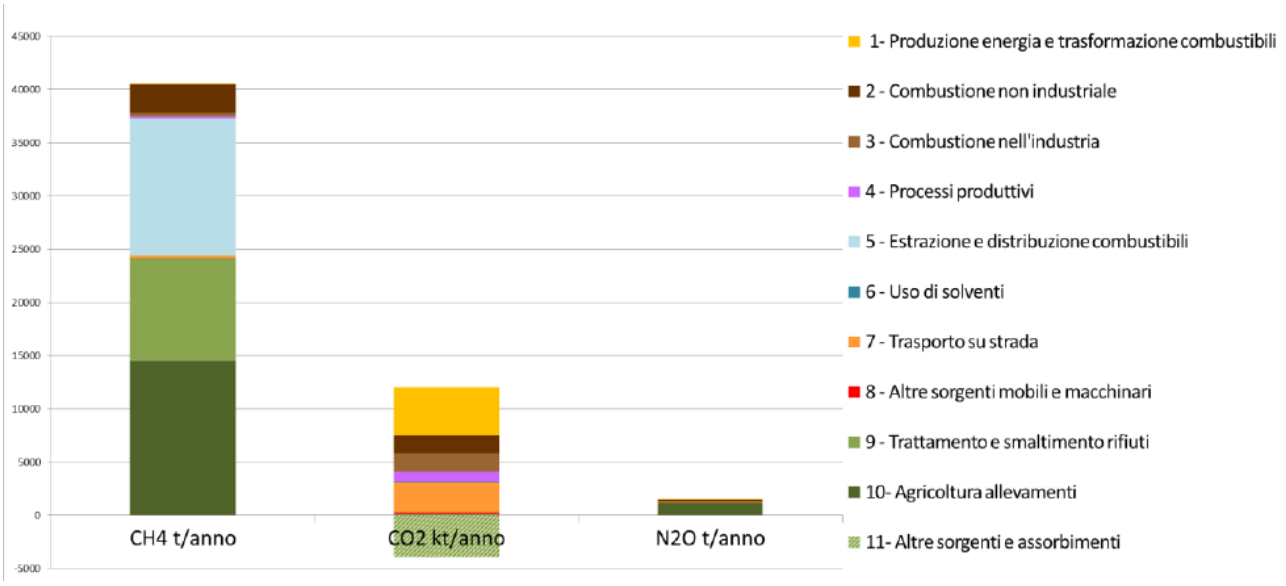


Figure 34. GHG emission in t (CH_4 and N_2O) and kt (CO_2) in FVG in 2010 [18].

4.3.3 Climate, observed climate changes, scenarios, risks and impacts

The main study on past and future climate changes in the FVG region has been carried on by ARPA FVG (Agenzia Regionale per la Protezione dell'Ambiente del Friuli Venezia Giulia), thus leading to the creation of the "Cognitive Study of Climate Changes and of their Impacts in Friuli Venezia Giulia" [19]. This document first displays a report of the climate changes detected during the 1961 – 2016 period then, through the analysis of Regional Climate Models (RCM), provides future climate change projections for the investigated region. The FVG region has peculiar geographic position and orography that influence its meteorology. The region is situated at mid latitudes where there is a strong contrast between the polar air masses and the tropical ones, a contrast that causes strong atmospheric perturbations. In addition, the northern mountain reefs significantly influence the atmospheric circulation, with wide effect on both temperature and rain. The Alps impede the flux of particularly cold air masses thus mitigating the temperature and retaining the fluxes of humid air from south-west and south-east. Very important is also the presence of the Adriatic Sea which also mitigates the temperature (particularly in the coastal area), allowing for cooler summers and warmer winters [19]. The average temperature in the coastal areas is around 15 °C, whereas in the plains is around 13,5 °C. In the high plains, hills and mountains, temperature varies according to the altitude and the orientation towards the Alps. Figure 35 shows the average temperature in FVG in the period 1993-2013 [19].

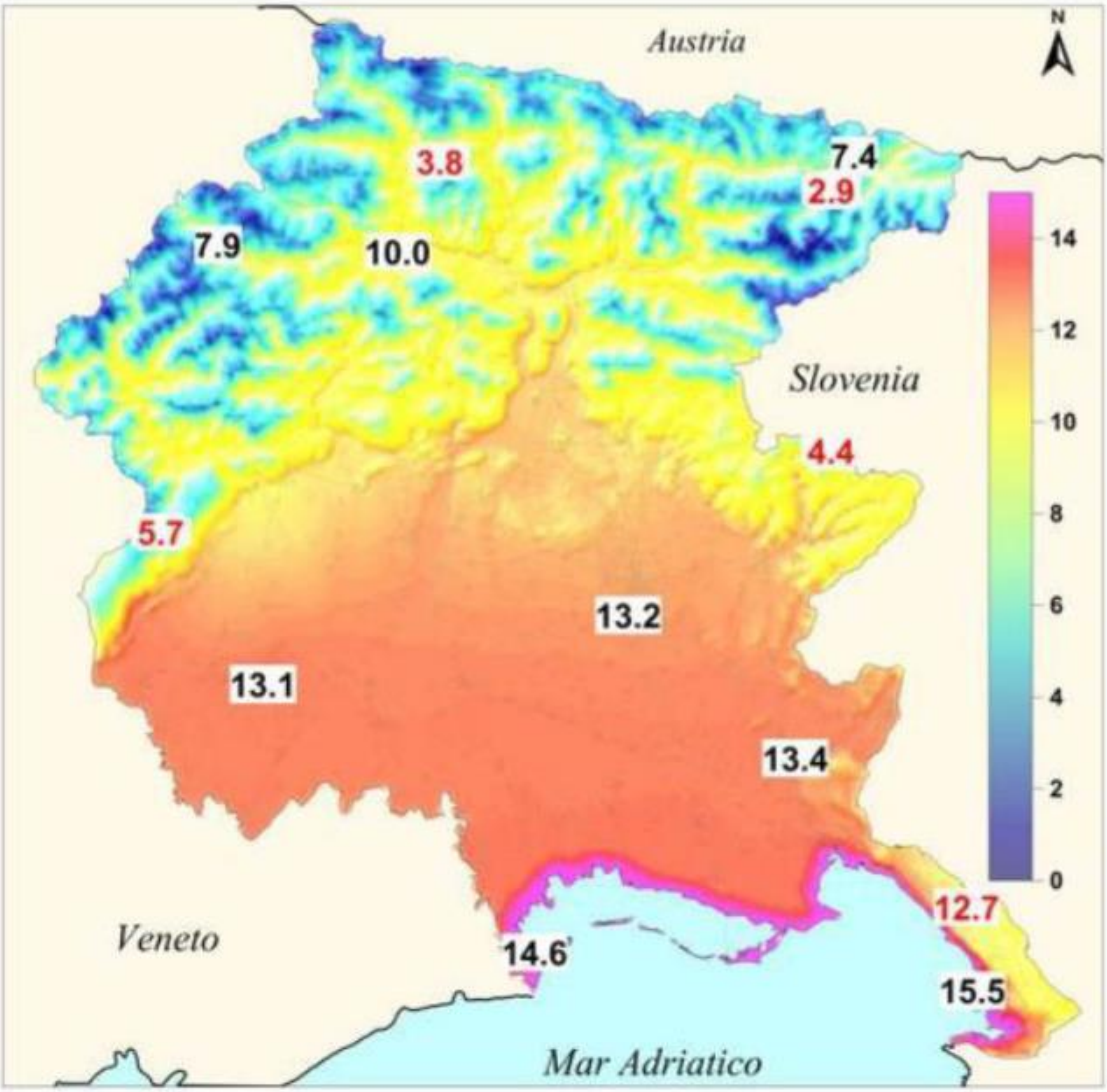


Figure 35. Temperature trends in FVG [19].

For what concerns precipitations, the FVG region can be divided in four distinct areas: coasts, plain and hills, pre-alpine, and alpine. The coast is the area with the least amount of rain, with annual average of 1.000-1.100 mm. The plain and hills areas measure a total of 1.200-1.800 mm of rain each year, whereas the pre-alps can reach 2.500 – 3.000 mm of precipitation. Finally, the Alps experience a total of 1.400-1.600 mm of rain per year [19]. Over the year, February is the month with the least amount of rain (60 to 140 mm, depending on the area), whereas during spring precipitation increases to reach its maximum in June, to drop again in July and August. From the end of the summer season, precipitation tends to increase significantly and make autumn the rainiest season. Figure 36 shows the mean annual distribution of rain in FVG [19].

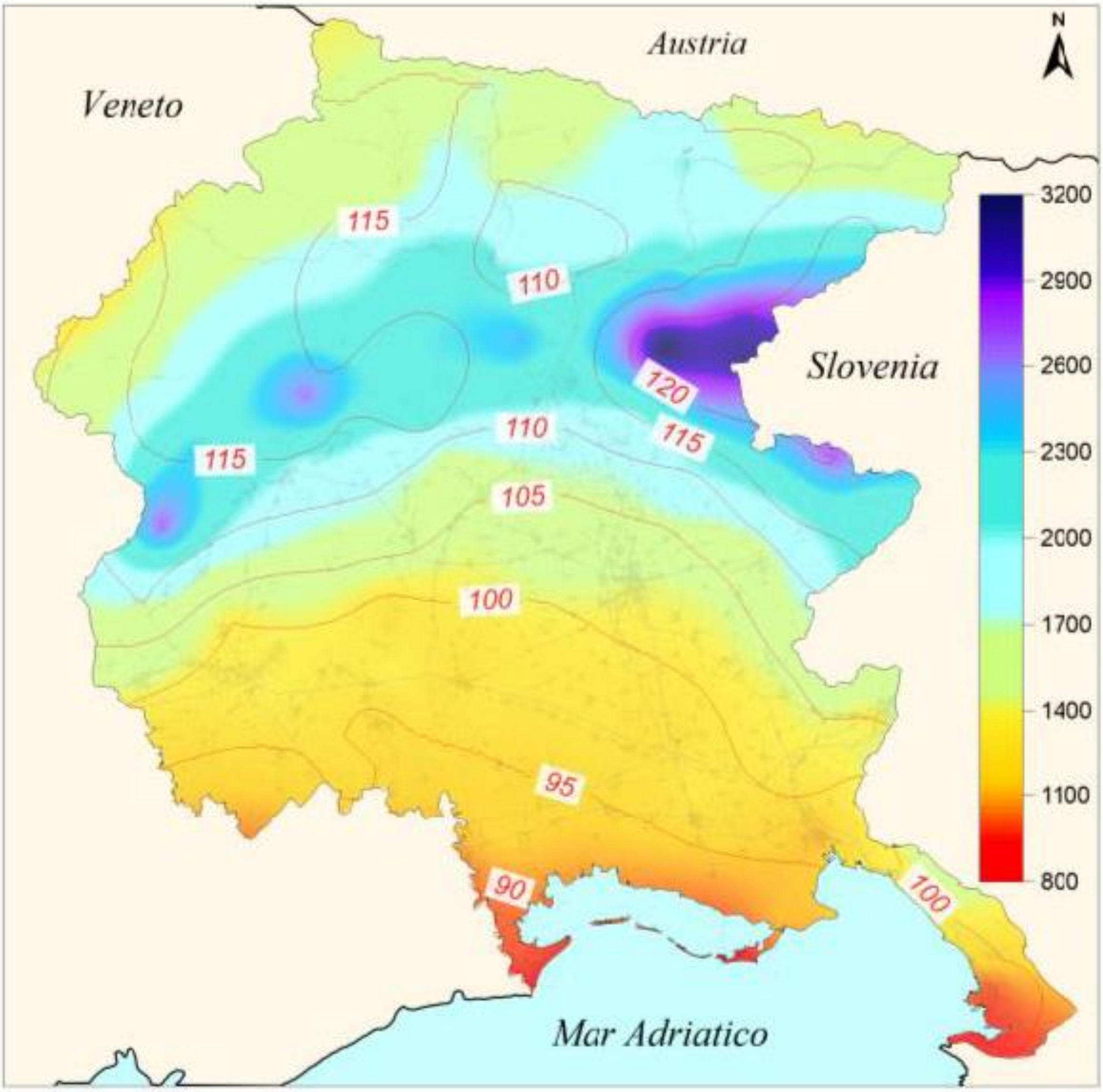


Figure 36. Precipitation trends in FVG [19].

Similarly to the national scale, in FVG an increasing trend of temperature has been detected and reached almost +1,5 °C since 1960. The yearly mean temperature increased 0,3 °C per decade over the last fifty years with a significant trend to accelerate in the last decades (Figure 37). This tendency is even more remarkable in the Alps, where the mean temperature at 2.200 m of altitude grew up to +1,7 °C if compared to the 1851 values, showing almost a double increase compared to the global values [19].

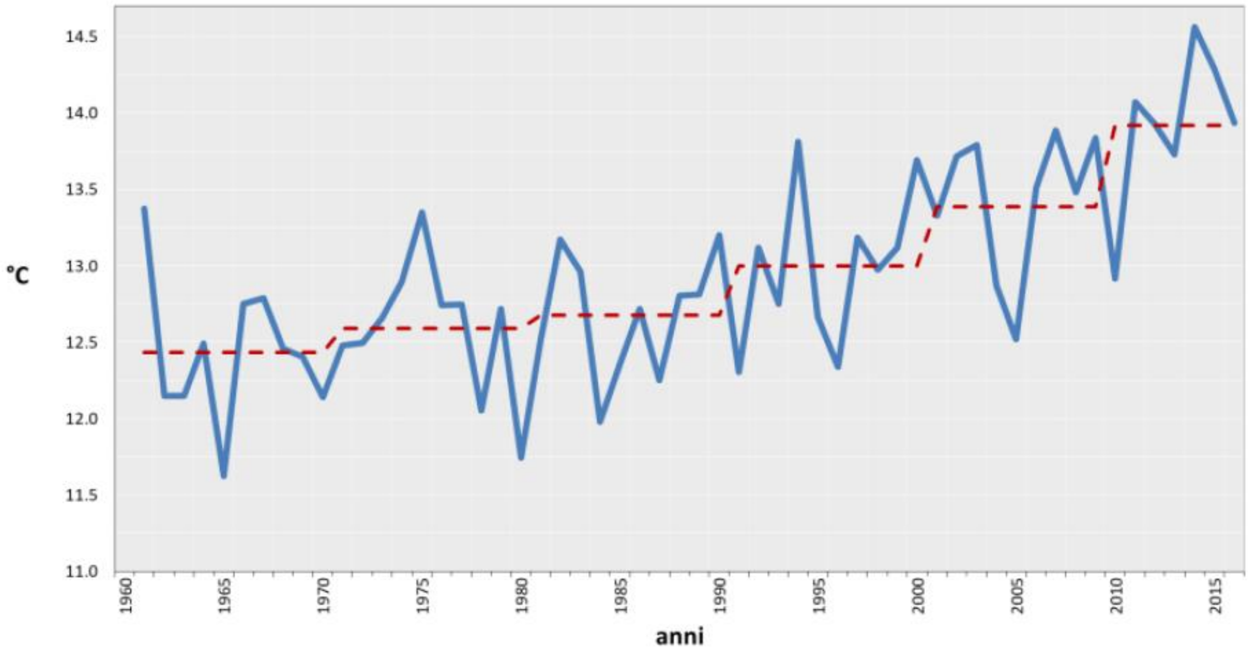


Figure 37. Yearly mean temperature trend in FVG during 1961 – 2016 period (blue line) and 10-year average temperature (red-dotted line) [19].

Regarding rainfalls, the actual trend shows an increase of the events in the western part of the region (more remarkable in the Alps) and a decrease of about 15-20% in the eastern part (Figure 38). Analyzing the seasonal behavior, in almost all the region, spring and summer rainfalls diminished of a value between 2 and 4 mm, while autumn and winter events show a slight increase [19]. Another important parameter is the number of rainy days, in which at least 1 mm of rainfall is measured. Similarly to what is observed for precipitation, the rainy days detected an increasing number in the western part of the region and a reduction in the eastern one. Regarding seasonal behavior, the same pattern of precipitation is detected.

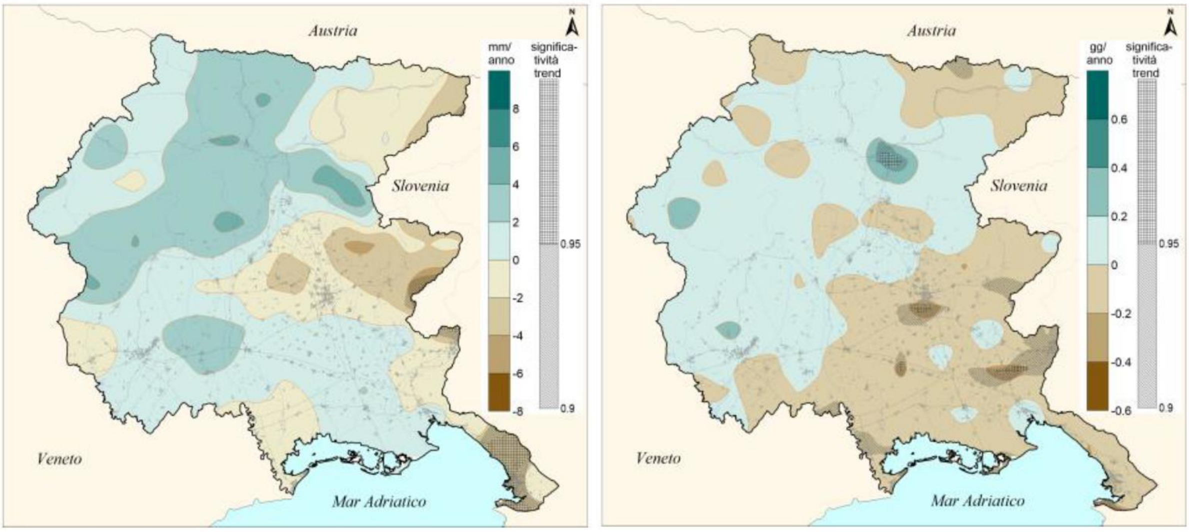


Figure 38. Rainfalls (left) and rainy days (right) change during 1961 – 2016 period in FVG [19].

In the analysis of the heat waves, compared with the mean temperatures in 1961-1990, there is a significant evidence of an increasing trend. In particular, during the summer season the number of days where the maximum temperature is over 30 °C increased from 30 to 50, while the number of 'tropical nights' (minimum temperature above 20 °C) increased from 5 to 15. Moreover, during winter season, frost days (temperature below 0 °C) diminished from 60 to 40 [19]. Unlike other northern Italy regions, in FVG the natural conditions to form permafrost and glaciers are not satisfied. This because no mountain reaches 3.000 m of altitude and the morphologically suitable areas for accumulation and preservation of ice masses are generally located between 1.700 and 2.400 m of altitude, far below the average altitude of zero temperature and of the equilibrium line of the glaciers. Despite of these specific characteristics, the Alps in FVG still preserve 23 snow-covered bodies, remnants of the Little Ice Age (LIA) occurred between the year 1300 and 1865 and characterized by a temperature diminution on the Alps of about 2 °C, associated with an increase of winter mean snowfalls. The reduction of glaciers began immediately after the end of the LIA and this situation is already in progress; however, it has been detected that in the last century and even more in the last thirty years, the reduction process was extraordinary fast. The peak glaciers surface during the LIA was 1,55 km^2 but now covers only 0,22 km^2, showing a reduction of 82%; regarding the volume, it passed from 45,40 km^3 to 1,82 km^3, a reduction of 96% [19]. Another consequence of the increasing temperature is the different behavior of snowfalls and of snow accumulation and ablation seasons. All these effects led the equilibrium line of the glaciers to move from the 2.300 m of altitude detected during the 1920 – 1940 period, to the actual 2.750 m. In this scenario of general reduction of the cryosphere, an opposite trend is detected since 2005. In fact, due to the abundant snowfalls occurred during the last years, a situation of stability was reached, sometimes even getting positive yearly snow mass balance, contrary to what is detected on the rest of the Italian Alps. This phenomenon also had an effect on the equilibrium line, which dropped its altitude of about 60 m in the last decade.

During the 1920 – 2000 period there were no remarkable changes in sea temperature and salinity, but an increasing trend for both has been detected since 1970, coherently with the atmospheric temperature increase. A small increase in salinity during spring and summer seasons since 1970, probably because of the reduced contribution of fluvial water from the rivers in this season. Regarding sea level, comparisons to 1901-2010 values indicate an increasing trend of +1,3 mm/year, lower than the global one, due to an interruption of the Mediterranean Sea level increase occurred during the 1960 – 1990 period. However, since 1992, the average rise in sea level has drastically increased to 4,4 mm/year. Totally, the sea level has risen 20 cm since 1880. To be taken in consideration are also the vertical movements of the Earth's crust (known as subsidence), that in the FVG region reach 0 to 3 mm/year depending on the area, with peaks up to 5 mm/year in some locations. In addition, generally during summer season, low pressure and Sirocco winds generate uprising of the sea level, in events known as storm surges, showing an increasing trend since 1918.

Related to climate change projections in FVG, since many coupled Global-Regional models are available, the ARPA FVG document chose the most representative ones following the prerequisites shown below:

- data availability for all RCP scenarios;
- availability of models having high, medium and low climate sensitivity;
- good performance while reproducing climatology during the reference period chosen (1970 – 2005).

Because of these prerequisites, five different models were chosen:

1. HadGEM2-ES_RACMO22E;
2. MPI-ESM-LR_REMO2009;
3. EC-EARTH_CCLM4-8-17;
4. EC-EARTH_RACMO22E;
5. EC-EARTH_RCA4.

The reference period covers the years between 1976 and 2005 while the projections cover the years 2005 to 2100. The scenarios used are the RCP2.6, RCP4.5 and RCP8.5. The future projection was compared with the reference one in order to obtain the predicted anomalies. The future anomalies of the relevant climatic parameters are then computed for every RCP scenario using every model listed above; to obtain a significant result that consider the intrinsic uncertainty of each model, the ensemble of the models was reported [19].

The different RCP scenarios for FVG show that in winter, the mean value of the investigated models for what concern temperature is predicted to increase from 1.3 °C (RCP2.6) to 5.3 °C (RCP8.5) at the end of the century (Figure 39). Summer temperatures shows a similar trend, with a possible increase up to 6 °C for the RCP8.5 (Figure 40). In the RCP8.5, the temperature continues to rise until 2100, while in the other two scenarios it tends to stabilize in the second part of the century. The five models used show a spread around the mean value of about +/- 1,5 °C for winter and of +/- 2 °C for summer temperature predictions. This is due to the different representation in the models of the investigated processes; moreover, this spread tends to increase in time, especially for summer season projections [19].

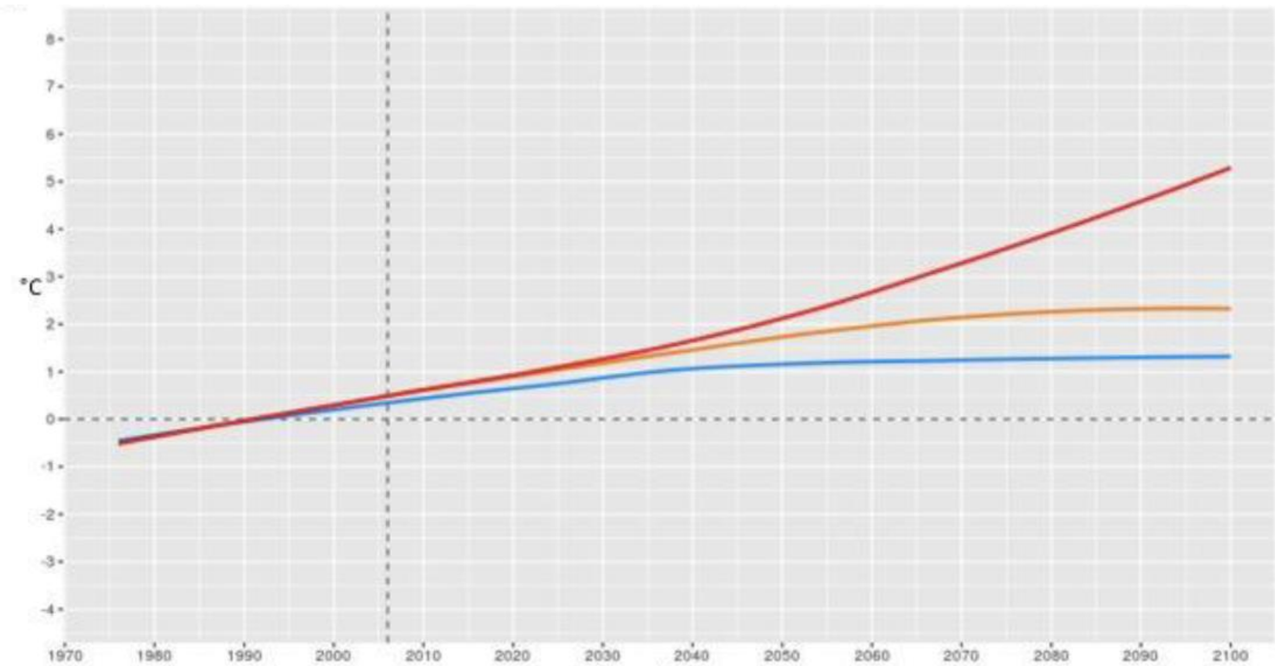


Figure 39. Winter temperature anomalies in FVG to 2100 for RCP2.6 (blue line), RCP4.5 (orange line) and RCP8.5 (red line) [19].

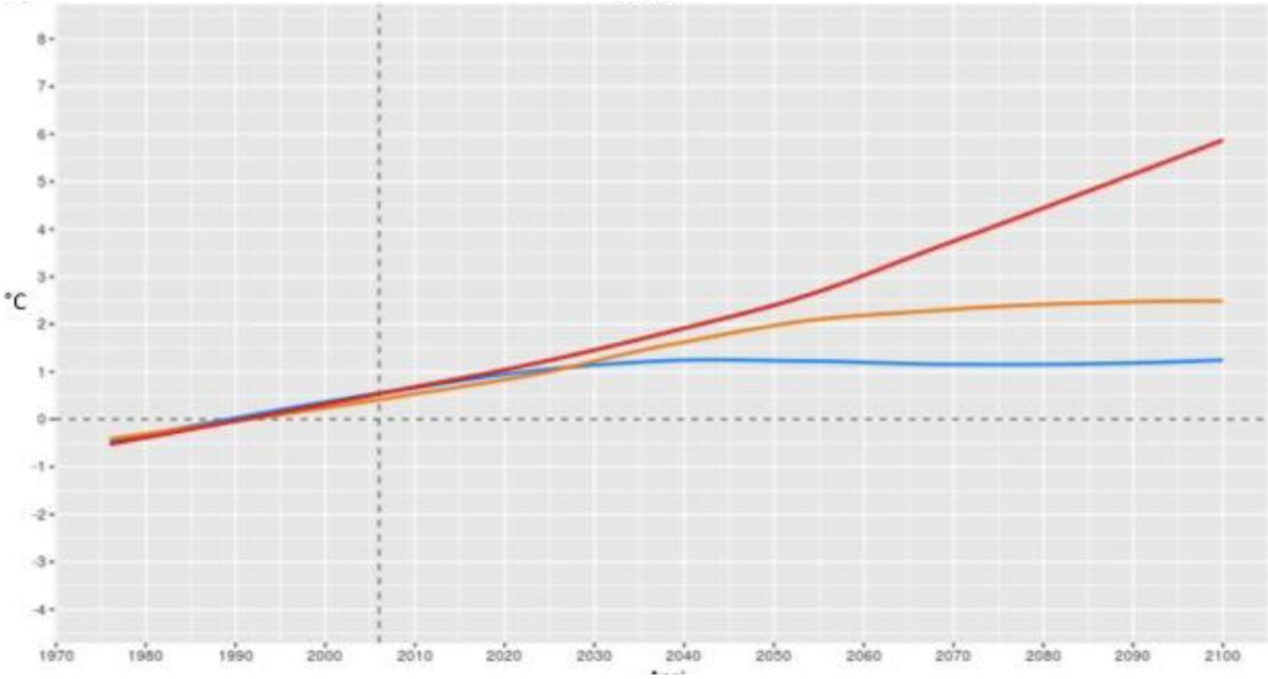


Figure 40. Summer temperature anomalies in FVG to 2100 for RCP2.6 (blue line), RCP4.5 (orange line) and RCP8.5 (red line) [19].

Precipitation constitutes another relevant climatic process to be investigated. The models report an increasing tendency of winter precipitation for all the RCP scenarios (Figure 41), more remarkable in the second half of the century, showing an increase of about 20 – 30% of precipitation in 2100. For the summer precipitation, the results show different behaviors (Figure 42), consisting in variations between +/- 10% compared to the reference values [19]. Only the RCP8.5 shows a significant tendency of precipitation decrease, with a deficit of about 25% at the end of the century. However, precipitation modelling is more uncertain than temperature ones, so the results should be read taking into account this aspect. Regarding the geographical distribution, rainfalls show a more variable behavior across the territory than temperature. In the RCP2.6, winter rainfall increase is more evident in the coastal area and in the Alps than in the plains, while summer rainfall variations are relatively small (in order of about 5%) for 2021 – 2050 period, showing a slight increase in coastal area at the end of the century [19]. In the RCP8.5, winter rainfall variations are more marked, showing more relevant rainfalls in the Alps and in the coastal area. During the summer season a remarkable reduction of rainfalls is observed in the central part of the region, especially at the end of the century, when the reduction could reach a percentage of about 20 – 25%.

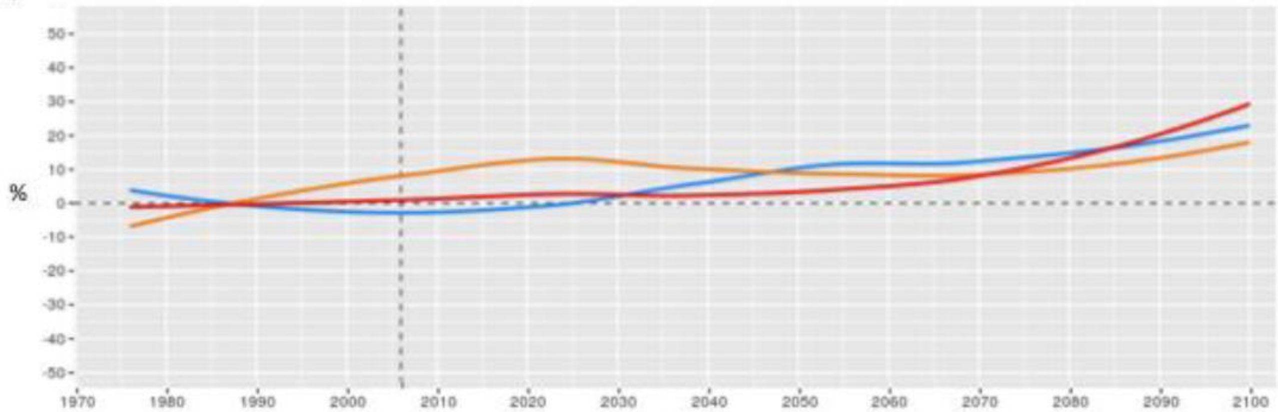


Figure 41. Winter rainfall anomalies in FVG until 2100 for RCP2.6 (blue line), RCP4.5 (orange line) and RCP8.5 (red line) [19].

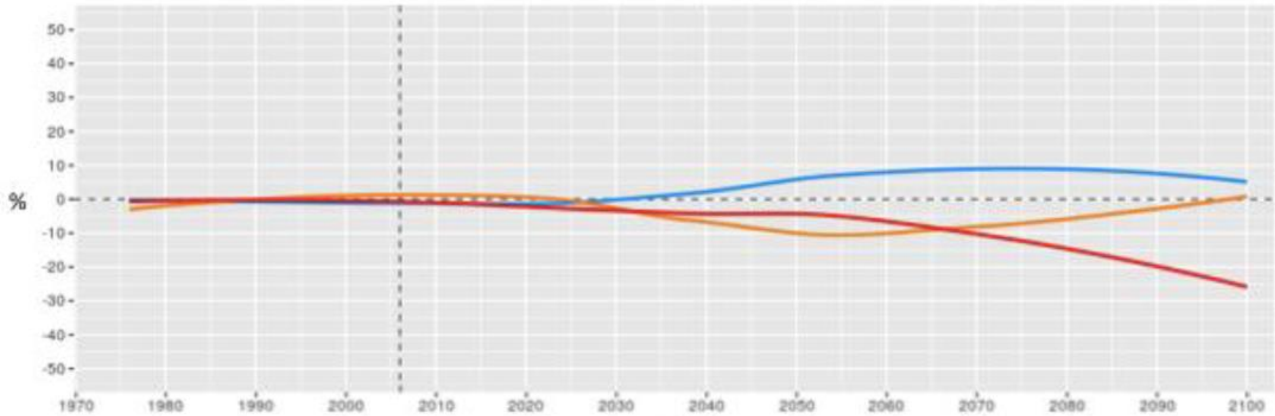


Figure 42. Summer rainfall anomalies in FVG until 2100 for RCP2.6 (blue line), RCP4.5 (orange line) and RCP8.5 (red line) [19].

A relevant aspect to be investigated is related to extreme events, both in temperature and in precipitation.

Heat waves, defined as periods of at least 5 days in which the daily mean temperature is above 5 °C the moving average temperature of the reference period. The number of days affected by heat waves in the reference period was less than 5 per year. The RCP2.6 scenario displays for the future 5-10 days per year (one or two heat waves). The same behavior is shown in the RCP8.5 for the period 2021-2050, while at the end of the century 40 days per year could be affected by heat waves. This could lead to remarkable consequences on human's health, agriculture, farming, glaciers and on the most vulnerable ecosystems.

Other extreme events are the hot days having maximum temperature over 30 °C and the tropical nights, showing minimum temperature exceeding the 20 °C. For these events, five FVG locations were analyzed: the four provinces (Trieste, Udine, Pordenone, Gorizia) and the town of Tolmezzo, representative of the mountain territory. In the following tables, the reference number of hot days (Table 7) and tropical nights (Table 8) are reported, as well as the ones predicted at the end of the century in the three RCP scenarios and the percentage of variation.

Location	Reference	RCP2.6	RCP4.5	RCP8.5
Trieste	20	30 (+50%)	40 (+100%)	70 (+250%)
Udine	30	50 (+65%)	60 (+100%)	90 (+200%)
Pordenone	30	55 (+85%)	65 (+115%)	95 (+215%)
Gorizia	25	50 (+100%)	60 (+140%)	95 (+280%)
Tolmezzo	15	30 (+100%)	40 (+160%)	70 (+360%)

Table 7. Number of 'hot days' in the reference period and predicted with all RCP scenarios and relative percentage of variation [19].

Location	Reference	RCP2.6	RCP4.5	RCP8.5
Trieste	40	70 (+75%)	90 (+125%)	120 (+200%)
Udine	5	20 (+300%)	35 (+600%)	70 (+1300%)
Pordenone	5	25 (+400%)	35 (+600%)	75 (+1400%)
Gorizia	5	20 (+300%)	35 (+600%)	70 (+1300%)
Tolmezzo	3	5 (+65%)	15 (+200%)	45 (+800%)

Table 8. Number of 'tropical nights' in the reference period and predicted with all RCP scenarios and relative percentage of variation [19].

Trieste, representative for the coastal area, is the location having the major number of tropical nights (40) and the minor of hot days (20) for the reference period. This is also the location affected by the minor percentage changes in the various RCP scenarios for 2100, showing an increase of tropical nights between 75% and 200% and of hot days between 50% and 250%. This is probably due to the mitigation effect of the sea. Regarding Udine, Pordenone and Gorizia, representative of the plains, in the reference period they display a relevant number of hot days (about 30) but very low values of tropical nights (5). This represents the typical temperature swing that occurs between day and night in the plains environment. Regarding the number of hot days predicted by the RCP scenarios, the three locations show a similar behavior, with an increase of hot days between 65% and 280%. About tropical nights, the behavior is essentially identical in all three locations, showing a huge increment in their number, between 300% and 1400%. Finally Tolmezzo, representative of the mountain environment, shows the lowest number for both hot days (15) and tropical nights (3), coupled with the greatest percentage increase of hot days, between 100% and 360%, and an intermediate increase of tropical nights, between 65% and 800%. Global warming, besides increasing the number of hot days and tropical nights, will also reduce the frost days in which minimum temperature falls below 0 °C. In Trieste, the reference number of frost days is 10 – 20 per year and is predicted to diminish in 2100 to less than 10 for RCP2.6 and 4.5 scenarios, and even to 0 for RCP8.5. Regarding Gorizia, Udine and Pordenone, the reference number of frost days is 60 – 70 per year, predicted to diminish in 2100 to 30 – 50 range for RCP2.6 and 4.5 scenarios and about 10 for the RCP8.5. Finally, Tolmezzo will see a reduction from 80 days per year (reference value) to 10 for the RCP8.5 scenario in 2100.

Finally, the last extreme events considered in the study are the particularly intense rainfalls, causing flash floods and erosion phenomena. These are usually studied considering the 95th percentile of the daily precipitation distribution. This index identifies the amount of precipitation exceeded only in 5% of rainfall events, therefore the most dangerous and harmful ones. This index is usually computed for a reference period (in our case 1986-2005) and is then used as an identifier of the most extreme events for the future. For FVG region, the number of days that exceed the 95th percentile were computed for future and then compared with the same number computed for the reference period. According to the RCP2.6 scenario, during the winter season the extreme events show an increase across all the region, more marked in the western part of it (Figure 43). During summer season instead, the eastern part of the territory is interested in a reduction of events, while the rest of the region shows a little increase (Figure 44). Considering the RCP8.5 scenario, during the winter a general increase of events is displayed and the most remarkable ones will take place in the coastal area. In summer instead, a general decrease of events will occur, especially in the plains and in the eastern part of the region. In general, it can be noted that the geographical distribution of the extreme events is similar to the distribution of the mean precipitation (explained before). However, the number of days with extreme events varies less. This means that on average extreme events intensity tends to vary more markedly.

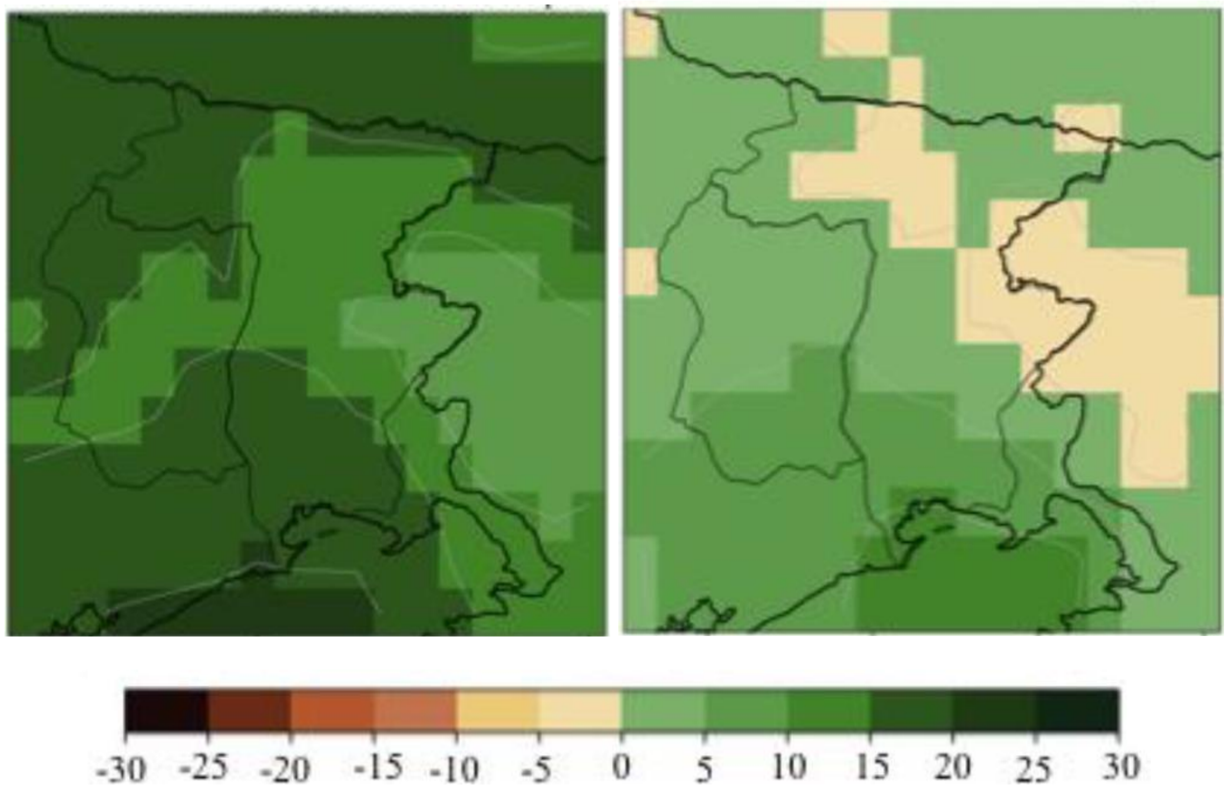


Figure 43. Intense rainfalls in FVG in 2071-2100 for RCP2.6 scenario in winter (left) and summer (right) [19].

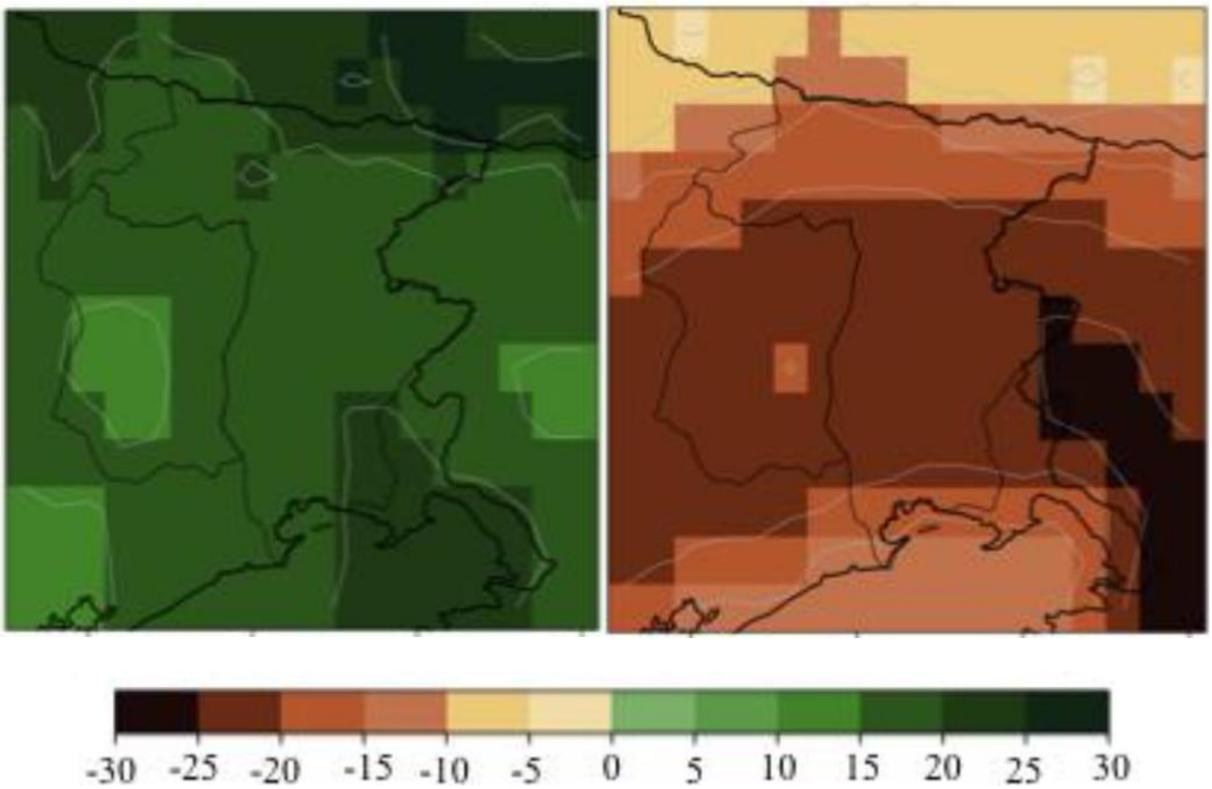


Figure 44. Intense rainfalls in FVG in 2071-2100 for RCP8.5 scenario in winter (left) and summer (right) [19].

Regarding the cryosphere, the main parameter to evaluate is the altitude of the equilibrium line of the glaciers, actually located at 2.700 m. For the RCP2.6 scenario, the line is expected to have a stabilization to 3.000m up to 2030, slightly reducing afterwards. The situation could be different in the other two RCP scenarios, where the line is expected to rise to 3.000 m in 2030, and reach a quote of 3.400 – 3.800 m by 2100, which would imply the total disappearance of the cryosphere in FVG by the end of the century [19].

The FVG sea behavior is only partially influenced by local weather conditions, while a significant part of its variability is affected by the circulation of the Adriatic and Mediterranean seas and by the Atlantic Ocean. On the Mediterranean scale, all models predict a sea warming and an increase in salinity for the 21st century. The last phenomenon is the result of the increase in the net water flow from the sea to the atmosphere, due to higher temperature, less precipitation and reduced fluvial intake and to the increase in evaporation, not compensated by significant variations in the flow across the Strait of Gibraltar. The detected change is greater in the northern Adriatic, which undergoes greater heating due to the low depth and where the salinity increases more due to expected lower river supplies. It is estimated that, by the end of the 21st century, an increase in the Adriatic surface temperature of 3,5 °C and of salinity equal to 0,96 will occur, while the average increase in temperature and salinity over the entire water column will touch 3,7 °C and reach 0,80, respectively. Regarding sea level, it is predicted an increase of 27 – 30 cm within 2046 - 2065 and of 52 – 63 cm within 2081 – 2100, with uncertainties of +/- 15 cm and +/- 19 cm respectively [19].

For the extreme events of storm surges, the studies don't show a clear trend for the future, having some predicting a slight increase of events, other seeing a decrease or a negligible variation compared to the actual events. Generally, all models predict an increase of the average level of the Mediterranean Sea, due to the augment of volume generated by water mass heating, only partially compensated by the volume reduction caused by the salinity increase [19].

4.3.4 Local mitigation and adaptation measures

In order to face up the effects of climate change many municipalities in the FVG region have already created countermeasures with the aim of mitigating them and of adapting to the future climatic environment. These measures are known as Sustainable Energy Action Plans (SEAP) and they represent an extremely local response being restricted to the city they belong to. In the FVG region 50 municipalities have entered the SEAP process, although with different degrees of progress: 38 of them have presented the Action Plan, 7 already have a in progress monitoring of the Plan, 4 are on hold and 1 have displayed the intention to enter the program (Figure 45).

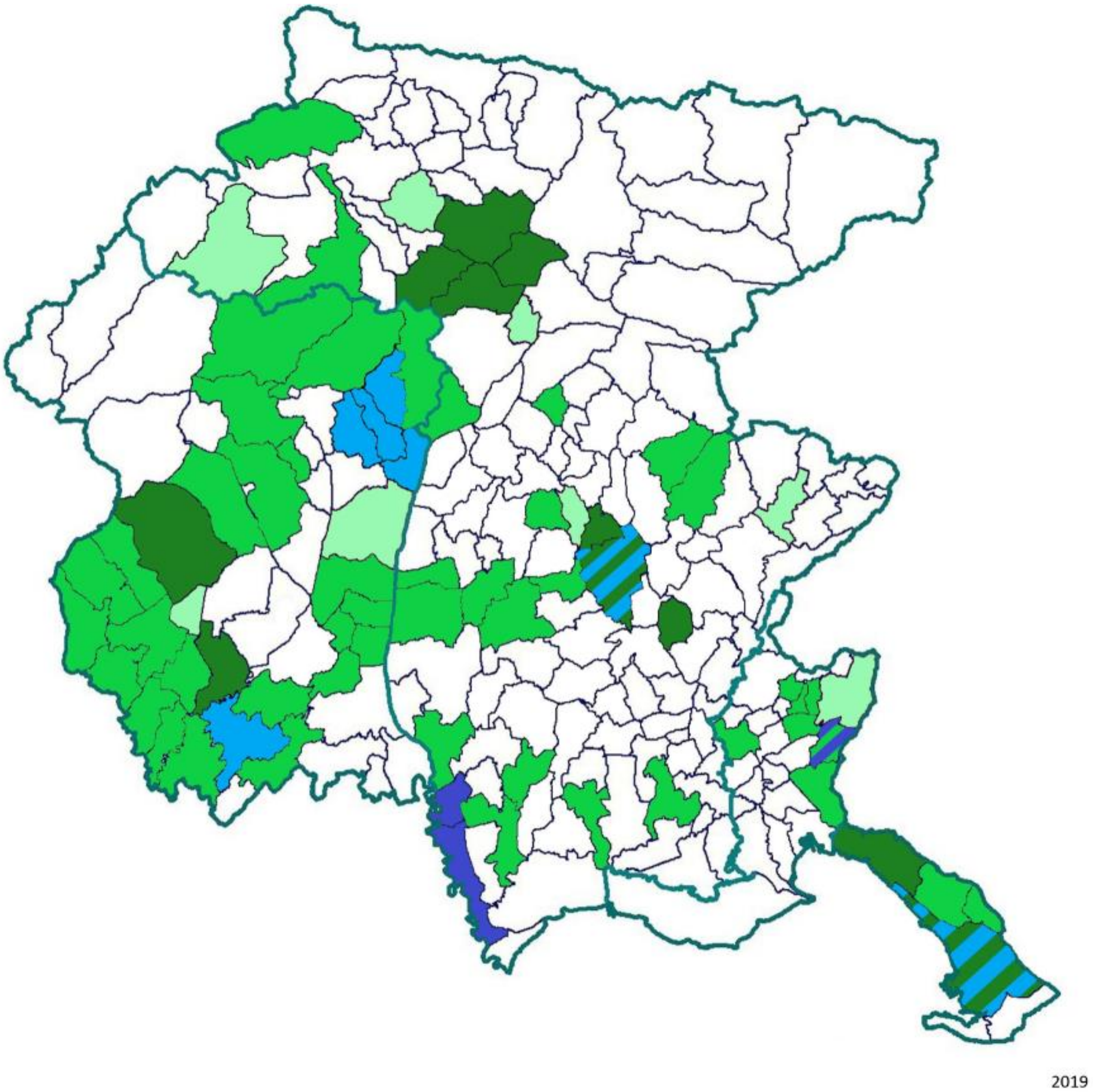


Figure 45. FVG municipalities that signed the Covenant of Mayors 2020 (light green), SEAP presented to the Covenant of Mayors but not monitored (green), SEAP approved by the Covenant of Mayors and monitored (dark green), municipalities that signed the Covenant of Mayors 2030 (light blue), SECAP presented to the Covenant of Mayors 2030 (dark blue).

In order to have a general outlook on every part of the region, five different SEAPs have been analyzed. The documents developed in Trieste [20] and Latisana [21] represent the coastal area of FVG region; the ones developed in Udine [22] and Pordenone [23] stand for the plains area and the one created in the inter-municipal area of Tolmezzo [24] represent the mountains one. Because of the different climatic zones in which these cities are located, different measures are planned to be set up in the future. However, in all the studied cases, some recurrent actions are detected in all the five SEAPs, due to common issues these urban settlements face. Obviously, all these actions are strictly connected with each other. In the following, the common actions adopted in every SEAP are reported, divided according to the sector of application.

- **Public and private energy consumption**: all of the five SEAPs strongly aim to reduce the energy consumption in the urban settlements. The first measure to be set up is the creation of a municipal energy management system. This will have the purpose to collect data about all the customers of the municipality in terms of served areas, consumption rates of electricity, gas, oil and other fuels, thus creating an efficient and upgradable informative system. Said this, the two main sectors in which the public administration could directly operate to reduce energy usage are the management of public illumination and of public buildings like hospitals, schools and offices. Once detected the critical issues of this public properties, an energetic refurbishment plan of buildings and illumination is set up. About the formers, the most suitable intervention is the substitution of the existing heat generators with newer and more performant ones. However, other suitable interventions are the thermal insulation of the buildings, the substitution of the windows and a rationalization of energy consumption; the latter could be reached through an adjustment of heating and cooling systems set-point temperatures and activation time. About the public illumination, a complete substitution of the existing lamps with new LED lamps is programmed. If the reduction of public energy consumption is an objective reachable in a relatively short amount of time, the private sector will probably take longer time to achieve such goal. This is due to the fact that in private sector there are many actors involved and less prominent to spend money to reach the aforementioned objectives. The public administration, however, can promote actions aimed to reduce energy consumption through the introduction of various incentives, like fiscal ones. Said this, the interventions needed to reduce energy consumption in private buildings are almost the same described for the public ones; however, the rationalization of energy usage cannot be obtained with external enforcement of temperature set-point and activation time limits for the plants. Instead, incentives to insert home automation in house heating and cooling management will be useful instruments to rationalize private energy usage.
- **Urban mobility:** the principal aim is to reduce the use of private vehicles and the emissions of public ones. To obtain this, a substitution of old buses with newer and less pollutant ones (for example buses that use methane gas as fuel) is programmed, coupled with the creation of new bicycle lanes and of limited traffic areas. Another useful improvement is the substitution of the intersections regulated by traffic lights with

roundabouts, thus decongesting the road network and reducing the emissions of the circulating vehicles. Another method to decongest the roads could be a planned rationalization of people and goods transport. Because of the number of circulating vehicles being extremely important for energy and fuel consumptions and air pollution, some measures like car-pooling and car-sharing would fit to reduce such number. Finally, new recharge points for electric vehicles are going to be set in the center of the settlements in order to promote the usage of such vehicles.

- **Waste treatment:** the municipalities are committing themselves with a series of initiatives and interventions to increase the percentage of recycled waste and consequently reduce the quantity of unsorted waste in their municipal area. A new waste collection system has already been introduced, involving the separate collection of organic waste, plastic packaging, paper, glass, grass and branches, in the so-called "proximity bins". Citizens were given kits of biodegradable organic waste bags and information documentation; the street bins have been replaced with an increase in those for the collection of plastic. The municipalities have also organized meetings with the citizens to illustrate the new collection methods. The call for bulky waste service was also launched to reduce the abandonment of this type of waste on the street and to provide a service to people in need or in difficulty. For the future all these measures are going to be strengthened in order to achieve even higher percentages of recycled wastes, thus reducing the impact on natural environment of this sector.
- **Sensitization and education:** in all the analyzed locations great attention is posed on the sensitization end education of citizens about climate change and anthropic impact on the natural environment. Information and training campaigns are planned to sensitize both citizens and companies about energy and water savings. Another important measure is the promotion of virtuous and conscious lifestyle including the use of products without packaging, initiatives like the ‘Water Houses’ and many others. Another specific objective of the activity is to raise awareness among students and teachers about energy and environment issues and, at the same time, obtaining concrete results about the reduction of CO_2 emission due to school buildings. The action develops with two activities: training about energy and energy usage reduction in schools, and monitoring of energy, water and materials consumption and waste production.
- **Public health:** an extremely important aspect to consider for local administrators is public health status; about this argument many factors should be taken into account. In the following some of the principal ones are reported, along with the measures to improve them. The predicted increase of mean temperatures will cause a major number of heat

waves during summer season, thus causing important health issues to the population, especially to the weakest parts of it, like old people, children and sick people. One major objective for the future is the mitigation of the effects of heat waves in urban settlements. This can be done by improving urban reforestation and through the creation of gardens and green roofs. These interventions will help reducing solar radiation effect and increasing transpiration and evaporation phenomena, then leading to a general reduction of air temperature in urban settlements, causing subsequently also a reduction of energy usage for building cooling. Very important will also be the capacity of the sanitary system to prevent possible diseases due to climatic phenomena and, when necessary, to quickly respond to sanitary emergencies. This will require a constant and adequate preparation of sanitary staff on all levels as well as monitoring systems for all the aspects that could influence public health, like air and water pollution.

- **Electricity production from renewable resources:** if the reduction of energy usage in both public and private buildings is fundamental, another crucial aspect to reduce human impact on the natural environment is to rely on renewable resources to produce electricity. Great attention will be posed to photovoltaic system as they constitute a non-pollutant solution. The public administration aims to install these systems on a large number of public buildings roofs where this is possible and not restricted by architectural regulations. Through the exploitation of solar radiation, the GHG emissions produced to provide electricity to the buildings, especially to cool them down, will be greatly reduced. These systems could also be installed on private buildings roofs and their usage is promoted through fiscal incentives for the private investors whom want to rely on these kinds of electricity production. There are plenty of methods to produce electricity with little to no gas emissions like exploiting the methane gas distribution network through the installation of a turbo-expander to recover the enthalpy jump of the gas when it passes from the SNAM to the local distribution network. Similar approach can be used in aqueducts environment, where the installation of hydroelectric power stations inside the aqueduct itself could exploit the hydroelectric jumps already present in the infrastructure, thus reducing non-renewable production of electricity and sensitizing the citizens about the energy theme. Even the sewer network could be useful in this way, in fact, by using an anaerobic treatment of sewage, biogas could be obtained to produce both electricity and heat.
- **Certified Green Electricity purchase:** local administrations often prefer to purchase electricity by third parties rather than produce it by themselves; about this practice, an alternative chance of growing importance is to purchase Certified Green Electricity (CGE).

Only the electricity that satisfy the prerequisites defined in the 2011/77/CE regulation, upgraded with the 2009/28/CE one, can be defined as CGE, i.e. only electricity proved to being produced only through renewable resources. This action is coupled with the aim to reduce the general energy consumption of the municipalities and its objective is to reach purchases of CGE that will cover up to 100% of the needed energy.

The measures described above are common to all areas; however, every single area face also specific issues. Because of this, the five SEAPs documents present some peculiar strategies to face these problems.

Regarding the coastal area, peculiar problems could be storm surges and flash floods events; on the other side, also availability and quality of potable water could prove to be a problem in the near future. Finally, being Trieste the major settlement of the region, it is also the one dealing with the major amount of waste, this being a challenging task for the local administration. In the following are then reported the solutions to these problems proposed in the SEAP of Latisana and Trieste:

- **Flash floods prevention:** this particular problem is actually faced only in Latisana because of the municipality being close to the Tagliamento river. In fact, Trieste, although being a coastal city, does not consider any plan to avoid flash floods or reduce their effects. Regarding Latisana, a plan of regular maintenance of the riverbed is already set up to avoid the possibility of the sediments being an obstacle to the water, thus causing flooding. Another measure is to maintain perfectly operative the rainwater disposal networks. Finally, organizing the municipality's staff in order to obtain a quick response in case of flash flood is essential to limit the possible damages to people and structures and to return to normality as soon as possible.

- **Water Houses:** due to climate change, a future great challenge for urban settlements, especially if located on the coastline, will be the availability and quality of potable water. Because of this, it is fundamental to promote ecological behavior among the citizens and projects to obtain a sustainable exploitation of this important resource. With this in mind, both in Trieste and Latisana water distribution stands have already been created, one in Trieste and three in Latisana. These stands, known as Water Houses, contribute to sensitize the citizens about sustainability and public utility themes and to reduce plastic usage, thus obtaining also a reduction of GHG emissions and plastic pollution.

- **Territorial planning:** climate change leads to an aggravation and intensification of natural disasters and events; for this reason it is very important to have planning tools that allow you to know what events can occur in the area and to what extent. Known the danger it is then necessary to prepare to face it through well-defined procedures, which allow the territory and the population to be resilient and to return to normal conditions as soon as possible. Latisana intends to carry out a careful survey of the areas affected by natural hazards, concentrating its attention, in particular, on the analysis of hydrogeological danger and seismic micro-zonation. These studies are the basis on which to build the Municipal Emergency Plan, which constitutes the coordinated elaboration of the operating procedures for intervention to be implemented if the expected event is announced and/or verified. The Emergency Plan must contain the forecast, the planning and the project of all the coordinated activities and all the procedures that must be adopted to face a calamitous event expected on the territory. The Municipal Emergency Plan must also be periodically kept updated.

- **Electricity production from wastes:** being the biggest urban settlement in FVG region, Trieste is also the major producer of waste. Waste treatment and disposal is usually a challenging task and sometimes takes a remarkable toll on the natural environment. That said, using wastes to produce electricity could be a useful process to reduce their impact on the environment and to help the city sustaining the electricity peaks of demand. This action should be actuated by using the waste-to-energy plant located in Trieste and managed by AcegasApsAmga S.p.A., thus obtaining a yearly reduction of about 16.000 tons of CO_2 emitted in the atmosphere to produce electricity.

Regarding the plains areas of the FVG, the strong presence of industry and productive companies leads to electricity demand problems and to huge energy consumption. If on one hand the presence of industries constitutes a destabilizing factor for natural environment, on the other hand they could be remarkable positive actors if correctly managed and exploited. In the following measures, the management and exploitation of the strong presence of industries are reported:

- **Cogeneration and district heating:** the objective of the action is to constitute the conditions for the diffusion of networks of district heating that can systematically and progressively serve different areas of the cities in plain areas up to a more complete and homogeneous coverage. The action involves the recognition of developed or planned specific cogeneration projects, the assessment of energy impact and environmental benefits connected to their development, the search for possible synergies due to the interconnection of two or more networks, the use of other energy sources (energy recovery, renewable sources, other fuels). This approach could lead to high efficiency systems that could serve well both to industrial and residential areas.

- **Energy efficiency in the commercial distribution network:** the plain areas of FVG host large scale food distribution networks. Because of the particular nature of the buildings involved in this activity, a huge amount of energy is used to power up the lightning, air conditioning and food refrigeration systems. Because these buildings have a great impact on the overall energy consumption in this area, the local administration aims to reduce about 30% the energy used to power up the aforementioned systems through the use of the most fitting and economically suitable technologies available. The refurbishment activity will initially concentrate on large shopping centers that have a more evident investment capacity, and then will focus also on minor businesses, resorting to specialized ESCO, linked to the Municipal Administration by a voluntary agreement.

- **Options for demolitions and high efficiency reconstructions:** because of the major issues to be encountered when facing a refurbishment rather than a reconstruction of a building, the municipalities in the plain areas aim to introduce criteria to encourage demolition and consequent rebuilding respect to restructuring of existing buildings. This can be done only when there are no architectural, historical, environmental or landscaping constraints. Before planning a renovation project, an analysis will have to be carried out to verify the economic and environmental elements that can be directed towards a reconstruction by demolition. If from the technical and economic analysis is observed that the restructuring involves a burden higher than the one necessary for the construction of a new building with equal volumetric characteristics, the customer will have to proceed by demolition and reconstruction (in most cases the restructuring cost exceeds the ones for a new construction).

- **Large photovoltaic systems:** production companies' buildings usually have large horizontal surfaces, or inclined to the South, which lend themselves to the installation of photovoltaic modules. For the municipal area, this represents an opportunity to produce energy by taking advantage of incentives. For the companies, an investment in photovoltaic plants can be convenient both to reduce energy costs, thanks to the on-site exchange contract, and to invest profits in fixed assets materials that have a certain and guaranteed annual income. Ground installations can also be considered if the urban planning compatibility of the intervention is satisfied.

Regarding the mountain areas, due to the particular morphology of the territory, various peculiar issues are encountered. First of all, the development of the urban settlements is strongly affected by land morphology and has to take into account a low-impact approach on the natural environment. More than in other areas, human activities are strongly connected and affected by natural events, so every action taken by the public administration has to consider this factor. Here are reported some actions to be considered and peculiarities of the mountain environment like the one of the inter-municipality areas of Tolmezzo:

- **Urban and territorial planning:** being located in a vulnerable environment like a mountain area, the inter-municipality area of Tolmezzo needs to set up an accurate urban and territorial planning in order to promote sustainable development, limiting its negative impacts and guaranteeing a sustainable use of local resources. The main document able to regulate urban development is the Building Regulation. This document already exists, and it will be updated through the insertion of measures like: water saving obligations, use of local and recyclable materials, obligation to connect to district heating (if present) and so on. Also, the geometrical characteristics of new buildings will have to be studied in detail to obtain the best orientation to reduce winter heating and summer cooling loads. Finally, the urban planning does not allow any unchecked urban expansion and enforce an equilibrium between urbanized and green areas.

- **Green Public Procurement:** Green Public Procurement (GPP), allows the public administration to include environmental aspects in goods, services and work procurement. This is applicable to buildings design, construction and management, to energy-consuming facilities purchase and also to electric energy purchase. Through this kind of public contract, a real chance to direct both public and private investors towards a reduction of their climatic impact is possible. This can be done because of two aspects: first, the public administration is a great buyer of goods, thus being able to significantly reduce the environmental impacts of goods by choosing the less pollutant ones. This leads to the second aspect: the administration resorting to low impact goods could lead to a virtuous circle where also private investors will be encouraged to buy less pollutant goods, services and works.

- **Creation of biomass-powered district heating:** as already mentioned above, the urban and territorial planning includes inside its pool of measures the connection to district heating if present. About this purpose, the Tolmezzo's inter-municipality area aims to create the conditions for the diffusion of district heating powered by local biomasses in order to substitute existing plants powered by diesel fuel, LPG and oil fuel. In particular, Tolmezzo aims to promote projects that aim to build biomass-powered plants that could serve, through district heating, many energy-consuming public buildings like the local hospital, the swimming pool, schools, auditorium and others. Successively, private buildings will be granted the possibility to connect to the district heating network.

- **Creation of a Consortium to exploit woodland resources:** a great role to achieve the aforementioned objectives is then played by biomasses availability. Because of this, it will be fundamental to set up a Consortium to exploit the woodland resources present in the area while maintaining a low anthropic impact on the environment. The role of the Consortium will be to reunite public and private local land owners in order to grant the biomasses needed by the power plants and to regulate the entity of wood withdrawal in order to guarantee a low impact on the natural environment.

- **Creation of biogas-powered plants:** in the mountain area of the FVG region many cattle and swine farms are present, causing the necessity to dispose of the sewages generated by their activity. There is, however, an alternative solution to deal with this problem: the construction of a biogas-powered plant. The municipality of Cavazzo (included in the area of Tolmezzo) has already planned the construction of such power plant that would exploit the sewages of the local farms to produce electricity, thus reducing the municipality GHG emissions.

4.4 Metropolitan City of Venice

4.4.1 Territory and demographics

The Metropolitan City of Venice borders with the Friuli Venezia Region on the north-east, the Adriatic Sea on the south, and the ex-provinces of Rovigo, Padova and Treviso on the west. Morphologically, the territory is almost entirely plain and ends with coastal areas (Figure 46) [25]. The plain areas are medium and low plains. The main rivers, from west to east, are Adige, Brenta, Bacchiglione, Sile, Piave and Tagliamento. Here the pendency is minimal and the river fluxes can be deviated by almost any obstacle favoring the formation of torrents and meanders [26]. During intense precipitation events, riverbeds and meanders can overflow and deposit sediments on the surrounding plains. Where the altitude of the plain is very low, this can favor the creation of swamps and small peninsulas [26]. The coasts extend from Chioggia to Bibione, some 120 km, and include the Municipality of Venice, Murano and Burano. The sediments of the coastlines are mainly argyle, lime, gravel and sand, brought by the main rivers, and create the ample sand littorals and lagoons [26]. The hydrology of the Metropolitan City of Venice is constituted from six main aquifers located several meters underground isolated by argillic and gravel stone stratifications. These aquifers are alimented by the high plain rivers from the north and provide water for people and agriculture through water wells. Since the '50s, a constant increase in water extraction led to the depressurization of aquifers and consequent subsidence, up to 20 cm in some areas. In addition of anthropic induced subsidence, this phenomena occurs naturally as well, as consequence of the stratification of sediments and represent today one of the biggest issues of the Metropolitan City of Venice [26]. In some areas, sea water intrusion leads to the contamination of freshwater resources which is bigger in areas of subsidence. Regarding sea levels, the coasts have many areas under sea level which represents a constant threat for its cities. Astronomic tides are summed to wind tides. The geographical orientation of the coast tends to favor the Bora wind, which brings an additional rise in sea level on the western coastlines (Chioggia), while Scirocco winds tends to increase sea level on the east coasts. High tides up to 100-130 cm have been registered, leading to the complete flooding of strategically important areas, such as San Marco's square in Venice or Chioggia's main streets. These events have aggravated in recent times upon an increase in precipitation and sea level rise due to climate change [26].

Administratively and demographically, The Metropolitan City of Venice is composed of 44 municipalities and extends for 2.473 km^2 (Figure 46) [25]. The number of inhabitants in 2017 was around 850.000, big part of which resides in the coastal areas, primarily Venice (>30%) (Figure 46) [25]. The population density (Figure 46) [25] is bigger in the western and central parts, with peaks of density in the municipalities of Spinea, Fiesso d'Artico and Martellago. The biggest densities are found in concomitance with the big industrial or commercial areas of Spinea, Mirano, Fiesso d'Artico, San Dona' di Piave and Portogruaro. The average index of natality is slightly bigger than the national average, while the index of population age is significantly lower. In terms of wealth, richer people are found in the western and central part, being Venice, Stra, Mirano, Marcon, Martellago, Spinea and Dolo, the municipalities with the biggest average income per inhabitant (>20.000 euros/year). On the contrary, Eraclea, Caorle, Cavarzere are the poorest municipalities (>16.000 euros/year).

In terms of infrastructure and urban development, the roots are backing to the Roman empire, when the trait the connects Romea – Idrovia – Padova – Venezia – Trieste was made [25]. This trait coincides with the biggest concentration of urban development in the Metropolitan City of Venice, which includes strong territorial transformation, infrastructures and water governance. The mobility network of Veneto [25] accommodates important and internationally recognized roads and rail systems, with Venice being its epicenter. It belongs to the Corridor 5 trait (Lisbon-Kiev), as well as to the Trans Europe Network Transport (TEN-T), which includes a high-speed rail network. A densely fitted web of local roads that intercept the City of Venice connects it to other important corridors such as the Genova-Rotterdam Corridor, Corridor I and the Adriatic-Baltic Corridor [25]. For what concerns the maritime transport, Marghera is the location where the main Venice port is found, one of the biggest in Italy, and strongly connected to international and national mobility systems. Another important transport center is the Marco Polo Airport, the fourth biggest by number of passengers and traffic in Italy.

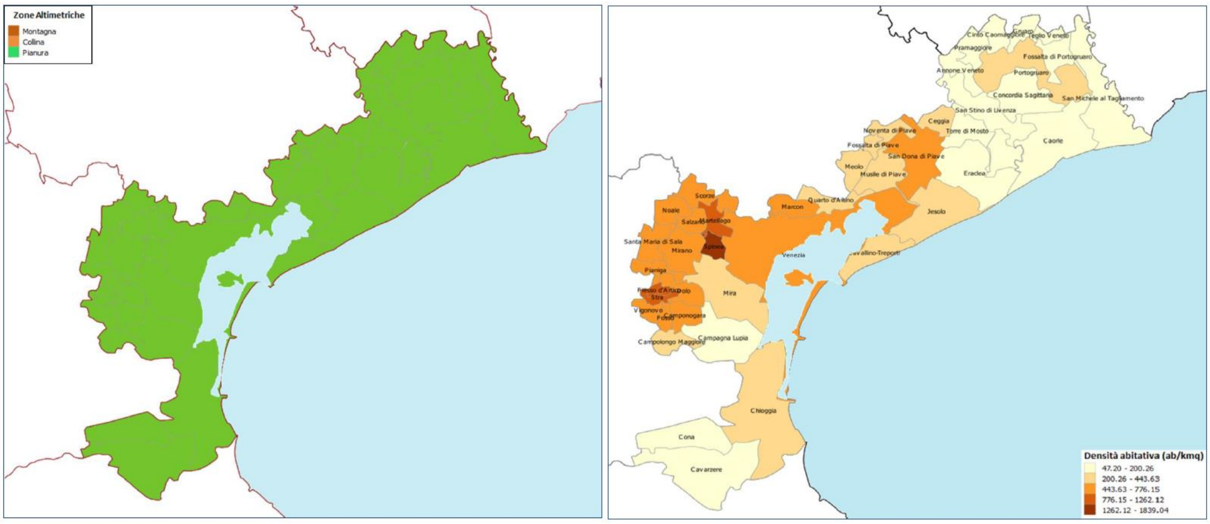


Figure 46. Main environments of the Metropolitan City of Venice (left) and administrative division by municipalities (right) including population density [25].

4.4.2 Energy consumption and baseline emissions

Data from the Environmental Department of the Metropolitan City of Venice, summarized in Table 9, show the total energy consumption and CO_2 emissions of its 44 municipalities. As it can be seen, in the residential, industry and tertiary sector, electricity and heat generation (produced using methane) were the primary source of energy consumption and CO_2 emissions. In the private and local public transport sector, the use of fuels (mostly Diesel) accounted for the most CO_2 emissions. In total, electricity, heat generation and transport accounted for most of energy consumption and CO_2 emissions in The Metropolitan City of Venice in 2017.

Category	Electricity	Methane	LPG	Diesel	Gasoline	Fuel oil	Biomass	Total
	ktoe (tCO_2)	*ktoe (tCO_2)*	*ktoe (tCO_2)*	*ktoe (tCO_2)*	*ktoe (tCO_2)*	*ktoe (tCO_2)*	*ktoe (tCO_2)*	*ktoe (tCO_2)*
Residential	83.449 (315.419)	295.168 (676.632)	5.986 (50.782)	13.928 (57.218)		790 (2.922)	33.221 (7.001)	**432.542 (1.109.974)**
Public road illumination	5.721 (21.626)							**5.721 (21.626)**
Tertiary sector	169.107 (639.184)	109.274 (250.496)						**278.381 (889.680)**
Industry	113.616 (429.441)	105.107 (240.944)				6.872 (25.407)		**225.595 (695.792)**
Private and commercial transport	341 (1.291)	5.780 (13.256)	21.805 (181.775)	261.565 (1.077.128)	56.506 (314.862)			**345.997 (1.588.312)**
Agriculture	5.345 (20.204)			29.249 (120.162)				**34.594 (140.366)**
Municipal buildings	232* (879)							**232* (879)**
TOTAL	**377.814 (1.428.044)**	**515.331 (1.181.328)**	**27.791 (232.557)**	**304.743 (1.254.508)**	**56.506 (314.862)**	**7.662 (28.329)**	**33.221 (7.001)**	**1.266.556 (4.131.767)**

Table 9. Energy consumption and CO_2 emissions of the Metropolitan City of Venice for year 2017.

4.4.3 Climate, observed climate changes, scenarios, risks and impacts

The climate of the coastal areas of the Metropolitan City of Venice is influenced by the presence of the sea that has a mitigation effect on atmospheric fluxes, although very constrained, as the waters are shallow and have a small thermal capacity, and are able to mitigate only the fluxes coming from south-east or east. The mean temperature average on the coasts of the Metropolitan City of Venice is around 13,4 °C [27]. The plains have a reduced mitigation effect from the sea; therefore, a more continental climate is found, with hotter summers and colder winters. Particularly in winter, it prevails a thermal inversion that favors the accumulation of humidity and fogs. Regarding precipitation, some 757 mm of rain drops each year. The precipitation is generally distributed equally during the course of the year, although with a small prevalence in spring and autumn while February is the month with the smallest amount of rain [28].

In terms of observed climate change, there is no coverage specific for the Metropolitan City of Venice but rather for the entire Veneto region. The average temperatures in Veneto in the period 1993-2017 has increased by 1,3 °C (Figure 47) [27] as measured by the 134 thermometric stations placed across the region. Other measurements compare the year 2017 with the mean values of 1993-2016 period. The distribution of the temperature increase was unequal across the region (Figure 48) [28], and monthly differences were also noted, with summer and winter being warmer than usual (data not shown).

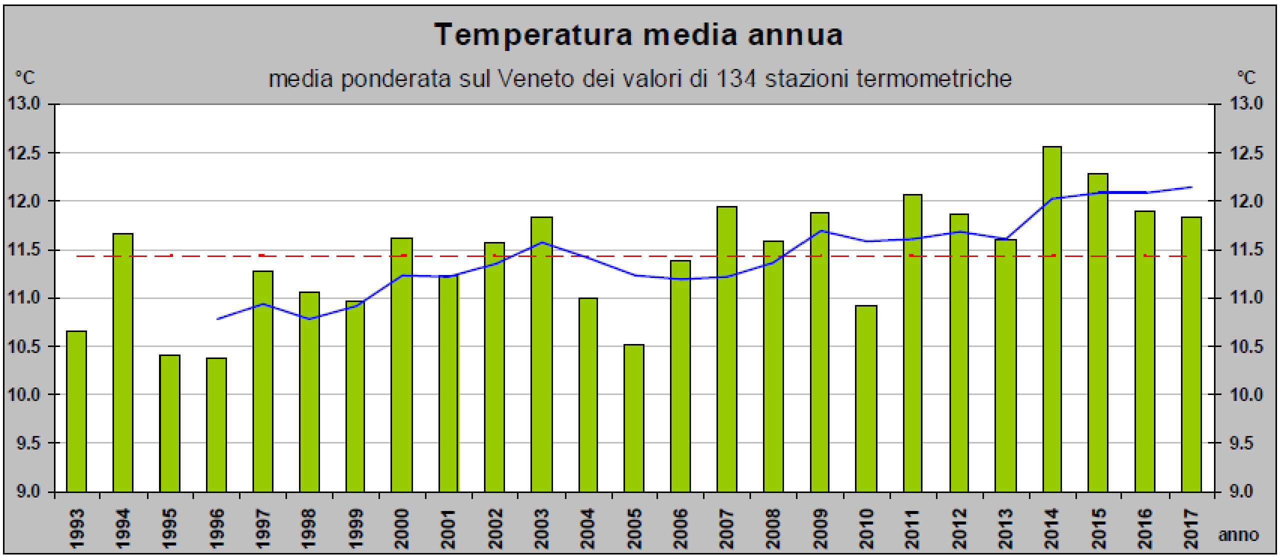


Figure 47. Average temperatures since 1993 in Veneto [27].

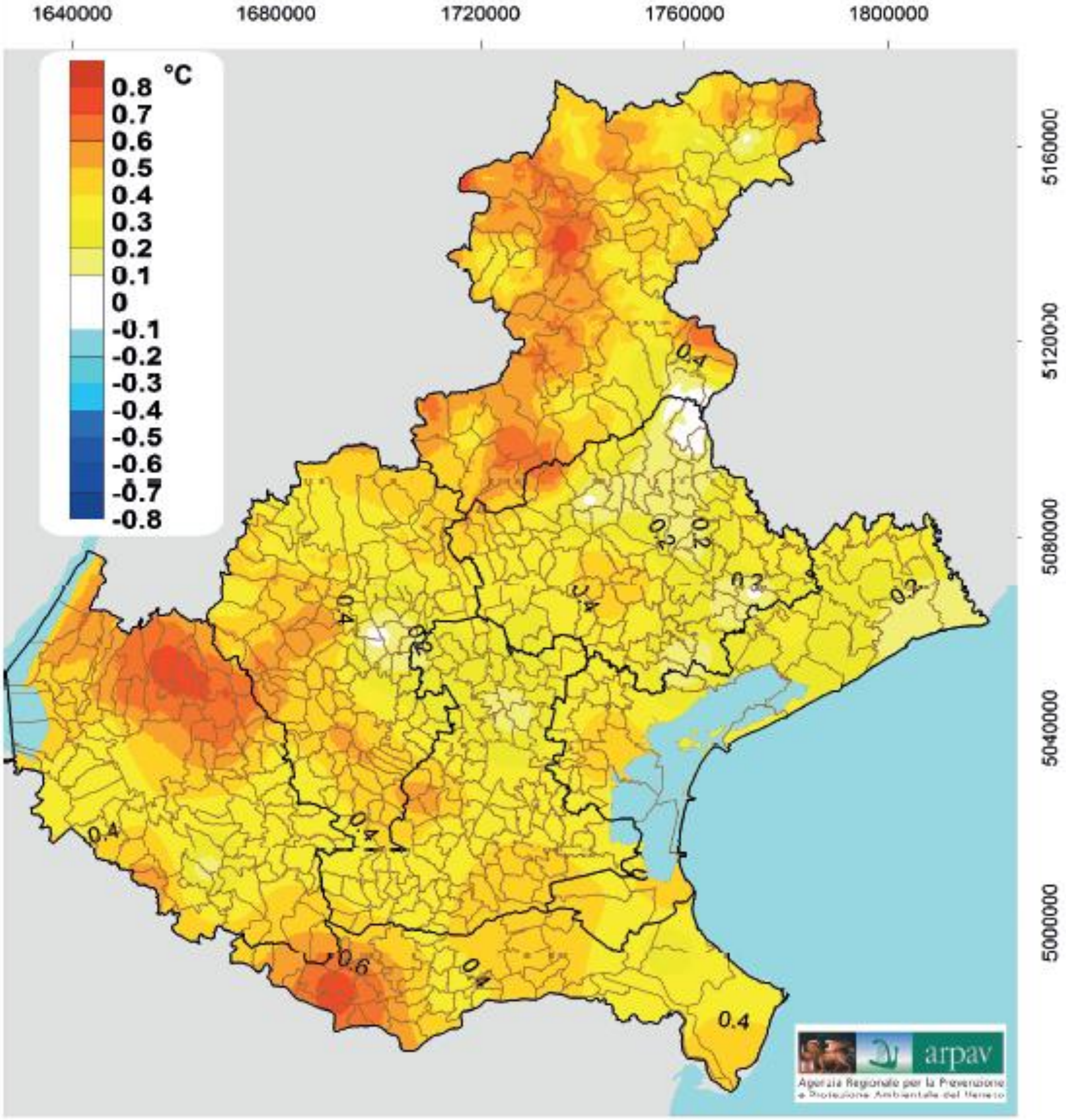


Figure 48. Distribution of temperature change in 2017 in comparison to 1993-2016 average in Veneto [28]-

In terms of precipitation, the 160 rain gauge stations in Veneto measured an increase in the annual precipitation average as shown in Figure 49 [27]. In 2017, however, there was -16% of total precipitation in comparison to the 1993-2016 referent period. This is not a single case, as regardless the amount of total precipitation has increased in the last 25 years, the average annual precipitation was in many cases below the referent period average. The years 2002, 2008, 2010, 2013 and 2015, on the contrary, were much above the average. This to say that when precipitation is being measured, there are many conditions and variables that make its prediction more complex and inaccurate [27].

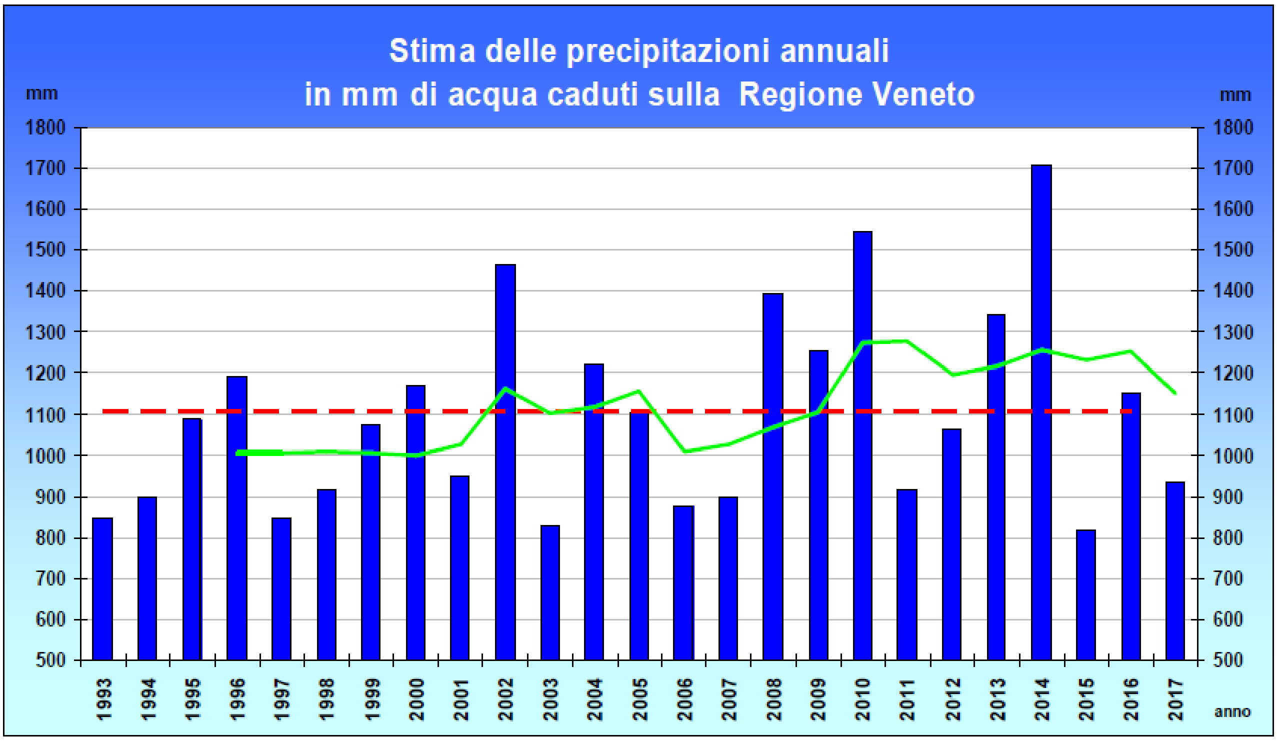


Figure 49. Average precipitation amount since 1993 in Veneto [27].

Concerning the distribution of rain, Figure 50 indicates the distribution of rain in mm in the entire region and compares 2017 to the referent 1993-2016 period. As can be observed, The Metropolitan City of Venice experienced a reduction in rain between 10 and 20%.

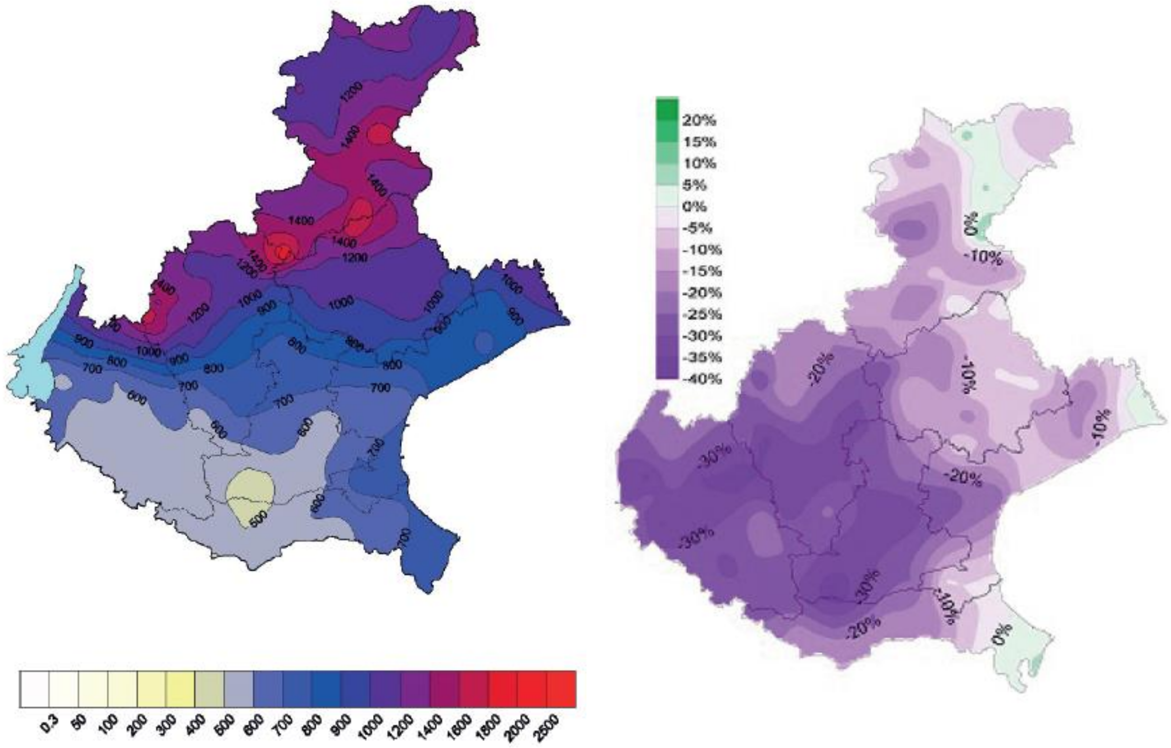


Figure 50. Distribution of average precipitation amount in mm in Veneto in 2017 (left), and % of change in comparison to 1993-2016 (average) [28].

About sea level, Venezia Punte Salute measurements in the 1872-2016 period shown an increase of 2,5 mm/year, a rise nearly double of that in Trieste, as a consequence of climate change but also because of subsidence. The sea level in Venice has reached a +25 cm in the last 100 years. More worryingly, the most recent measurements (1994-2016), have shown an increase in the speed of sea level rise to a staggering +5,6 mm/year.

Concerning climate change scenarios, risks and impacts, there are no documents specific for Veneto or The Metropolitan City of Venice. When scenarios are needed, these are generally derived from the Italian National Strategy and Plan for Climate Change Adaptation, described earlier (Chapter 4). According to this plan, The Metropolitan City of Venice belongs to the M.R. 1, which predicts for RCP4.5 a relevant diminution of summer rainfall and a reduction in frost days in winter, while according to the RCP8.5, a relevant diminution of summer and an increase in winter rainfalls, accompanied with a stronger reduction of frost days in winter.

4.4.4 Local mitigation and adaptation measures

The Metropolitan City of Venice pursuits its own energy and environmental strategy and provides support and coordination for its municipalities in both mitigation and adaptation. The main instruments are:

- **The Metropolitan Strategic Plan:** approved in 2018, in addition to the general metropolitan plans, this document includes an environmental resilience, conservation and valorisation plan.
- **The Territorial Information System (SIT):** a platform shared by the municipalities that includes a repository of all relevant information related to energy requalification and adaptation measures undertaken.
- **The Metropolitan Urban Sustainable Mobility Plan (PUMS):** conceived in 2019, it is a planning instrument that aims to improve the organization of the urban traffic, reduce pollution and improve the quality of life.
- **Municipal Water Management Plan:** after the extreme alluvial events occurred in 2007, the 2008 Territorial Coordination Plan imposed to all the municipalities to present a Water Management Plan, that must exhibit all the minor and major hydrographic networks, the norms and competences required for their maintenance, the altimetry of the territory and of the areas subject to flooding. In addition, it must contain a list of appropriate projects or construction works related to the safe management of water systems, the foreseen programmes and investments inherent to the reassessment of the territory, and the planned norms and necessary provisions to be included in the existing plans or to be made *ad hoc*. Up to now, 30 municipalities have approved their Water Management Plans, and another 12 municipalities are in the approval stage.
- **The production of a database of public buildings energy consumptions:** The database includes some 1600 buildings and was the starting point for the project **AMICA-E** (Metropolitan Intermunicipal Action for the Environment and Energy), that at the end of 2015 received the ELENA funding from the European Bank for Investments. In total, 26 municipalities are now participating to the AMICA-E project, and planning energy efficiency interventions for 121 buildings and installation of photovoltaic systems. Besides the AMICA-E project, the Metropolitan City of Venice will conduct an energy audit for all its buildings.
- **The creation of an integrated methodology for mitigation and adaptation**: By 2019, 43 municipalities have joined the Covenant of Mayors (4 have adhered to the SECAP while the remaining 39 have adhered to the SEAP). Through the **Alpine Space SEAP** project, an integrated methodology for a harmonious transition from SEAP to SECAP has been developed. This project also helped to acknowledge the climate change risks and potential impacts in case of extreme meteorological events, and also listed potential adaptation options, all of which can be transferred to the municipalities water management plans.

Besides these plans and projects, the Metropolitan City of Venice participates to several other European projects such as: **LIFE Veneto Adapt** (adaptation strategy for the central area of Veneto region), **Interreg SECAP** (mitigation and adaptation strategy for wider program area), **Interreg VISFRIM** (integrated municipal water management), **Interreg Crossit Safer** (prevention, planning and response to natural disasters).

5 Slovenia and program area: energy and climate

5.1 Energy consumption, GHG emissions, objectives, politics and measures

According to the 7th National Communication & 3rd Biennial Report from Slovenia under the United Nations Framework Convention on Climate Change [29], energy consumption is the most important source of GHG emissions in Slovenia and contributed 80% of the total GHG emissions in 2015 (Figure 51). In 2016, liquid fuels (34%) prevailed in the structure of the energy consumption, followed by nuclear energy (22%). Renewable energy sources (RES) saw an increasing share which caught up the share of solid fuels (17%). Natural gas had the share of 10%. The structure of gross inland consumption significantly changed in the period 1992-2016. The share of liquid fuels was high in the period 1992-2000, with the exception of 1992, and it declined after 2000 with the exception of 2008. Nuclear energy retained the share of approximately 20% in the period 1992-2000, while in the period 2011-2016 its share increased up to 25% due to operation optimisation in 2014. The share of gaseous fuels remained around 12% in the period 1992-2010 and after 2010 it decreased to 10%. After 2000, solid fuels have been used mainly in electricity and heat generation and in industry (paper and pulp production, cement production).

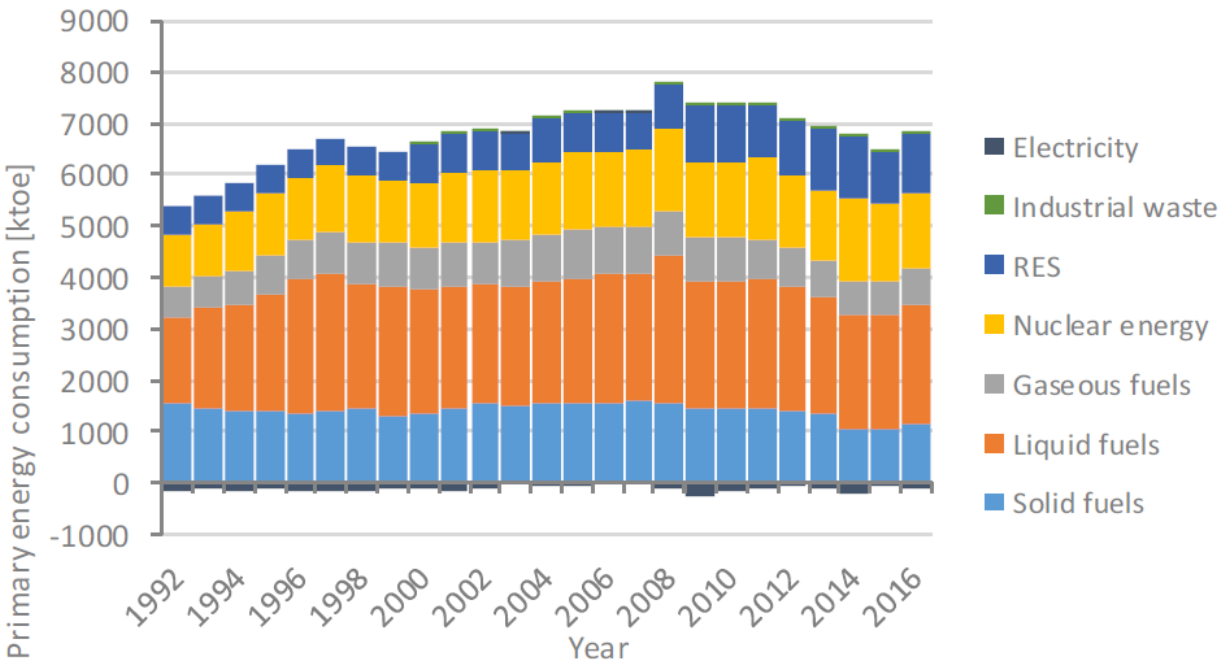


Figure 51. Energy consumption by source in Slovenia since 1992 [29].

In the period 1992–2016, the largest increase in final energy consumption was recorded in the transport sector and the other use sector (the service sector and agriculture) (Figure 52). In transport, 115% (1.018 ktoe) more energy was consumed in 2016 than in 1992 and 55% (672 ktoe) more than in 2000. In the other use sector, energy consumption was higher by 151% in 2016 compared to 1992. In 2016, the manufacturing and construction industries represented a 25% share in total final energy consumption, which is 10% lower than the share in 1992. In 2016, households represented 24% of total final energy consumption, 7% less than in 1992 and 1% less than in 2000.

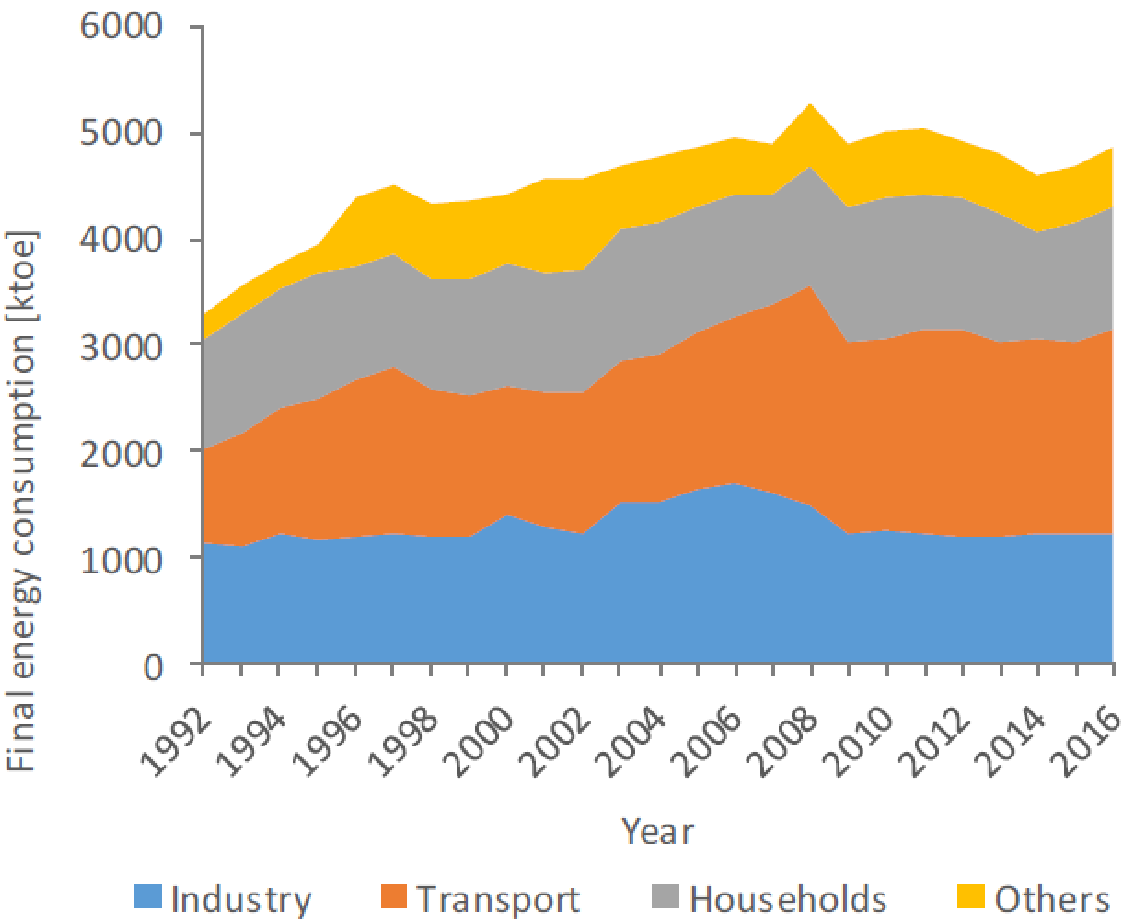


Figure 52. Energy consumption by sector in Slovenia since 1992 [29].

The total GHG emissions in 2015, sinks not considered, amounted to 17.000 ktCO_2-eq., which represents a 17,4% decrease of emissions compared to the year 1986. In the period 1986-1991, a reduction of emissions was recorded due to the economic conditions at that time and the fact that the Republic of Slovenia gained its independence. In the period 1992-1997, a strong increase of emissions was recorded, which was a consequence of increasing economic growth and revival of industrial production. In the second half of that period, the increased emissions were a consequence of the “gasoline tourism” (25% of the total sale of motor fuels in the Republic of Slovenia), since the prices of motor fuels in the Republic of Slovenia were appreciably lower than in the neighboring countries [29].

In the period 1998-1999, emission decreased due to the measures taken by the neighboring countries to curb the "gasoline tourism" and due to the increased supply of electrical energy from the Krško Nuclear Power Plant. In the period 2000-2002, the emission kept increasing again due to the renewal of the obligatory export of electrical energy from the Krško Nuclear Power Plant to the Republic of Croatia. After joining the EU in 2004 and after acceptance of Romania and Bulgaria into the EU in 2007, emissions from road transport have increased drastically and have prevailed over the decrease in other sectors which has occurred due to the policies and measures taken in the manufacturing industry, agriculture and waste sector [29].

In 2009, emissions from fuel use and from industrial processes started to decrease due to the global financial crisis. In 2010 and 2011, emissions stayed almost the same as in 2009, while from 2012 to 2014 a further decrease has been observed. In 2015 emissions in all sectors slightly increased and were 1,3% higher than in 2014 [29].

CO_2 emissions in 2015 represented 80,8% of overall emissions of GHG. CO_2 emissions excluding LULUCF followed the consumption of energy and with regard to their fraction exerted a major impact on total emissions. Compared to 1986, they decreased by 18,3% in 2015. CH_4 emissions represented 12,1% of total emissions in 2015 and were by 20,3% lower than in 1986. N_2O emissions represented 4,9% of total emissions and were by 11,4% lower than N_2O emissions in 1986. F-gases represent 2,2% of total emissions and some gases (HFCs and SF_6) have shown significant increases since 1995 (base year for F-gases), while PFC decreased drastically in 2008 and has continued to decrease in 2009. Since then a slow increase of emissions has been observed [29].

According to the projection with measures, emissions will increase 8,0% by 2020 compared to 2015, but they will be decreasing after 2020. Compared to 2015, emissions will be 1,7% lower in 2030. By 2035, emissions will further be reduced by 8.0% than in 2015 (Figure 53)[29].

The main source of CO_2 emissions is the combustion of fuels, reaching 92% in 2020 and will stay almost the same in 2030; the most important source of emissions within this sector is transport reaching 36% of total emissions in 2020 and will increase to 39% in 2030. The second most important source is energy transformation, holding 37% but predicted to drop to 29%, combustion of fuels in the industry that will contribute 17% in 2030, and other sectors 7%. The remaining CO_2-eq emissions are mostly the result of industrial processes (8% in 2030), and 1% is contributed by fugitive emissions. By 2030, emissions will mostly be reduced in the energy sector by 500 ktCO_2-eq compared to 2015, due to the reduction in coal consumption, and in other sectors by 400 ktCO_2-eq due to higher energy efficiency of buildings and the reduction in the use of fossil fuels. Emissions will also be reduced in the transport sector by 100 ktCO_2-eq, while they will increase in industry (by 500 ktCO_2-eq) and industrial processes 300 ktCO_2-eq [29].

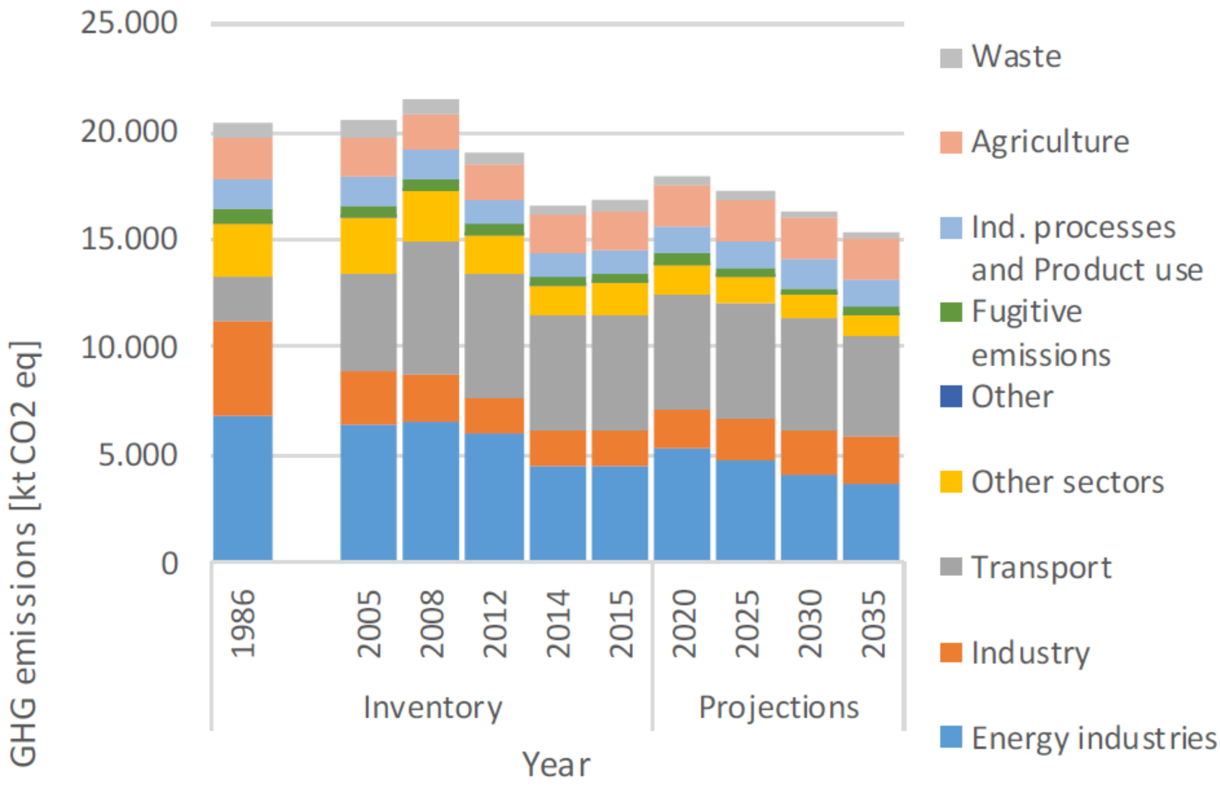


Figure 53. CO_2 eq emissions in Slovenia since 1986, and emission projection with measures to 2035 [29].

Below, we have provided a short cross-section of policies and measures designed to achieve the 2020 targets, which will be the basis for Slovenia to efficiently elaborate its policies and measures for the 2030 targets in the National Energy and Climate Plan (NEPN) [30].

- **Decarbonization**

In 2014, Slovenia adopted the Operational Program for reducing greenhouse gas emissions to 2020 (OP GHG 2020), which is a plan of measures that supports Slovenia in reaching the objectives of reducing GHG emissions on the basis of the Decision 406/2008/EC. The measures for reducing GHG emissions laid down in OP GHG 2020 are oriented towards achieving greater investments of public financial resources and improving the cost-efficiency of the implementation of measures. Therefore, OP GHG 2020 is focused on measures on areas or in sectors that represent the highest shares of GHG, which are energy performance in buildings, emissions from transport, agriculture and GHG in waste management [30].

OP GHG 2020 provided a stable framework for the implementation of activities and was building on programs already adopted and instruments and measures already established in the country, while enhancing and upgrading them by new and additional measures (OP GHG 2020, 2014, page 4) [30].

OP GHG 2020 is a complex program of measures planned for different sectors (OP GHG, 2014) [30]:

- green economic growth;
- buildings,
- transport;
- agriculture,
- other sectors (non-ETS industry, non-ETS energy, waste),
- education, training, information and awareness raising.

Almost half of the measures of OP GHG are implemented in cooperation with two or more institutions (Podnebno ogledalo, 2018b, page 22) [30].

- **Renewable energy**

Promoting renewable energy sources and prioritizing the efficient use of renewable energy sources are components of the Energy Act (EZ-1) defined as energy policy goals. In the area of developing renewable energy sources, Slovenia must achieve ambitious targets that will contribute to increasing the reliability of energy supply, reducing impacts on the environment, economic growth and the development of jobs and employment (Draft AN OVE 2010–2020 - 2017 update) [30]. On the basis of the directive on the promotion of the use of energy from renewable sources (RES), Slovenia must obtain at least 25% of renewable sources in the overall energy consumption by 2020. According to this, the Government adopted the National Renewable Energy Action Plan 2010–2020 (AN OVE-2010). In 2017 a proposal to update the AN OVE was prepared and included also the projections of production and use of renewable energy sources by 2030, and an indicative national target in the field of RES by 2030 (minimum 27%) [30]. In order to reach the targets by 2030, two scenarios were elaborated: wind (better use of wind energy) and solar (better use of solar energy); the solar scenario has proved better from the economic and environmental point of view and was thus chosen to be the scenario of the updated AN OVE (draft AN OVE 2010–2020 - 2017 update, page 9) [30]. Among the technologies for electricity production from RES, large hydro power plants (HPP) have energy and macroeconomic advantages; therefore, both scenarios were elaborated in such a way as to enable maximum possible and realistic use of water potential, namely that from the full unrealized technical potential for energy production in HPP, which amounts today to 51%, additional 13,6 % of potential are planned to be used, meaning that 62% of the technical potential will be used by 2030 [30]. However, the projection does not take into account the exploitation of the entire technical potential on the planned water bodies but about one quarter less, mainly as the result of environmental restrictions related to the implementation of projects. The program or projections in principle consider that potentials for RES outside the protected areas should be prioritized for exploitation. However, in order to achieve the targets set in relation to RES at the minimum level, also RES in the protected areas should be exploited; thus, projects are planned also in the NATURA 2000 area (draft AN OVE 2010–2020 - update 2017, page 9) [30].

- **Energy efficiency**

In December 2017, Slovenia adopted the Action Plan for Energy Efficiency 2017–2020 (AN URE 2020), which is the second action plan that Slovenia has prepared under Directive 2012/27/EU on energy efficiency. The action plan covers the essential measures to improve energy efficiency, including the expected and achieved energy savings, with the aim to achieve the national objective of increasing energy efficiency by 2020, and the Slovenia's contribution to achievement of the common EU objective – increasing energy efficiency by 20% (Action Plan for Energy Efficiency 2017–2020, 2017, page 8) [30].

The effectiveness of the implementation of AN URE 2020 action plan is vital to achieving objectives of reducing GHG and achieving a 25% target share of RES in the balance of gross final energy consumption by 2020. Energy efficiency is amongst the most cost-effective measures for achieving these objectives. It also significantly contributes to the objectives in the field of air quality (Action Plan for Energy Efficiency 2017–2020, 2017, page 8) [30].

According to AN URE 2020 action plan, Slovenia will implement horizontal and cross-cutting measures to improve energy efficiency, and take measures in the public sector, in buildings, industry, transport, in heating and cooling, as well as transformation, transmission and distribution of energy [30]. Update of the action plan resulted in the addition of several new measures, mainly in establishing the financial instruments for a comprehensive energy renovation of buildings and for guaranteeing the quality of planning and implementation of measures associated with such renovations, considering the fact that the existing building stock represents the sector with the biggest potential for achieving energy savings. Besides the renovation of existing buildings, the AN URE 2020 action plan introduces several new measures to promote or improve technologies that improve energy efficiency. These measures are the starting point for the necessary accelerated development of sustainable heating and cooling which are among the priorities of the Energy Union (Action Plan for Energy Efficiency 2017–2020, 2017, page 8) [30].

- **Energy security**

In order to achieve the long-term objectives, Slovenia will have to considerably restrict the use of fossil fuels. This represents a major challenge for the production and distribution of electricity, heating mode and in particular for transport [30]. In the long term, electricity generation will be the most affected by international mitigation commitments, which follow the direction of reducing GHG emissions, increasing the share of RES and achieving energy savings. In projections, the speed of transition will be significantly affected also by the EU ETS. Energy in Slovenia will have to adjust to such transition on time. With a view to reducing dependency on the use of fossil fuels and their phase out, ReEKS motion emphasizes more efficient energy consumption and greater use of renewable and low-carbon sources (ReEKS Motion, paragraph 49) [30].

According to the 7th National Communication & 3rd Biennial Report from Slovenia under the United Nations Framework Convention on Climate Change [29], the measures and instruments for reducing GHG emissions in Slovenia are the following.

- **GHG emission allowance trading:** reduce emissions where this is most cost-effective.
- **Environmental tax on the pollution of air due to CO_2 emissions**: internalization of the external costs of air pollution due to CO_2.
- **The use of best available techniques**: reducing energy consumption by using the best available techniques.
- **Taxes and charges**: greater use of environmentally friendly fuels by influencing the price of fossil fuels.
- **Education and training, informing, awareness and promotion:** high level of awareness, information and knowledge is necessary for the successful implementation of measures.
- **Green economy growth**: long-term GHG emission reduction by transition to green economy, which is based on innovations that increase energy efficiency and reduce GHG emissions.
- **Energy efficiency labelling and minimal standards for products and appliances**: improvement of products and appliances in terms of energy efficiency.
- **Obligations on energy suppliers for energy savings**: increasing energy efficiency for the final consumers.
- **Technological modernization of thermal energy sector**: number of large thermal power plants are already nearing the end of their life expectancy and their replacement is being planned. This will also result in a larger share of the use of natural gas.

- **Promotion of power generation from RES and high efficiency CHP**: a promotion scheme as the basic instrument in this area, which is implemented in the form of fixed feed-in tariffs of electricity and operational support.
- **Promotion of district heating based on RES and CHP with high efficiency:** increase of energy and emission efficient generation of heat for district heating.
- **Promotion of energy efficiency in industry**: reduction in production costs, promoting efficient energy use in industry by various programs.
- **Promotion of energy efficiency and use of RES in buildings:** taking into account various aspects of energy efficiency and the use of RES in spatial planning, feasibility studies of alternative systems of energy supply, pilot projects, renovation of cultural heritage, energy performance contracting, trainings of stakeholders in the area of building renovations and RES technologies, excise duty policy.
- **Promotion of energy efficiency and the use of RES in households**: promoting investments in households by subsidies and soft loans; consulting network ENSVET has been established.
- **Promotion of energy efficiency and the use of RES in the public sector**: set an example for the population in implementing the measures. Promote financial incentives and green public procurements.
- **Promotion of the use of the public transport**: increase the number of passengers using public transport.
- **Sustainable freight transport**: extend and modernize the railway network, which represents a precondition for the transition of freight transport from road to railway.
- **Vehicle efficiency improvement, promotion of efficient driving, an increase of vehicle occupancy rate and promotion of the use of low CO_2 emission fuels:** use of private vehicles will decrease due to European legislation which sets out allowed emissions per km for new passenger cars, fiscal pressure, informing and awareness rising. Also, a non-negligible influence of green public procurement is to present financial incentives for clean vehicles. The shares of RES in sold quantities are prescribed until 2020 for motor fuel distributers.
- **Promotion of non-motorized traffic**: cycling and walking are two significant ways of mobility which can add to a decrease of GHG emissions. They play an important role in the integrated transport strategies for municipalities.
- **Development of integrated transport strategies for municipalities**: integrated strategies contribute to the increase in share of sustainable mobility, the improvement of infrastructure and change in behavior.

- **Reduction of F-gas emissions from stationary equipment**: decrease in F-gas emissions by reduction of leakage, replacement and diligent handling with devices and introduction of quantitative caps for HFC gases on the EU market.
- **Reduction of F-gas emissions from mobile air-conditioning vehicles**: the legislation lays down restrictions on the use of F-gases in air-conditioning systems in new cars.
- **An increase in the range of grazing for cattle**: grazing is currently promoted by subsidizes and educational measures; it produces lower emissions by avoidance of emissions generated through the storage of animal manure.
- **Rational fertilization of agricultural land by nitrogen:** within the framework of the Rural Development Program, numerous measures are being implemented, directly contributing to the reduction in the use of mineral fertilizers.
- **Reduction in the quantity of biodegradable waste:** several measures to reduce the amount of deposited biodegradable waste; for instance, separated collection of fractions, an environmental tax on waste disposal, treatment of waste before disposal.
- **Waste reduction**: prevent waste generation.
- **Capture of landfill gases**: capture of landfill gas, mandatory since 2005.
- **Sustainable forest management and CO_2 emission sinks**: increase in the supply of wood simultaneously with an increase in CO_2 sinks are a result of the work planned by the Slovenian Forest Service.

The monitoring system on achieving quantitative targets of GHG emission reduction in Slovenia has not changed in comparison to the previous biennial report. The improvement of the system is planned also by the help of the results of the LIFE Climate Path 2050 Program started in 2017.

5.2 Climate, observed climate changes, scenarios, risks, impacts and adaptation measures

Slovenia lies at the intersection of the Alps, the Dinaric Alps, the Adriatic Sea and the Pannonian basin, which is reflected in its diverse climate and climate change impacts. The regional diversity of Slovenia contributes to local climate differences. Local processes can have a significant impact on large scale weather signals, causing a different local change in temperature and precipitation compared to that on a larger scale. Local changes may be more pronounced or more subtle compared to the changes on a regional scale.

The annual mean air temperature in Slovenia depends mainly on altitude. On average, the temperature decreases by about 1 °C for every 180 meters of elevation. Other important factors include the proximity to the sea, topography and settlement. These factors make Goriška and the coastal region the two warmest regions in Slovenia with an annual mean temperature of 13 °C. In most of Slovenia the annual mean temperature is between 8 °C and 11 °C, whereas in the high mountains it is only about 0 °C. On average and almost everywhere in the country, January is the coldest and July is the warmest month. The difference between the two months is usually about 15 to 20 °C and is greatest in the lowlands of the central and eastern part of Slovenia. The smallest differences are recorded in the mountains and along the coast. In addition to the annual temperature cycle, air temperature is characterized by diurnal temperature variation. Mornings are typically a few degrees cooler than afternoons. The difference increases in clear and calm weather conditions, while in cloudy or windy conditions the temperature can change by only a few degrees throughout the day. Diurnal variation is generally greater in summer and in the lowlands. Inter-annual fluctuations of the mean air temperature are of the order of several tens of degrees Celsius. The most variable are the months from January to March with temperature fluctuations (standard deviation) between 2 and 2,5 °C relative to the climate signal. From April to October, fluctuations are half the size. Thus, at a seasonal level, summer is the most stable and winter the most variable season.

Due to its location in the mid-latitudes and proximity to the sea, Slovenia is a relatively a wet area. Large differences in precipitation amounts between individual regions in Slovenia arise from diverse orography and varying distance from the sea. Generally, the amount of precipitation increases from the sea to the Alpine-Dinaric barrier and gradually decreases thereafter. Significant peaks occur in the Kamnik-Savinja Alps and Pohorje. Such precipitation distribution is a consequence of the frequent inflow of moist and relatively warm air from the southwest. The average rainfall is 1.000 mm for the coast, up to 3.500 mm for the Alps, 800 mm for the Southeast and 1.400 mm for central Slovenia.

In Slovenia, there are several distinguished precipitation regimes. The peaks in different parts of the country occur at different times of the year. For the wettest part of western Slovenia, there is an autumn peak, while eastwards (inland) the summer peak increases and the autumn peak turns into gradual decrease of precipitation in winter. Winter is the season with the least precipitation.

The amount of precipitation is very variable both spatially and temporally. According to the long-term mean in the period 1981–2010, winter is the most variable with precipitation indicator fluctuating between 29% and 214%, while in spring and autumn the variability is lower. Summer, when the deviation from the average does not exceed 42%, is the least variable season. There are noticeable regional differences in the course of the annual precipitation amount; the driest and wettest years vary from place to place.

The document that analyses the observed climate changes and scenarios in Slovenia is the "Climate change projections for Slovenia over the 21st century" produced by the Slovenian Environmental Agency (ARSO) [31]. According to this document, in the period 1961–2011, the most significant change of climate in Slovenia is the increase of mean air temperature by about 0,36 °C per decade. The most evident warming is observed in spring and summer, which is about 0,4 to 0,5 °C per decade in most of Slovenia. Conversely, autumn temperature change is not statistically significant. The increase in seasonal daily maximum and minimum temperatures is similar to that of seasonal daily mean temperature. Due to the general increase in air temperature, the frequency of the number of "typical days" has changed. We observed an increase in the number of hot and summer days, while the number of cold, frost and icing days has slightly declined [31].

The trend in annual precipitation amount in the 51-year period is negative nearly throughout Slovenia and equals up to a few percent per decade, though it is statistically significant only in the west. The negative trend is mainly a result of observed decline in precipitation in spring and summer (on a national scale, it equals about –3% per decade), while in autumn and winter the trend is either insignificant or highly uncertain in the majority of Slovenia [31].

In accordance with the expected gradual warming throughout Europe, Slovenia will also be subject to significant temperature rise, ranging from 1 °C to 4 °C depending on the RCP scenario (Figure 54). All three RCP scenarios project an increase in annual mean temperature by 2100, RCP2.6 by approximately 1,3 °C, RCP4.5 by approximately 2 °C and RCP8.5 by approximately 4,1 °C. In the first two scenarios, presuming reductions in emissions of GHG, the temperature will initially rise and then roughly stabilize by the end of the 21st century. RCP8.5 shows a steeper temperature increase in every successive period [31].

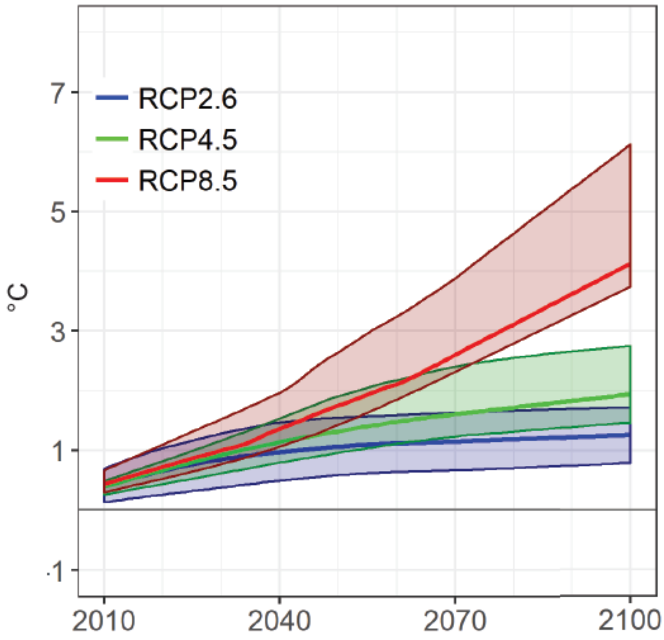


Figure 54. Temperature rise in Slovenia according to RCPs to 2100 [31].

Slovenia will experience significant temperature changes in all seasons (Figure 55) [31], with a slightly enhanced warming in winter. Warming will be the least pronounced in spring. The difference between warming in winter and spring is statistically significant in the last two projection periods and is limited to certain parts in the north and west of the country, such as the Alps. Projected changes according to the RCP4.5 are reliable and show strong agreement with the projected changes in much of Europe; the greatest temperature rise is expected in the northern part of Europe in winter and in southern part of Europe in summer, while the Alpine region will experience above average warming in both seasons. The differences in temperature changes between the Alpine region and the rest of Europe are less pronounced in the case of RCP8.5, which is also reflected in Slovenia [31].

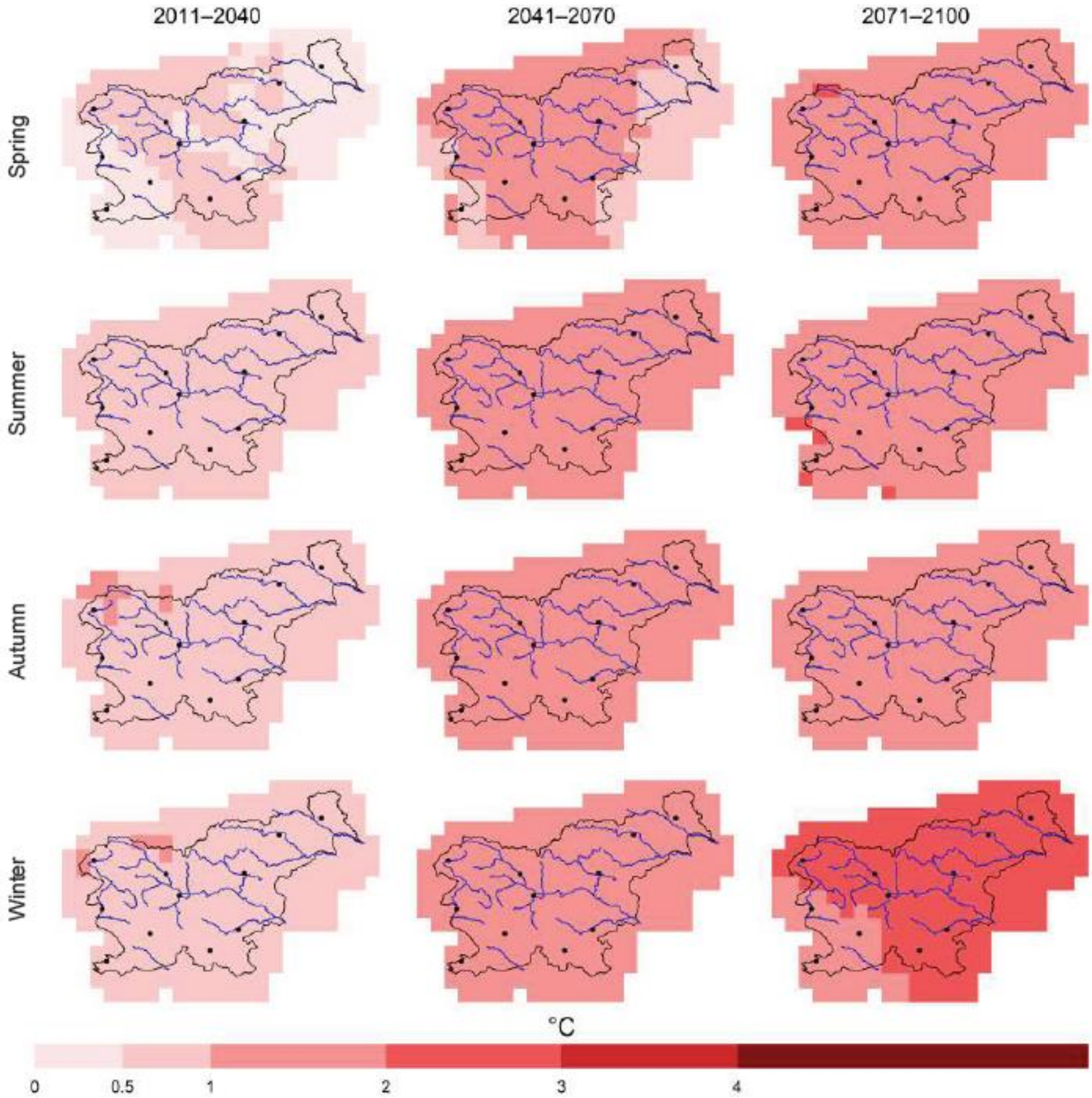


Figure 55. Projected changes in seasonal mean air temperature for Slovenia in the period 2071-2100 relative to the reference period 1971-2000 under RCP4.5 scenario [31].

In contrast with temperatures, projections of changes in precipitation are less reliable due to the complex nature of precipitations and its greater temporal and spatial variability [31]. There are noticeable differences between precipitation changes under different RCP scenarios, particularly in the second half of the 21st century [31]. In the case of moderately optimistic scenario RCP4.5 (Figure 56) no significant changes are expected initially, though the signals increase as we look further in the future. With the beginning of the second period, an increase in precipitation will begin to spread from the east to the west of Slovenia [31]. By 2100 an expected increase in the annual mean precipitation amount in Slovenia will approximately be 10% relative to the reference

1981-2010 period, with the exception of the northwest, where a smaller increase is projected. Projections of changes in precipitation are most reliable in the north and east of Slovenia, and much less reliable in the west (Figure 57) [31].

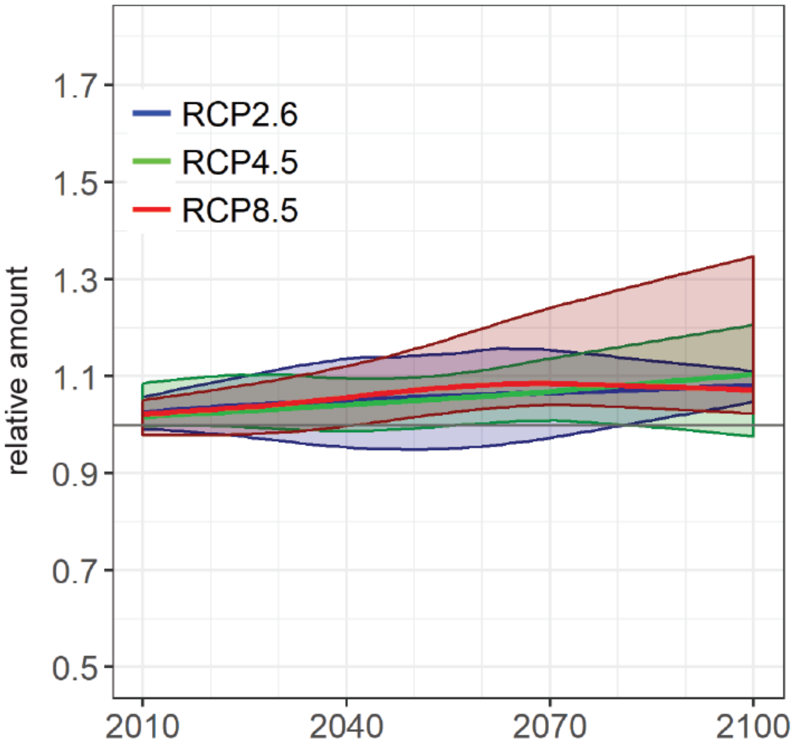


Figure 56. Mean annual precipitation amount in Slovenia to 2100 relative to the reference period 1981-2010 for three RCP scenarios [31].

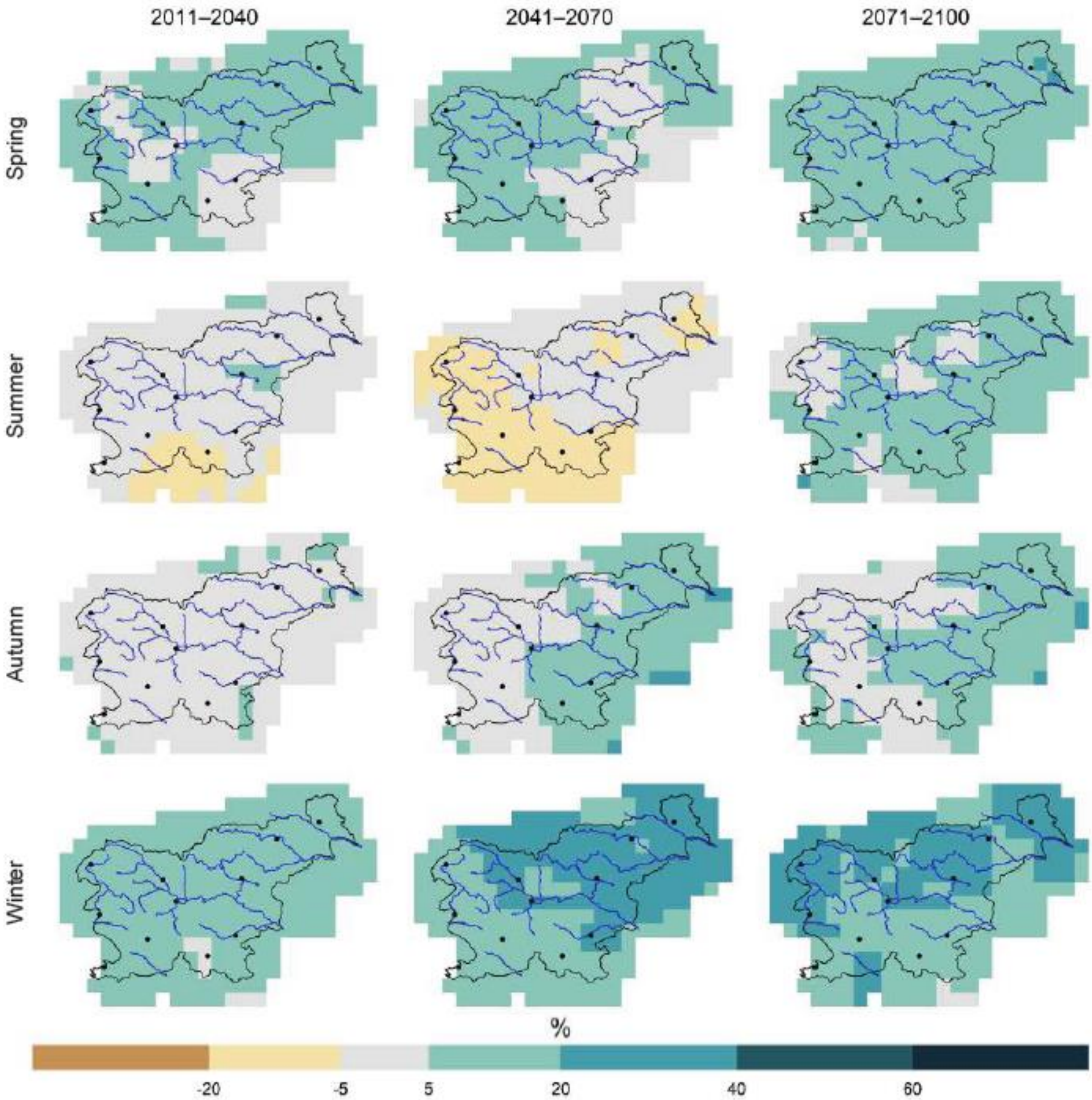


Figure 57. Projected changes in seasonal mean precipitation amounts for Slovenia in the period 2071-2100 relative to the reference period 1971-2000 under RCP4.5 scenario [31].

As an EU Member State, Slovenia has undertaken to realize the European climate policies and implement the joint measures. For what concerns adaptation, Slovenia started working on a National Action Plan (NAP) for adaptation. Many sectors are in the initial stages of exploring and integrating climate adaptation [29]. However, in the sectoral policy plans, some adaptation options have already been identified, for instance, in the strategy and action plan for the Adaptation of Slovenian Agriculture and Forestry to Climate Change (2008) which covers The River Basin Management Plans for the Danube and Adriatic Sea Basins for 2016–2021, and contains measures for climate adaptation, based on a vulnerability assessment.

While a comprehensive program of measures for climate change adaptation will be prepared after climate impact assessments analysis, the need for adaptation actions was already addressed in the following areas:

- **Sustainable and integrated water resources management:** The River Basin Management Plan for the Danube and Adriatic River Basins for the period 2016-2021 was adopted, which also defines measures in the area of adaptation to climate change.
- **Reduction of flood risk:** on the basis of defined areas of significant impacts of floods in the Republic of Slovenia (i.e. preliminary flood risk assessment), the Flood Risk Reduction Plan was adopted in June 2017 defining measures of comprehensive flood defense, taking into account climate change impacts.
- **Drought risk management:** In 2006, Slovenia accepted a mandate for the organization of the work of the Drought Management Centre for South-eastern Europe, DMCSEE, (within the framework of the UN Convention to Combat Desertification, the UNCCD, and the World Meteorological Organization, WMO), expert groundwork was prepared for the national action plan for drought management and soil degradation, and the DriDanube project is ongoing, which will provide tools for assessing and responding to droughts in the SEE region.
- **Spatial planning:** a new law on spatial planning was adopted, which provides for regional spatial plans. In the process of environmental impact assessment, impacts of climate change will also be considered.
- **Biodiversity conservation:** Slovenia has set up special protection areas and implemented several individual projects with included climate change impact assessments, and some are still underway. An updated Management Program by 2020 for NATURA 2000 sites is being implemented.
- **Natural disasters:** Slovenia prepared the National Disaster Risk Assessment and in 2016 the document was also upgraded with an available assessment of the impacts of climate change, as well as some individual disaster risk assessments already incorporated in their assessments. The Ministry of Health, for example, prepared a "Risk Assessment for the Dangers of Biological, Chemical, Environmental and Unknown Origin to Human Health" and complemented it with consideration of climate impacts on the occurrence of infectious diseases.
- **Agriculture and forestry:** as early as 2008, the Climate Change Adaptation Strategy for Slovenian Agriculture and Forestry provided guidelines for adaptation that have been carried out in the past in the framework of the Action Plan for Adaptation of Agriculture

and Forestry (2010-11), and in recent years mainly in the framework of legislative solutions and measures such as in the area of prevention (education, training, provision of guidelines), as well as in the field of mitigating the consequences of natural disasters (co-financing agricultural insurance, providing disaster relief and rehabilitation, etc.) A special example of good practice in the field of adaptation is taking place in the Vipava Valley region. The Ajdovščina Development Agency has prepared and is implementing LIFE ViVaCCAdapt project. In the framework of the project, a strategy for adapting agriculture to climate change has already been prepared, and pilot actions are currently being implemented that support the decision-making process for irrigation and plant green windbreaks.

- **Cultural heritage:** In August 2017 the Architectural Policy of Slovenia - Architecture for people was adopted, that sees spatial planning and construction as activities that contribute to climate change adaptation. Guidelines for the energy renovation of cultural heritage buildings have been produced and published, and they specify, among other, a set of measures for energy refurbishment that improve energy efficiency of cultural heritage buildings. The procedures necessary for the successful planning and implementation of energy refurbishment measures are set forward, which also represent a measure of adaptation to climate change.
- **Information and awareness rising:** ARSO together with the National Institute of Public Health (NIJZ), regularly informs the public in cases of dangerous climatic and hydrological events (providing instructions to the citizens). ARSO also regularly publishes climate change information and newsletters information on climate monitoring. In the area of awareness-raising, the project Slovenia reduces CO_2 also included climate adaptation examples among good practices, events, consultations, and guidelines for decision-makers were prepared.
- **International development cooperation:** in the resolution on international development cooperation and humanitarian aid, adopted in 2017, the fight against climate change, including climate change adaptation, is one of the two priority areas for development cooperation, indicating an increase in the share of adaptation measures in the future.
- **Public health:** The Ministry of Health and the NIJZ found that heat waves represent a considerable threat to the public health. Vulnerability of people varies according to age, health status, socio-economic status and living environment (countryside, city). So, for example, in the period of heat waves, more people die due to cardiovascular diseases, and particularly vulnerable are elderly people whose number and proportion of population is growing in Slovenia. Heat waves also strengthen other factors of human health, such as ambient air pollutants (particles and ozone), create more favorable conditions for the

reproduction and spread of pathogens, vectors and allergenic plants. In 2017, the SEA and the NIJZ set up a renewed forecasting and display of data on ambient air pollution. They identified the levels of pollution and recommendations for people on days with excessive air pollution with particles and ozone. The NIJZ, in cooperation with dermatologists and with the support of the Ministry of Health, has been implementing the Safe in the Sun program for a decade aimed at informing the target population about the harmful effects of sunlight and the measures that can effectively prevent these consequences. This could contribute in the long term to stopping the increase in skin cancer in Slovenia (especially melanoma type). The program targets preschool children in kindergartens and schoolchildren.

Some adaptation actions are being carried out in the agricultural, forestry and water management sectors, in line with the existing national-level sectoral action plans:

- **Strategy for the Adaptation of Slovenian Agriculture and Forestry to Climate Change (2008):** its action plans of 2010 and 2011, with measures still being implemented under the 1st and 2nd pillar of the RDP, supported by a number of applied research projects related mainly to new technologies and cultivation of more climate-resilient crops.
- **The River Basin Management Plans for the Danube and Adriatic Sea Basins for the 2016-2021**: define a range of measures also contributing to climate adaptation, including preparation of a set of indicators for droughts, and measures related to improving the water status and management.
- **The Flood Risk Mitigation Plan 2017-2021**: defines a large set of flood protection projects, which include measures to adapt to land-use change, energy and transport infrastructure, and undertake regular hydrological and meteorological monitoring.
- **LIFE ViVaCCAdapt project:** in the Vipava Valley region, the Ajdovščina Development Agency autonomously implements the LIFE ViVaCCAdapt project with MESP's financial help (20%) from the Climate Fund. A Strategy for adapting agriculture to climate change for the period 2017-2021 has been prepared, as the first regional strategy of its kind. The implementation started recently, and pilot actions are currently being taken that support the decision-making process for irrigation and planting of green windbreakers.

These actions are carried out by the respective national governmental departments, within available financial resources. Implementation of all three action plans in the water sector started just recently and there are no available progress reports yet. Adaptation-related actions in agriculture and forestry have been implemented since 2010 and progress is reported annually, as part of agricultural development monitoring reports issued by the Agricultural Institute of Slovenia. Measures in all action plans are primarily sectoral, and not horizontal in nature.

5.3 Gorenjska, Osrednjeslovenska, Primorsko-Notranjska, Obalno-Kraška, Goriška

5.3.1 Territory and demographics

Slovenia is situated in Central Europe and covers an area of 20.271 km^2 (Table 10) [32]. It has borders with Italy, Austria, Croatia and Hungary. Four major European geographic regions meet in Slovenia: the Alps, the Dinaric area, the Pannonian plain and the Mediterranean. The coastline is only 46,6 km long, but there are 26.000 kilometres of rivers and streams, some 7.500 freshwater springs, including several hundred of first class therapeutic mineral springs. Forests cover half the territory; Slovenia is the third most forested country in Europe, right after Finland and Sweden. Remnants of primeval forests are still to be found, the largest in the Kočevje area. Bears, which can no longer be found north of this region, still live in these forests, and it is also possible to encounter wolfs or lynxes. Grassland covers 5.593 km^2 of the country, and fields and gardens 2.471 km^2. There are also 363 km^2 of orchards and 216 km^2 of vineyards. Most of Slovenia has a continental climate with cold winters and warm summers. Slovenia is home to more than 15.000 animal species and 3.200 plant species. Approximately 11% of Slovenia's territory is protected; the largest area with such a regime is the Triglav National Park with a surface area of 848 km^2. The Škocjan Caves entered on the world heritage list at UNESCO in 1986, and the Sečovlje saltpans and Cerknica Lake are included on the Ramsar List of Wetlands.

The regions in Slovenia part of the program area belong to the western part of the country and include the cities of Ljubljana, Koper, Kranj and Nova Gorica. It is the most developed part of Slovenia and its GDP per capita is 105,4% of the European Union average. It stretches across the Alpine range and across the karst, the partly wooded Dinaric Mountains to the extreme northern part of the Mediterranean. In the Alps, which end in the north and northwest of Slovenia, the Triglav National Park is found, the only existing national park in the country. The southwestern edge of the region extends up to 47 km long coast of the Adriatic Sea. There is an intersection of two European transport corridors, while the infrastructure network has two major transport hubs - Koper with the international port of Luka Koper and the capital Ljubljana with the international airport Jože Pučnik Ljubljana.

DATA FOR THE YEAR 2016	Slovenia	Program area	Central Slovenia	Upper Carniola	Gorizia	Coastal-Karst	Littoral - Inner Carniola
Area (km²)	20.273	9.296	2.334	2.137	2.325	1.044	1.456
Population	2.064.241	1.025.264	537.893	203.654	117.931	113.193	52.593
GHG ($ktCO_2$-eq)	16.831	8.360	4.386	1.661	962	923	429

Table 10. Surface area, population amount, GHG emissions, and number of companies in Slovenia and in the five regions of the program area [32] [33].

5.3.2 Energy consumption and baseline emissions for the Gorenjska region

About the energy consumption and baseline emissions in the program area, the only available information at local level is found for the Gorenjska region from the "Gorenjska Sustainable Energy and Climate Plan" [34]. Other regions do not collect energy data on a regional level since the Statistical Office of the Republic of Slovenia – SURS, and ARSO collect them only at the national level. Table 11 summarizes these values. As it can be noted, the residential, the industry, and the transport sectors were the main energy consumers and CO_2 emitters.

	Final energy consumption [toe]			**Emissions of tCO_2**		
	2005	**2011**	**2016**	**2005**	**2011**	**2016**
Municipal public buildings	5.167	4.867	4.361	18.626	17.544	16.212
Public lighting	1.048	910	640	5.977	5.191	3.649
Residential buildings	125.297	124.104	112.404	393.646	267.845	230.085
Industry		136.308	151.288		529.717	583.281
Transport	36.465	40.247	51.178	107.268	119.852	153.299
Total	**167.979**	**306.437**	**319.874**	**525.517**	**940.149**	**986.526**

Table 11. Final energy consumption and CO_2 emissions in the Gorenjska region in 2005, 2011 and 2016.

5.3.3 Climate change scenarios, risks and impacts for the Gorenjska region

In a more detailed analysis of climate trends in the program area the only available information exists for the Gorenjska region, from the "Gorenjska Sustainable Energy and Climate Plan" [34] For reference, we also included the ARSO meteorological stations Rateče and Jože Pučnik

Ljubljana Airport, which have a sufficiently long set of measurements, and at the same time represent the major part of the inhabited area of the Gorenjska statistical region.

In the case of a moderately optimistic RCP 4.5 emission scenario, in the Gorenjska region the average air temperature will increase by approximately 0,8 °C in the period 2010-2040 (Figure 58). The warmest month will be February (1,2 °C), the least warm April (0,3 °C). Based on meteorological seasons, the maximum change in temperature will occur in autumn and the change will be the smallest in spring. In the case of the RCP4.5 scenario, the average maximum temperature will rise most in August (1,1 °C) in the Rateč area, while in the area of J. P. Ljubljana Airport in February (1,7 °C).

The increase in the average annual temperature, as well as in the maximal and minimal temperatures, will lead to a decrease in the amount of snowfall in the winter season, and in the summer season these changes will increase the risk of more frequent hot days, heat waves, and water shortages. Expected temperatures contribute to increasing the occurrence of these extreme weather events (both by number and by the intensity).

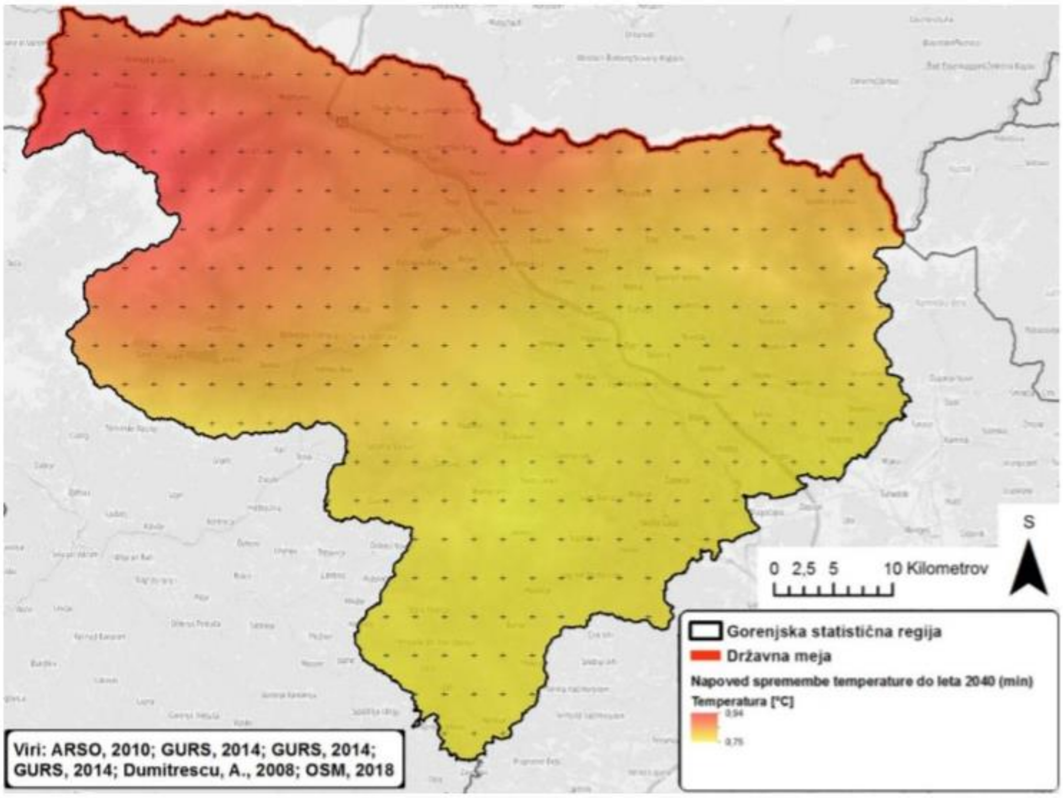


Figure 58. Change in the distribution of the average air temperature to 2040, according to the RCP climate scenario 4.5, for the Gorenjska statistical region [34].

The average annual rainfall will increase according to the RCP 4.5 scenario by 2040 (Figure 59). In the Rateče area, the average annual rainfall for the 2011-2040 period will be around 1.479 mm, while in the area of J. P. Ljubljana Airport around 1.405 mm. According to meteorological seasons, in the Rateče area, the greatest change in precipitation will occur in winter (+9,6%) while in the area of J.P. Ljubljana Airport, the greatest changes in the amount of precipitation will occur in spring (+7,7%).

Due to the increase in precipitation, an increase in the frequency and intensity of floods is expected in the Gorenjska region according to scenario RCP 4.5, as the maximum flow of all the streams will increase. Increasing the maximum river flows in the Gorenjska region will contribute to an increase in the number and intensity of floods. For the Kokra River, maximal flows are expected to increase by around 10%, Sora by 21%, Poljanska Sora by 28%, Selška Sora by 28%, Sava by 13%, Sava Bohinjka by 6%, Sava Dolinka by 30% and Tržiška Bistrica by 5%.

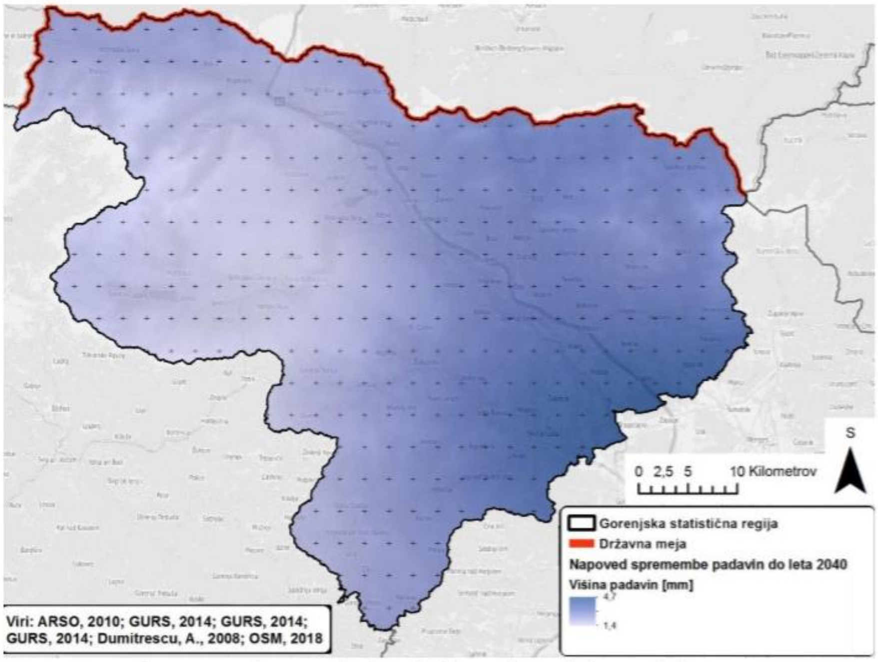


Figure 59. The predicted change and distribution of the average annual amount of precipitation, according to the RCP 4.5 climate scenario, for the Gorenjska statistical region [34]

In terms of impacted sectors, vulnerability of road transport to climate change by 2030 is small to moderate. The reason for this is, in particular, the fact that climate change is not expected to be significantly different then today, or that changes are similar to the last decade or two. At the same time, the ability to adapt in the road transport system is mostly good or at least moderate. The problem remains a low level of awareness of systemic adaptation, but it is positive that the systems of designing and maintaining roads in Slovenia are well established. At the same time, the transport system is mostly sufficiently responsive, especially in the field of remediation, but less in the area of adaptation. The vulnerability of rail transport in Gorenjska until 2030 is small and moderate. The reasons for this are a small amount of infrastructure and traffic. The course of the route is different - much more difficult events related to climate change (especially rainfall events) affect the Bohinj route but is not the priority of railway investments in Slovenia. For the aircraft traffic the impacts will be low.

Tourist outdoor activities and destinations not related to winter-sports tourism will be able to attract even more visitors due to higher temperatures in winter. Higher temperatures will be more favorable for cycling and hiking, as well as visits to hills and low mountains in the winter. Higher winter temperatures are also more favorable from the point of view of traffic safety, which can contribute to greater visits from tourists.

On the contrary, the rise in temperature will have an impact on winter sports, as the rise in temperature contributes to faster melting of snow, and at the same time it makes it difficult or even impossible to make artificial snow on ski slopes. Warmer winters would have a negative impact on the ski slopes, since most of the ski resorts in Gorenjska are at relatively low altitudes (1.500 m above sea level) with modest reliability of natural snow cover. According to research in Austria, it was found that with the temperature rise by 2-3 °C, the duration of the ski season would be reduced by one month, and reliable snow cover would remain only in high mountains (in Slovenia, this is above 1.500 m above sea level). With artificial snowmaking with compact snow, the desired duration of the ski season can still be guaranteed, but in the future, even more intense snowmaking would not help solve the problem of the shortened ski season in the lower ski slopes. When the temperature raises by 1 °C, the snow limit in the Alpine area will increase by 150 m. According to a Swiss survey [35], when the temperature increases by 3 °C, the winter snowfall in the central Alps will rise by 300 m in winter, and in the pre-Alpine regions even by 500 m. Under an altitude of 1.200 m, uninterrupted snow cover will be scarce. In the future, only mountains above 1.500 m will have a reliable snow cover. Studies on the 1981-1990 reference period show that the reliability of snow cover at Slovenian ski resorts was most influenced by altitude, but also other factors, such as local climatic features and ski slopes, have an important impact. Upon raising the reliability of the snow cover at 1.200 m, in the Gorenjska region, of the larger ski slopes, only the Vogel, Krvavec and Soriška planina will have a fully reliable snow cover. When raising the reliability of snow cover at 1.500 m, Slovenia would have a completely reliable snow cover only in the Kanin ski area, while only a few of the highest skiing trails on Vogel and Krvavec will be adequate for ski activities.

In the future, threats will increase for almost all forests. The situation is expected to be further aggravated in already endangered areas, but low-lying forests will also be at risk. In all forests, we can expect a decrease in productivity (annual increment) in years with increased droughts, the continuation of spruce bark beetles attacks and possible increased occurrence of pests or diseases on other tree species. Potential consequences of negative impacts of climate change on forests include:

- Change in the composition of forests and accelerated rejuvenation of forests;
- Reduction or cessation of the provisions of individual functions and ecosystem services of forests, including the protective functions (e.g. prevention of erosion and avalanches);
- Increase in the cost of providing protective functions with forest restoration and infrastructure operations;
- Reducing the attractiveness of the landscape for recreation and tourism;
- Increasing the costs sanitation harvesting and simultaneous reduction in wood prices on the market;
- Reducing the profitability of forests for their owners;
- Time fluctuations or interruptions in yields from the forest as a result of damage and early restoration of sanitation harvest.

6 Conclusions

Since the industrial revolution, increasing quantities of GHG emissions derived from anthropogenic energy related activities are causing temperature rise and severe consequences on all the Earth's natural systems. In line with this, the EU has directed to its member states to adopt mitigation and adaptation strategies to fight climate change. Both Italy and Slovenia consume most of their energy and emit most of theirs GHGs in the transport, residential, and industry sectors and aim to reduce their GHG emissions by 40%, increase energy efficiency and turn to renewables. However, as extreme weather events are intensifying in both Italy and Slovenia, both countries are developing their adaptation plans, mainly focused to increase resilience in water and coastal management, environmental protection (including agriculture and forestry), and public health. The Metropolitan City of Venice, the Friuli Venezia Giulia region, and the west regions in Slovenia (Gorenjska, Osrednjeslovenska, Primorsko-Notranjska, Obalno-Kraška, Goriška), that form the program area of project SECAP, face similar energy and climate issues. For all these regions, the mitigation option consists of energy requalification of buildings, increase in renewables, and management of the urban mobility. However, official energy consumption data are often lacking, being at times only partially available or outdated. Furthermore, a shared methodology in data collection between the regions of the program area is missing. Adaptation options are more context specific, and consist of better spatial planning, flood prevention, water management, environmental resilience, and public health. However, sometimes higher resolution climate change projections are missing, which makes the choice and implementation of adaptation options more difficult. Also, it seems there is a lack of communication and poor best practices exchange between the regions in the program area.

The project SECAP takes the successful example of The Covenant of Mayors initiative to meet the EU and national mitigation and adaptation objectives and face the energy and climate related issues in SECAP programme area. The project will consist in producing a shared mitigation and adaptation strategy, providing support for local municipalities in the transition from their SEAPs to SECAPs, helping them to choose the appropriate and context specific mitigation and adaptation actions, taking a bottom-up approach in fighting climate change.

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8 List of figures

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