Executive Summary

The International and European framework

- In order to limit the global warming between 1.5°C and 2°C compared to pre-industrial levels, the Paris Agreement, adopted at COP 21 in Paris on 12 December 2015, invites Parties to submit by 2020 their "Long-term low greenhouse gas emission development strategies" by 2050.
- In this perspective, the Regulation on the Governance of the Energy Union¹, in article 15, provided that the Commission shall adopted, by the beginning of 2019, a proposal for a Union long-term strategy for greenhouse gas emissions reduction and that, by 2020, each Member State shall prepare and submit to the Commission its long-term strategy with a perspective of at least 30 years.
- In November 2018, the Commission approved the Communication "A Clean Planet for all", accompanied by an in-depth *Analysis Document*², which identified several decarbonisation pathways to reduce GHG emissions for the EU in 2050 (compared to 1990) of between 80% and 100%.
- Along these lines, Commission President Ursula Von der Leyen, in her Communication on the European Green Deal, outlined a growth strategy "aimed at transforming the EU into a just and prosperous society with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases by 2050 and where economic growth is decoupled from resource use". This orientation was confirmed in the Conclusions adopted by the European Council on 12 December 2019, with the explicit support of the Italian Government.

The approach adopted

- In this context, the National Long-term Strategy (hereinafter referred to as the "Strategy") identifies the possible pathways to achieve "climate neutrality" in Itay by 2050, in which the remaining greenhouse gas emissions are offset by CO2 sequestration and the eventual use of CCS-CCU.
- In order to quantify and qualify the effort to be made in this direction, the Strategy goes through two logical steps:
 - as a first step, a *Reference Scenario* has been elaborated based on the three essential elements:
 i) the achievement of the objectives of the Integrated National Energy and Climate Plan (NECP),
 "extending" until 2050 the consequent virtuous energy-environmental trends; ii) the adoption of exogenous GDP and population dynamics, in line with the most recent ISTAT forecasts available³; iii) the integration of the effects of climate change, in terms of potential variations in day degrees, crop yield and forest fire frequency⁴ and highlights the consequent priority actions in terms of "adaptation";
 - starting from the emission gap identified in the framework of the Reference Scenario, several simulations were conducted to identify combinations, synergies and critical issues of the potential levers that can be activated to achieve climate neutrality by 2050 (*Decarbonisation Scenario*). These levers can be identified as follows: i) reduction of energy demand, in particular linked to a decrease consumption in transport and civil sectors; ii) a radical change in the energy mix in favour of renewables (RES), combined with a deep electrification of end uses and the

¹ Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the governance of the Energy and Climate Action Union amending Directives (EC) No 663/2009 and (EC) No 663/2009. 715/2009 of the European Parliament and of the Council, Directives 94/22/EC, 98/70/EC, 2009/31/EC, 2009/73/EC, 2010/31/EU, 2012/27/EU and 2013/30/EU of the European Parliament and of the Council, Council Directives 2009/119/EC and (EU) 2015/652 and repealing Regulation (EU) No 525/2013 of the European Parliament and of the Council.

² <u>https://ec.europa.eu/clima/sites/clima/files/docs/pages/com_2018_733_analysis_in_support_en_0.pdf</u>

³ The latest official projections predict a lower GDP growth and population than the previous ones, recommended by the EC, incorporated in the NECP: the adoption of a different set of exogenous population, by 2030, has a visible but relatively limited effect, which does not affect the development of infrastructure and the layout of energy production outlined in the Plan. The first update of the NECP will be an opportunity for alignment.

⁴ The Central Scenario - RCP 4.5- of the latest IPCC Report is taken as a reference.

production of hydrogen, to be used as it is or transformed into other fuels, also for the decarbonisation of non-electrical uses iii) an increase in the CO2 sequestration guaranteed by forest land (including forest soils) obtained through sustainable management, the restoration of degraded land and afforestation, accompanied, if needed, by the use of forms of CCS-CCU.

It should be noted that the Scenarios outlined do not take into account the impact, still difficult to
quantify, of the health emergency linked to the SARS-CoV-2 virus. In addition to the short and mediumterm negative production shock, the effects of the health crisis on the decarbonisation process will vary
according to a multiplicity of factors such as the possible acceleration of economic recovery measures in
a sustainable key (both at European and national level) or a structural change in citizens' working habits
and methods (for example, greater recourse to smart-working). The evaluation of these aspects, which
is clearly incompatible with the timing of this document, can be fully addressed in a future update of the
Strategy.

The historical data and the Reference Scenario

The latest Greenhouse Gas Emissions Inventory⁵ reports that emissions decrease by about 17%, between 1990 and 2018, from 516 to 428 millions of CO2 equivalent tonnes (Mton CO2 eq). Including the emissions and removals from land use, land use change and forestry sector⁶ (about 36 Mton CO2 eq in 2018), the amount of emissions is reduced to about 390 Mton CO2 eq: this value represents, therefore, the overall effort needed to achieve the full decarbonisation by 2050.

- The "first section" of the decarbonisation process, for the period 2021-2030, has already been outlined in the NECP, which has identified specific objectives regarding the growth of renewable sources (30% of final consumption), the improvement of energy efficiency (-43% compared to the Trend Scenario⁷) and the reduction of greenhouse gas emissions, divided between the "ETS" and "non-ETS" sectors (at least -43% and -33% respectively compared to the 2005 figure).
- Confirming and extending to the following twenty years the virtuous energy-environmental dynamics of the NECP, in the *Reference Scenario*, at 2050, there are about 220 Mton CO2 eq remaining which, taking into account the removal of the LULUCF sector, fall just below 200 Mton CO2 eq (roughly 40% of the 1990 level)
- Reading this figure at the macro-sector level, it appears that about 70% of the remaining emissions by 2050 comes from "energy uses":
 - the transport sector is the first in terms of emissions, covering about 30% of the total (including agricultural machinery). There is insufficient improvement in the efficiency of traditional fossil fuel-based vehicles and their only partial replacement with low-emission technologies;
 - the industrial sector shows a significantly decrease, about 25% of the total, in terms of emissions. The energy sector with a progressive penetration of renewables, greater efficiency in thermoelectric conversion and the use of natural gas instead of more polluting sources, sees emissions fall to about 1/3 of the current level; the "other" industries, on the other hand, show an objective complexity to make a "technological (and investment) leap forward", compared to the process of gradual energy efficiency that has been undertaken for some time;
 - the residential and commercial sector, although recording a decrease second only to that of the energy industry, still retains a significant reduction potential, corresponding to about 15% of total emissions.
- Looking at the "non-energy uses" sector, which covers the remaining 30% of the total, it emerges, as
 already noted in the NECP, that it is substantially difficult to compress emissions from
 agriculture/livestock and industrial processes.

⁵http://www.sinanet.isprambiente.it/it/sia-ispra/serie-storiche-emissioni/national-inventory-report-2018/view

⁶ Covers net greenhouse gas removals from land use, land use change and forestry (Land Use, Land Use Change and Forestry). ⁷ PRIMES 2007 scenario produced by the European Commission.

• Given, therefore, that the simply "extension" of current trends, however virtuous, would be insufficient to reach the target of climate neutrality by 2050, it is necessary to foresee a real change in the "Italian energy paradigm" which, inevitably, goes through investments/choices that affect the technologies to be applied, infrastructures but also the lifestyles of citizens.

The decarbonisation process

- On the methodological level, the *Decarbonisation Scenario* requires three orders of premises:
 - the complete closure of the "emission gap" can be achieved through different options, also cumulative;
 - the pathways outlined highlighted a series of critical issues technical, operational, economic, social that must be addressed; in particular, assumptions are made about the availability and diffusion of different technologies necessary for the full deployment of the decarbonisation process (for example, storage systems and applications for the production and use of hydrogen): However, it should be stressed that, at least in part, the achievement of these conditions depends on investment guidelines and choices to be defined at European and International level (e.g. in terms of sector coupling and energy carriers to be favoured for certain end uses, even going beyond the principle of technological neutrality);
 - it is assumed that it is possible to balance the need for strong development of renewable sources with other environmental objectives

Energy demand

- A first important challenge is that final consumption will be reduced significantly, by about 40% compared to the current level. Part of this reduction is already incorporated in the *Reference Scenario* as a result of the trends triggered by the NECP, in full coherence with the European principle "energy efficiency first": the additional effort must be concentrated, first of all, in the residential/commercial and transport sectors. In particular:
 - the "annual renovation rate" of buildings, mainly "deep" building renovation, must accelerate significantly: considering that the 2030 objectives of the NECP require a rate of 0.9% for the residential sector, by 2050 it will be necessary to increase to about 2%, of which about 80% of deep renovation;
 - a further increase, in the share of private mobility needs, of public/sharing transport is expected, with a significant reduction in the number of cars on the road and, on the goods side, more effective logistics are needed (for example, with a drastic reduction in "empty journeys");
 - in the non-energy industry sector, significant cuts in production have been excluded, and therefore demand remains essentially unchanged because it is already "efficient" in the *Reference Scenario*, where are considered schemes to give a (high) price to the CO2 emitted.
- The reduction in consumption must be accompanied by an important recomposition of energy sources and vectors used:
 - electricity exceeds 50%, with significant peaks in some sectors (for example, cars will be mainly electric and buildings heated with heat pumps);
 - renewables, as well as in the form of electricity, also grow in the form of biomethane and hydrogen, reaching, overall, no less than 85-90% of final consumption;
 - a development of the circular economy is assumed, to the extent that the energy from waste is marginal.
- This double step on quantity and quality of consumption requires several "enabling factors" to which obviously correspond important critical issues. In particular:
 - the willingness of citizens to change their behavior, starting with the transition to public transport and cycling (to be adapted in terms of infrastructure/means);
 - the possibility and the willingness, always of citizens, to carry out "invasive" interventions for the deep renovation of buildings;

• the possibility to make a "technological leap" in some sectors of the industrial sector, for example in steel, to replace highly emissive fossil fuels with renewable energy.

Energy supply

- Based on these evolving demand requirements, energy supply will have to manage several crucial aspects.
 - Electricity production must more than double its current level and be between 600-700 TWh with a share covered by renewables between 95% and 100%, depending on whether or not a complete abandonment of fossil fuels is adopted in both electricity generation and the steel industry.
 - This result is achievable thanks to the deployment of unexploited sources, first of all offshore wind power, and solar energy: the installed photovoltaic capacity estimated at 2050 varies between 200 and 300 GW (i.e. 10-15 times that of today). Of course, the possibility of usig imports, i.e. the development of other technologies, is not affected.
 - The exponential increase in production from renewable sources, in addition to a coherent adaptation of the electricity grid, requires that pumping, also of marine origin, be fully exploited and enhanced and that centralised and distributed storage systems be developed: in particular, electrochemical storage systems should reach 30-40 GW, 4-5 times the level already incorporated in the NECP by 2030.
 - With the assumptions made about the sources used, a significant share of electricity, at least 25-30%, is destined, particularly in the overgeneration phase, for the production of hydrogen: in perspective, it will therefore be essential to manage this vector in a technologically effective (share mixable in the network with gas/biomethane, direct use in transport and industry, possibility of storage) and economically efficient way (production cycle costs, transport, storage, reuse).
 - Hydrogen derived from renewables combined with captured CO2 of "bio" origin allows the production of biomethane and fuels similar to conventional ones but with zero greenhouse gas emissions (e-fuels), thus favouring the reuse of existing infrastructures and vehicles. In compliance with air quality objectives, the potential of biomass must therefore also be fully exploited, including the valorisation of wood deriving from sustainable forest management.
 - From an infrastructural point of view, the progressive replacement of gas with hydrogen will require an upgrading and an overall reconfiguration of the network, for example, with portions dedicated exclusively to the transport of hydrogen itself and peripheral sections of the distribution that could be closed (because served by local systems), as well as an appropriate coupling of the electricity and gas sectors.
 - 0 While a part of these important volumes of energy from renewables could also be acquired from abroad, any case, for the decarbonisation process, in the aspects of location/authorisation/acceptance of plants and works for the adaptation of the networks will be directed: as already well highlighted in the NECP, it is necessary to identify effective ways to recompose/resolve potential conflicts between the development of renewables and "other" environmental objectives, such as land consumption or landscape protection.
- Overall, in the *Decarbonisation Scenario*, these demand-side and supply-side dynamics come to draw a completely different picture of energy flows from the current one. On balance, emissions from energy use should be in a "fork" of 15-35 Mton CO2 eq. In detail:
 - residual emissions derive from the industrial sector where a share of gas remains, even in the hypothesis of complete exit of fossils from electrical generation and hydrogen reconversion of steel (lower part of the "fork");
 - transport and civil emissions are in fact zeroed with a combination of electricity (from renewable sources), bioenergy, hydrogen.

The non-energy sector, sequestration and capture

- Emissions in the non-energy sector are the hardest to compress. The margins of improvement with respect to the *Reference Scenario* are in the order of 20%, with a residual stock of around 50 Mton CO2 eq, much higher than that resulting from energy use. In particular:
 - for agriculture an improvement can be incorporated, however relative, related to the management of livestock farms and innovative virtuous techniques to increase the stock of carbon in the soil;
 - in industrial processes, net of energy aspects, with respect to what has already been considered in the *Reference Scenario*, no other intervention margins have been incorporated, both because the maintenance of production levels has been assumed and because no further abatement technologies seem to be possible at the moment.

The possible offsetting of residual emissions (energy and non-energy sectors), corresponding to a total of 65-85 Mton CO2 eq, starts from the forest sector's capacity to increase sequestration (LULUCF):

- with fire-fighting and sustainable soil management policies, the aim is to bring back the "carbon sinks" to their historical maximum, equal to about 45 Mton CO2 eq.
- In order to "zero the emission residue", equal to another 20-40 Mton CO2 eq, it is possible to exploit part of the available potential estimated at national level for the storage of captured CO2 (CCS), in particular in industry (energy and non-energy).
- As an alternative, even partial, to CCS, further changes in habits, technologies and production methods can be hypothesized that directly impact those segments where emissions are more difficult to reduce, also as a consequence of the actions expected at European level for the implementation of the Green Deal. For example with: a) the change in eating habits that affects the agricultural sector, it being understood that a reduction in the number of animals bred can have a significant impact on the availability of biomethane; b) the availability of technologies that allow the complete phase-out of F-gas with a high GWP, or applications that allow the "imprisonment" of carbon captured in solid form in products/materials; c) the revision of energy taxation; d) the adoption of challenging European action plans for the circular economy and climate neutrality of energy intensive industrial sectors.

Considerations and conclusions

- The analysis carried out in order to define the long-term strategy highlights limits/criticalities to be addressed in the decarbonisation process, but also useful suggestions to give an immediate impulse and coherence to National, European and International policies on a variety of issues.
- At a National level, it is considered necessary that such an important and radical transformation as the
 one envisaged in this Strategy should permeate all public policies, in a broadly shared path. First steps in
 this direction have been taken with the transformation of "CIPE", Interministerial Committee for
 Economic Planning, into "CIPESS", Interministerial Committee for Economic Planning and Sustainable
 Development, and with the launch of the Green Deal, which has also been mentioned in the NECP.
- However, a change of attitude on the part of the various institutional levels, citizens and businesses is
 desirable, as too often the path towards decarbonisation, even in view of the 2020 objectives, meets
 some resistance. These resistances, while motivated by the defense of other legitimate interests, should
 be mitigated on the basis of a greater sharing of the need to proceed convincingly along the path of
 transition. In addition, the concept of a "just transition" will need to be continuously and concretely
 translated into measures that fairly distribute benefits and costs, without leaving behind those who may
 be displaced by the transition.
- In terms of strategic choices, in the 2050 horizon, the emergence of the fundamental role of electricity and hydrogen suggests evaluating the possibility of a progressive reconversion of gas infrastructures for transport and distribution, first of gas-hydrogen mixtures and then of hydrogen. Operationally, this translates into the promotion of enhanced cooperation between electricity transmission and gas

transport system operators, with joint planning, experimentation and study of infrastructure adaptation needs.

- At European level, it is considered necessary to arrive at a unified framework within which the National Strategies have a number of major common axes of intervention. A single market for energy and energyconsuming appliances is not conceivable without uniform guidelines and coordinated action on certain major issues, such as, for example: the role of hydrogen and renewable fuels for the decarbonisation of sectors such as heavy transport, sea and air transport or the steel, chemical and cement industries; or, energy carriers (and related infrastructure) to be favoured for certain end uses such as private transport, for which technological neutrality or choices made at the level of individual states could be economically unsustainable, as well as probably creating difficulties in the functioning of the single market.
- In general, major infrastructure connecting Member States, such as power lines, gas pipelines, roads, rail, maritime and air transport routes, should continue to be interconnected so that the needs of consumers and businesses can be met in a homogeneous way.
- The strength of a united Europe must be harnessed to drive the search for technological and operational solutions that make it possible to reconcile the significant growth in renewable energy sources with the need to protect the environment and the landscape.
- It will be even more important that the European path towards decarbonisation is shared on a global scale: this is essential not only because a "solo flight" would be insufficient to achieve the results set out in the Paris Agreement itself, but also to avoid displacement effects on the European production system. This is not a marginal aspect, considering that, within the framework of this Strategy, the substantial maintenance of the lifestyle and the productive and industrial structure of our country has been assumed.
- Finally, in order to fully cover the emissions gap and achieve climate neutrality, political choices with a high social/sectorial/local impact, technologies that are still not yet ready to be pursued only on a coordinated European basis, as well as an international sharing of the decarbonisation process, are necessary. In order to take into account all these issues the Strategy must inevitably considered as a dynamic tool, updated periodically.