Net Zero E-conomy 2050

Decarbonization roadmaps for Europe: focus on Italy and Spain

The European House Ambrosetti
enel Foundation

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The contents of this Executive Summary refer exclusively to the analysis and research carried out by The European House – Ambrosetti, Enel and Enel Foundation and represent their opinion which may not coincide with the opinions and viewpoints of the individuals involved in the initiative.

Preface

Francesco Starace
Chief Executive Officer
and General Manager, Enel

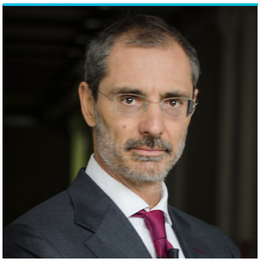
Two years after the outbreak of the COVID-19 pandemic and its massive implications for the global economy, the war in Ukraine has made concerns about the sustainability of the current energy system more pressing than ever.
With markets still recovering from the effects of COVID-19, the Russian invasion of Ukraine has in fact had an enormous impact on the global energy sector, with concerns about supply security matching price spikes, with oil reaching levels of more than $120 a barrel and gas TTF spot price hitting 270 €/MWh. The uncertain duration of the conflict and its global—political and economic—implications though make it difficult to predict how much of the market disruption will be permanent and how much is just temporary.

These events have reinforced the evidence of the unsustainability of an energy system based on fossil fuels. If the need to tackle climate change alone is more than a sufficient reason to pursue a clean energy transition, the vulnerability of our economies reliant on gas and oil has made this a more than compelling urgency. Accelerating the reduction of fossil fuel use through an equally accelerated deployment of smartly interconnected renewable energy sources, an enhanced effort on energy efficiency and electrification of final uses is a perfectly viable solution to ensure a secure, healthy and more prosperous existence. The enormous challenges emerged in the last two years, therefore, represent at the same time a tremendous opportunity for Europe to get rid of costly, unhealthy and unsecure fossil fuels (and limit the impact of climate change) by maximizing the environmental, social and economic benefits of a transition to a green economy.
All these concerns have already been addressed by the European Commission with the Next Generation EU, in 2020, and the "REPowerEU" initiative, further boosting the energy transition objectives set out in the "Fit for 55" plan adopted just one year ago. The EU's ambitions are thus heightened to respond to vital challenges, focusing its efforts on fossil phase-down (and substitution), renewables deployment and electrification of final consumption.
Nevertheless, despite the initiatives of the EU and its Member States and the efforts undertaken by the private sector, the results achieved can be greatly improved. Economies are far from being carbon neutral and dependence on the import of natural gas has gotten even worse in the last two decades.

The 2021 Study "*The European governance of energy transition: enabling investments*" underlined that Europe and Italy are not progressing at sufficient speed to meet the "Fit for 55" objectives in due time, and that – especially in Italy – it will be essential to address a number of governance issues that are limiting the effectiveness of the efforts towards decarbonization.

This year's Study, "*Net Zero E-conomy 2050*", is focused on Italy and Spain within the European context. It confirms that neither the EU nor Italy are yet progressing at a sufficiently swift pace towards the energy transition, and, while Spain seems to be on the right track for renewable deployment, it is still not on due course as far as energy efficiency and electrification is concerned. Unsurprisingly, the advantages of quickly rolling out an energy transition based on renewables, smart grids, electrification, and energy efficiency are immense and not fully understood yet.
The Study highlights that investing resources to reach "Net Zero" by 2050 would not only bring us faster towards a clean, sustainable and energy secure future, but will use resources more efficiently, create more jobs and bring more significant savings than pursuing a less ambitious pathway. Each Euro spent towards "Net Zero" by 2050 will yield 1.64 Euros in Italy and 1.28 in Spain.
The pathway towards "Net Zero" by 2050, will create 2.6 million net jobs in Italy and 1.8 in Spain. Also, effectively deploying the "Net Zero" pathway will also allow to dramatically reduce the spending for fossil fuels, which are mostly imported, with a subsequent benefit in terms of energy independence and security of supply. In fact, between today and 2050, Italy and Spain could save about 1,900 billion Euros and 1,300 billion Euros worth of fossil fuel expenditures respectively with respect to a Counterfactual scenario where a "Net Zero" pathway is not undertaken.

Finally, the dramatic reduction in polluting emissions (such as nitrogen oxides, sulphur oxides, particulate matter) could result in Italy and Spain in cumulative savings of 614 billion Euros and 317 billion Euros in terms of improved health, recovered productivity, and lives saved.
Pursuing this path will therefore bring huge benefits to the economy and the environment and will contribute to creating a more sustainable, just and prosperous society.
To achieve this goal, huge investments must be deployed quickly, and this will require close cooperation of different sectors both among themselves and with the public sector and all citizens.
National and European institutions have been working not only to set targets but also to accelerate the efforts for the transition, earmarking resources and removing some obstacles which could slow down the deployment of the needed investments. In a context of global turbulence and great uncertainty, this is very positive. A lot of work lies ahead of us all. We are ready to do our part.



Valerio De Molli
Managing Partner and Chief Executive Officer,
The European House – Ambrosetti

"The world will not be destroyed by those who do evil, but by those who watch them without doing anything."

Albert Einstein

After the reduction in 2020 due to COVID-19 crisis, global CO_2 emissions reached an all-time negative record in 2021 with 36.3 billion tonnes. This trend highlights more than ever the need to rethink the current energy system in order to keep global warming under the 1.5°C threshold by the end of the century, as established in the Paris Agreement in 2015.

Moreover, the energy crisis, with the surge of prices in international energy markets, and the outbreak of the Russia-Ukraine conflict, has brought to light the EU's vulnerability and energy dependence on fossil fuel imports. Europe is 57% dependent on energy imports and over the 20-year period 2000-2020 this share remained almost unchanged, if not increased by about one percentage point. Security of supply is even more important for European Union countries like Italy that are heavily dependent on foreign gas. Indeeed, Italy ranks 2nd (just behind Malta) for gas dependence index, with a value of 41.2%. Considering the same index only on the Russian dimension, Italy is the 4th most exposed countries to the threat of a shortage in Russian gas supplies, as it accounts to 19%. Moreover, Italy is the 5th country for gas intensity of GDP index and imports 93% of the gas consumed from abroad.

Thus, with the "Fit for 55" package from one side and the "REPowerEU" plan from the other, the European Union and its Member States are going through a period in which major changes must be put in place to address the climate and energy crises, which are strongly interrelated. Indeed, equipping countries with renewable energy sources (which are typically domestic) and at the same time increasing electrification of consumption would reduce dependence on foreign fossil fuels and at the same time decarbonize economic systems.

However, each EU country needs greater efforts to implement this change, since at the current pace they risk falling short of their national targets and facing climate change catastrophes. Focusing on the two countries analysed in this Study, at the current pace, Italy and Spain would reach the 2050 GHG national policy targets in 2109 and 2154 respectively.

Therefore, as Albert Einstein's quote suggests, timely decisions and actions need to be put in place to facilitate a rapid change of course. This Study "Net Zero E-conomy 2050", conducted with the Enel Foundation and Enel, goes precisely in this direction. The analyses identified two decarbonization scenarios ("Low Ambition" and "Net Zero") for Italy and Spain in order to identify a possible pathway to reach the 2050 zero emissions target ("Net Zero" scenario) and compare the economic, social and environmental impacts with respect to a less ambitious scenario ("Low Ambition" scenario).

Looking at the technology and solution deployment in the two scenarios, the "Net Zero" one envisages investments for 3,351 billion Euros in Italy and 2,215 billion Euros in Spain in the 2021-2050 period, less than the investments needed by the "Low Ambition" scenario. Investments in the "Net Zero" scenario are driven down by transport, since it will lead to lower number of private cars thanks to supportive policies for public mobility and a strong push towards shared mobility models.

The "Net Zero" scenario envisages not only lower investment but also higher benefits. Indeed, "Net Zero" scenarios in Italy and Spain are associated with relevant benefits by 2050, in terms of Value Added (+328 billion Euros and +223 billion Euros), employment (+2.6 million jobs and +1.8 million jobs), reduction of pollution (-614 billion Euros and -317 billion Euros of health and productivity costs), savings in fossil fuel expenditures (-1,914 billion Euros and –1,279 billion Euros), gas intensity of GDP index (-94% and -92% in the gas intensity index of GDP) and energy dependence (-73.5 p.p. and -54.9 p.p.).

Introducing policies that can accelerate the energy transition and ensure the achievement of a zero-emission economy by 2050 is therefore a priority not only to preserve the earth's sustainability but also to seize important opportunity for value creation and employment and for a greater energy independence.

Therefore, the Study has identified two prerequisites and five policy areas to overcome the current shortcomings of the energy transition in European Union, in Italy and Spain, and to put the continent on a more accelerated path towards a sustainable future.

This ambitious Study would not have been possible without the concerted efforts of the top management of Enel and Enel Foundation, starting with Francesco Starace, Carlo Papa and Simone Mori, together with their teams, in exploring an issue at the forefront of debate today, and without the invaluable contribution of the Scientific Committee – Laura Cozzi (Chief Energy Modeler, IEA – International Energy Agency), Claudio De Vincenti (Professor of Political Economy, University of Rome "La Sapienza"; Chairman, Aeroporti di Roma; former Minister for Territorial Cohesion and the Mezzogiorno), Andris Piebalgs (Professor, Robert Schuman Centre for Advanced Studies - European University Institute; Adviser to the President of Latvia; former European Commissioner for Energy and for Development) and Marina Serrano (President, Aelec – Spanish Association of Electricity Companies) – to whom go my deepest thanks.

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Remarks by the Scientific Committee

Laura Cozzi
Chief Energy Modeler,
International Energy Agency

The need to accelerate the energy transition has been exacerbated – together with the COVID-19 pandemic - by the current energy crisis triggered by international geopolitical tensions and more specifically by Russia's invasion of Ukraine. Costs decline in clean energy technologies allow us to tackle both energy security and climate change with the same mix of solutions. Increasing the use of renewables and energy efficiency will in fact have the dual objective, on the one hand, increasing national energy independence and security and, on the other hand, containing emissions and the increase of temperature.

However, CO_2 emissions reached in 2021 all-time negative record with 36.3 billion tons. There is an urgent need of action and an extraordinary cooperation to reach long-term net zero greenhouse gas (GHG) emissions goals. To this extent, back in March 2020, the IEA urged governments to put clean energy investments and sustainability at the centre of their economic recovery efforts to place global emissions on a steady downward path.

The same year we published the landmark "*Net Zero by 2050*" roadmap for the global energy sector, to help governments, industries and the finance sector to identify concrete steps and actions needed to live up to keeping temperature rise below 1.5°C. More recently, we have been supporting the European Union and its members with a plan to increase energy security. On 3 March 2022, we published the strategy to reduce European reliance on Russian gas in a 10-point strategy, which – if implemented by the end of the year – could lead to a reduction of Russian gas demand in Europe by one third with respect to the 155 billion cubic metres of gas imported in 2021, while at the same time reducing GHG emissions.

In this context, the number of countries announcing commitments to achieve net zero emissions over the coming decades continues to grow. But the pledges by governments to date – even if fully achieved – fall well short of what is required to bring global energy-related carbon dioxide emissions to net zero by 2050 and give the world an even chance of limiting the global temperature rise to 1.5°C.

It is precisely in this direction that the strategic value of the Study "*Net Zero E-conomy 2050. Decarbonization roadmaps for Europe: focus on Italy and Spain*" fits in, underlying the need to accelerate the decarbonization process, analyzing ambitious scenarios for Italy and Spain and identifying a set actions roadmap to the decarbonization. In particular, the Study delves into the main levers to achieve a fully decarbonized economy, by focusing on the electrification of final consumption and the massive deployment of renewable energy production. The report importantly finds that clean and green energy transition delivers numerous social, economic, environmental and energy security benefits, in terms of value added, employment, reduction of emissions, fossil fuels expenditures savings and increased energy security.

The world faces a huge challenge to transform the ambition of net zero by 2050 from a concept to a reality. There is no time to waste.

Claudio De Vincenti
President, Aeroporti di Roma;
former Italian Minister for Territorial Cohesion and South;
former Italian Secretary of the Council of Ministers

This Study makes a relevant contribution, in terms of analysis and proposals, to the energy transition in Italy and Spain according to the European Green Deal strategy. In particular, it focuses on the measures that are necessary to accelerate the transition towards the development of renewables, a wider use of electricity in transport and industrial processes, as well as a higher energy efficiency in buildings.

Until four years ago, Italy had a positive track record in renewables development and energy efficiency improvement, which allowed the country to achieve and exceed the 2020 targets originally set at European level both for the reduction in GHG emissions and for the renewables share. However, following the sustained growth recorded in 2008-2017 period, as well as the previous positive Italian track record in energy efficiency, renewables development has dramatically slowed down over the past 3-4 years. The current trends will not allow Italy to reach the 2030 targets set in the 2019 National Energy and Climate Plan. At the same time, these targets must be revised and strengthened in order to meet the new targets set by the European Union in its Climate Law and in the "Fit for 55" package.

Therefore, Italy needs to quickly remove the factors that have hindered its energy transition in recent years. The main stumbling blocks that to be removed are related to:

- (i) Authorization procedures, characterized by a number of administrative steps with a Byzantine overlapping of decision-making responsibilities.
- (ii) The environmental "gold plating" practice, a proliferation of environmental requirements far beyond EU rules, which has the paradoxical effect of harming effective environmental protection by generating a situation of uncertainty and confusion.
- (iii) The particular multilevel governance structure, characterized by an overlapping of legislative powers which that produces a continuous conflict between the State and the Regions.
- (iv) The behaviour of part of the judiciary, which sometimes goes beyond the correct limits of its role, with an "a priori" accusatory approach that determines a paralyzing defensive attitude in political and administrative decision-makers.

Thus, reforms are the key to unlocking the transition investments. The Government's recent simplification measures have started to deal with the above issues by introducing:

- (i) Accelerated administrative procedures for investments that fall under the National Recovery ad Resilience Plan and the National Energy and Climate Plan.
- (ii) For the same investments, the centralization of environmental impact assessment procedures in a dedicated National Committee.
- (iii) A justice reform aiming at a more correct delimitation of judiciary powers without weakening, while indeed clarifying, the responsibility of political and administrative managers.

Further measures will be necessary to enhance such first steps towards unlocking investments: this Study provides several useful insights in this direction.

More broadly, it is necessary to radically improve the institutional balance of powers by strengthening the role of the central government in planning, executing, and monitoring the plans, by enhancing the role of municipalities in implementing services for citizens and firms, as well as by clarifying the administrative responsibilities of Regions.

Finally, regulatory improvements are necessary at EU level, too. It is referred to the taxonomy the Commission is elaborating as a guideline for green investments to be financed. In the light of the First Delegated Act, the extreme detail of the provisions and the rigid interpretation of the "do no significant harm" principle, which reduces it simply to a "do no harm" principle, risk introducing a further overwhelming administrative burden for the national authorization procedures and a straitjacket for several technologies that are decisive for accelerating the transition path. This is particularly true in the context of the so-called "hard to abate" sectors, requiring an evolutionary approach to technologies, which is – by definition – incompatible with rigid and detailed prescriptions. Accordingly, the urgent implementation of a rapid transition strategy requires a different, more open-minded approach by European authorities.

Andris Piebalgs
Professor, European University Institute;
former European Commissioner for Energy, European Commission

The invasion of Ukraine by the Russian Federation in late February 2022 has had a deep impact on Europe's energy sector. It has enormously increased uncertainty about international energy flows and driven the surge in wholesale gas and electricity prices, which was originally expected to weaken with the end of winter. In addition, the war has extended the surge in prices for oil and its derivatives.

Outside Europe, a price explosion for several raw materials, disruption of many supply chains and increasing tension between global powers have exacerbated problems in international co-operation and suggested a broader shift towards a more complicated global order. This development has several implications for the energy transition, including a need to extend the notion of 'energy security' to include critical raw materials and intermediate goods.

The invasion of Ukraine and the escalation of the energy crisis have shifted the attention of European and national policymakers to new short-term policy priorities and strategies, such as containing the impact of increasing energy prices on consumers and identifying alternative gas supplies. Implementation of the strategies and policy priorities adopted before the outbreak of the war does not seem feasible at the moment. However, it remains essential for current national emergency strategies and priorities not to undermine the important achievements of the past such as the internal energy market and not cancel long-term policy aims such as reaching "Net Zero" carbon emissions.

Accelerating the transition to a low-carbon economy in Europe is key to addressing the causes of the crisis that the European Union is experiencing and enhancing its energy security in the medium and long term.

In the short term the European Union and its Member States have to urgently address the shock caused by the dramatic surge in energy prices. They should support those segments of society and the economy that have been hurt the most by the increase in energy prices and their volatility, and that will continue to suffer until the end of the most acute phase of the crisis. Support measures should ideally be targeted so that they distort to the minimum possible extent the signalling of the cost of resources by market prices.

Once the most acute phase of the current crisis is over, the EU and its Member States will have to reconsider what to do in the decades going up to 2050. This vision will have to be quickly translated into a roadmap based on no-regret options consistent with the strategy for 2030 and exploiting all the main decarbonized technologies. In this roadmap energy security will continue to rank high on the list of priorities but will no longer focus on fossil fuels.

The Study "*Net Zero E-conomy 2050. Decarbonization roadmaps for Europe: focus on Italy and Spain*" provides valuable input for designing an efficient pathway to addressing Europe's energy challenges. After a robust analysis of current trends, successes and failures, it proposes various scenarios and concludes that the most ambitious is also the most efficient. Importantly, the Study identifies two prerequisites for Europe to successfully rebuild its energy system. EU energy policies should be consistent, transparent and stable and the development of new green energy technologies should be a part of the backbone of Europe's industrial policy.
Europe should be ambitious, consistent and strong throughout the energy supply value chain.

Marina Serrano
President, Aelec – Spanish Association of Electricity Companies

The latest assessment report by the IPCC states that:

"Global surface temperature will continue to increase until at least mid-century under all emissions scenarios considered. Global warming of 1.5°C and 2°C will be exceeded during the 21st century unless deep reductions in CO_2 and other greenhouse gas emissions occur in the coming decades[1]."

And Spain is likely to be one of the most exposed countries in the European Union in terms of climate change.

Current trends in global CO_2 emissions have to be drastically changed and the European Union has risen the challenge by setting the goal of reaching a "Net Zero" economy by 2050, which implies the intermediate target in 2030 of decreasing emissions by 55% compared to 1990 levels.

Additionally, the Ukraine invasion has led to the outbreak of a crisis in the supply of some basic resources, which is rekindling inflation pressures across Europe. The reduction of fossil fuel imports has become an urgent policy goal. And this will become a reality only if the electricity renewables are deployed in order to fully ensure energy independence from third countries.

The main reason behind this is that the increase in the share of renewable energy sources in electricity production has shown to be the most efficient tool to both reduce emissions and increase energy independence. And the "Net Zero" target demands 100% renewable electricity production, which will be only feasible with the help of some new technological developments in the field of storage. Apart from pumping hydro plants, successful technological developments related to green hydrogen and batteries would have a very positive impact to achieve a 100% electricity mix.

However, electricity production is not the main source of emissions since agriculture, buildings, industries, or transport are also sectors to decarbonize. Therefore, the 2050 climate neutrality goal also requires an extensive effort to shift to renewable energy in final energy consumption to replace the current intensive use of fossil fuels with electrification.

1
IPCC: Climate Change 2021. The Physical Science Basis.
Summary for Policymakers (p. 14)

Electrification is the main driver for decarbonization. However, electrification in the Spanish energy-intensive sectors is not so clear at present:

- In transport, we see slow electric vehicles sales compared to neighbor countries.
- In buildings, we face a real heating system challenge, as 70% of existing buildings are block of flats.
- Spanish industry is highly dependent on fossil fuels and there are many technological uncertainties on alternatives.

Additionally, energy consumption will have to decrease drastically. Energy efficiency and the reduction in the production of final goods and raw materials, thanks to the generalized extension of the application of circular economy principles, are the main tools to significantly cut energy consumption. Here, again, the accelerated transition to electricity-based efficient technologies such as electric vehicles or heat pumps are key drivers in reaching the energy efficiency targets. This also requires additional infrastructure developments for instance to create a nation-wide network of recharging points.

The "Net Zero" economy target will need a massive investment process, mainly driven by the private sector and a large part of these investments should be allocated to the electrification process in the period 2031-2050, since the electrification rate has not increased as much as needed to reach an electricity contribution that can cover energy demand in line with the 2050 target.

The main uncertainty concerning these massive investments is how to attract capital, as the private sector requires stable regulations and well-known conditions in areas where the technology solutions are not mature yet. However, the design of the electricity market is regularly put into question, and it is far from clear whether all essential technologies will be economically viable in the upcoming years.

The great value added by this Study is to focus on the measures to be taken to accelerate the pathway to a "Net Zero" economy with specific analysis on Italy and Spain, stressing the need for a strong cooperation in the energy transition at European level and representing a valuable contribution to achieve the ambitious targets in the coming decades.

The Study's Key Findings

1 → To contain global warming, a paradigm shift in the energy system is necessary. To this end, the European Union has set itself the goal of becoming "climate neutral" by 2050. Italy and Spain need to speed up on decarbonization to prevent the risk of significant delays in meeting the 2050 decarbonization targets.

To reach ambitious climate targets, it is necessary to **electrify final consumption** as much as possible and at the same time support such electrification with a **massive deployment of renewable energy production and smart power networks**.

In fact, the trend in global CO_2 emissions – which in 2021 reached an all-time negative record of 36.3 billion tons – has highlighted more than ever the need to rethink the current energy system to keep global warming under the 1.5°C threshold by the end of the century, as established in the Paris Agreement in 2015. The need to rethink our energy system has been **exacerbated by the current energy crisis** triggered by international geopolitical tensions and more specifically by the Russian-Ukrainian war, which has further highlighted the need for a rapid transition to alternative energy sources.

To respond to these challenges, the European Union has set itself the goal of becoming **"climate neutral" by 2050** in its **Climate Law**, one of the first legislative proposals implementing the Green Deal. This also includes the intermediate step necessary to achieve net zero emissions by 2050: to keep pace with the 2050 final goal, **in 2030 GHG emissions need to decrease by 55% with respect to 1990 levels**. In addition, in July 2021 the European Commission launched the "Fit for 55" package of proposals which includes the Climate Law's GHG emissions reduction target, a review of both the EU Directive on renewables (**increase in share of renewable energy sources – RES – in overall final consumption from 32% to 40%**) and the Directive on energy efficiency (considering the target of +36% improvement in energy efficiency in final energy consumption). Under the Governance of the Energy Union Regulation, **Member States had to present their own national plans and strategies for pursuing the decarbonization of their economies by 2050** in order to align their GHG emissions reduction, RES deployment and energy efficiency improvement goals with those of the European Union. Focusing the attention on Italy and Spain the two countries taken into consideration in the Study - despite the growing ambition at European level, both register some criticalities with regards to the **main energy transition levers**.

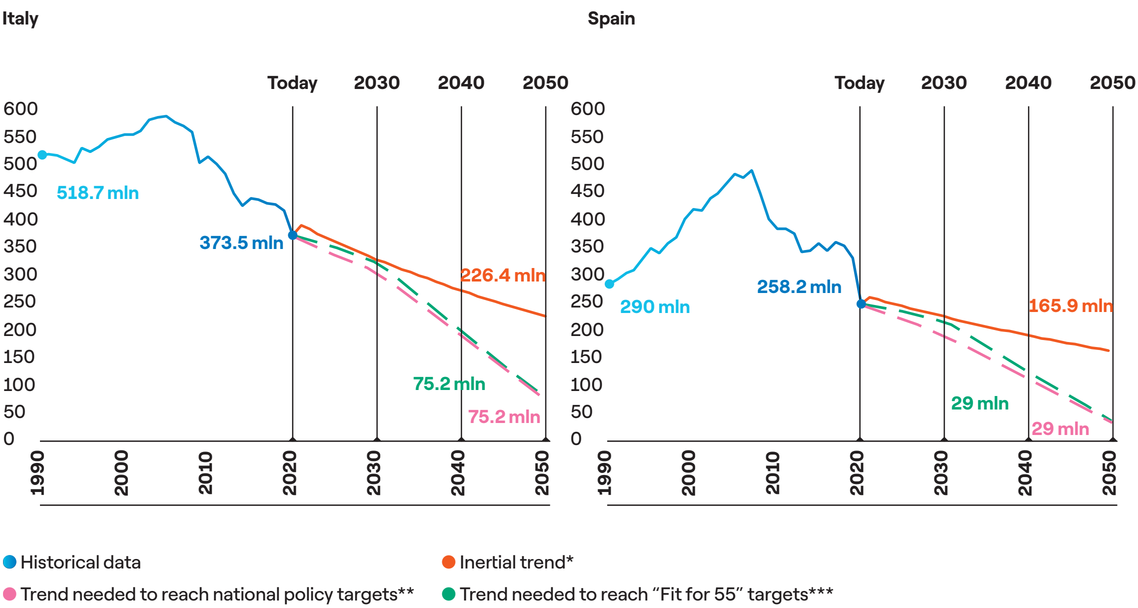
As for **RES**, based on current trends **Italy is still far from reaching the 30% target for 2030**, with a gap of nearly 8 percentage points. The situation is **even worse looking at 2050**, where the gap is 60.7 percentage points. In terms of **energy efficiency**, Italy needs to accelerate: the current trend will lead to a **difference of 35.1 Mtoe in 2050 compared to the policy scenarios**. In terms of **GHG** reductions, Italy is also slightly **underperforming** in the period 2021-2030 on the target set under the policy scenario (with a gap of 2.3 Mtons CO_2-eq.). Moreover, between 2030 and 2050, in the light of more ambitious long-term targets – namely, reducing gross GHG emissions by 84/87% compared to 1990 levels – the gap broadens further to **around 151.2 Mtons CO_2-eq. in 2050**.

With regards to Spain, **RES** projection suggests that the distance from the policy scenario is already marked in the short-term, with a gap of **15 percentage points** compared to the national policy target in 2030 and of **53.5 percentage points in 2050**[1]. However, including in the analysis also year 2020 (year in which there was a significant increase in the penetration of renewables in Spain, also due to regulatory enhancement), even though Spain won't achieve the policy target in the short-term (with a gap of 5.7 percentage points in 2030), it will overperform it in 2050 with a value of 106.4% (vs. 97% given by the national policy and "Fit for 55" targets).

Regarding **energy efficiency**, like in Italy the gap between the inertial trend and the policy scenario is broadening as time goes by. The current scenario would lead the energy efficiency trajectory in the **opposite direction** compared to the trend needed to reach the policy targets in 2030, 2040 and 2050 (with a gap of 79.3 Mtoe compared to national policy and "Fit for 55" targets). With regards to **GHG reduction**, Spain reports an inertial trend that is **underperforming** with regard to the path outlined in the policy scenarios for 2030, with a gap of 9.2 Mtons CO_2-eq. From 2030 onwards the gap between GHG reductions in the policy scenarios and the inertial trend increases further, reaching a **difference of 136.9 Mtons CO_2-eq. in 2050**.

1
The projection is based on the 2015-2019 trend so to take into account the evolution of RES prior to the exogenous shock caused by COVID-19.

FIG I → **Gross GHG emissions in Italy and Spain, 1990-2050^E (Mt CO_2-eq.)**



* The inertial trend has been calculated by projecting the CAGR from 2009 to 2019[2].
** The policy targets are the ones reported in the 2030 Integrated Energy and Climate Plan and the 2050 Long-Term strategies.
*** The "Fit for 55" targets in 2030 were estimated by projecting the same percentage increase estimated at European level.

Source → The European House - Ambrosetti and Enel Foundation elaboration of European Environment Agency, INECP and long-term strategy, 2022

2
It is worth mentioning that from 2020 onwards the RES performance has steadily improved and, at the same time, most of the coal-fired generation capacity has been eliminated.

2→ Italy is 5th for the gas intensity of GDP index and 2nd for natural gas dependence index among EU countries. Nevertheless, the decarbonization process is a key tool to achieving energy independence. In fact, over the past 10 years, the reduction in energy dependence in Italy and Spain (-9.1 percentage points in both countries) has been accompanied by an increase in electrification rates (+1.5 p.p. in Italy and +3.2 p.p. in Spain) and RES deployment (+2 p.p. in Italy and +4.7 p.p. in Spain) in final energy consumption.

The current energy crisis, with the surge of prices on international energy markets, and the outbreak of the Russia-Ukraine conflict, has brought the **EU's vulnerability and energy dependence on fossil fuel imports** under the spotlight. Europe is **57% dependent on energy imports** and over the period 2000-2020 this share slightly increasing by about one percentage point.

The natural gas dependence index[3] in Europe is equal to **23%**. Italy ranks **2nd** (just behind Malta) with a value of **41.2%** and Spain **8th** with a value of **26.1%**. Considering the same index only for Russian gas, **Italy is, with an index value of 19%, the 4th most exposed countries to the threat of a shortage in Russian gas supplies**. Russian gas dependence index of Spain is just 3% since Spain has a broader range of commercial partners. Lastly, it is important to mention that **Italy is 5th in Europe by gas intensity of GDP index[4], with a value of 34.9 toe per million Euros of GDP**, thus highlighting the structural dependence of the economy on natural gas.

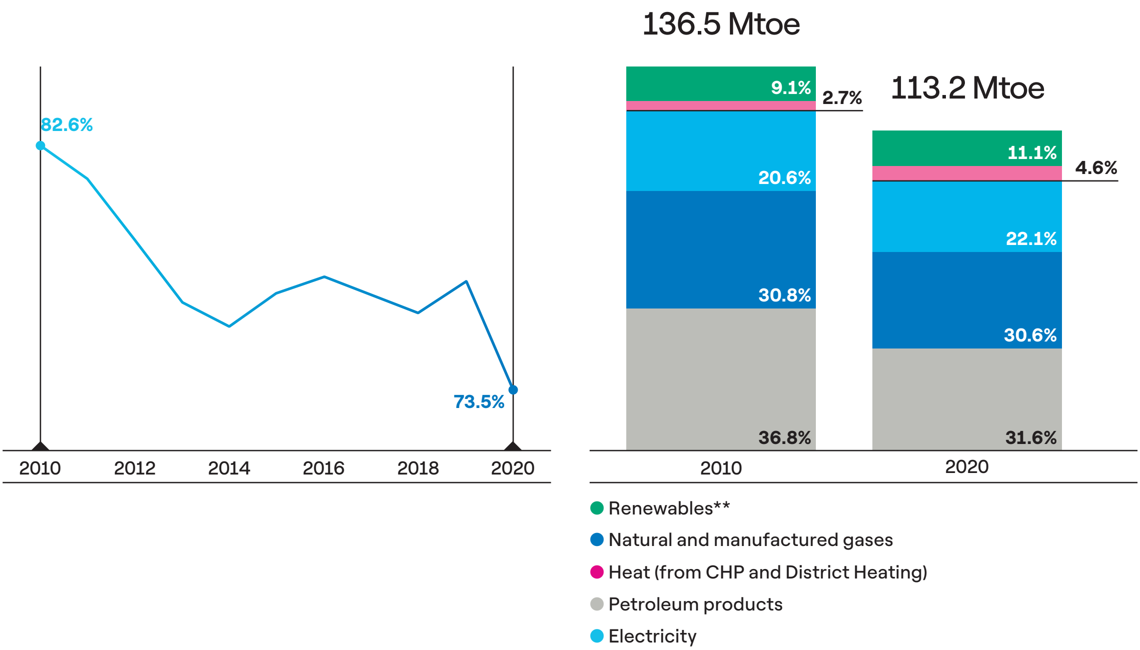
Overall, in order to tackle the energy emergency issue, the European Commission recently proposed the **"REPowerEU" plan with the aim of increasing the resilience of the energy system and eliminating Russian gas imports from the European mix by 2027**. Although the solutions proposed in the Plan are **fundamental for addressing the threat of a gas shortage in the short term**, while accelerating renewables deployment and increasing energy efficiency, they risk to be not as effective in pursuing the long-term decarbonization goals set by the European Union. In the medium-term, National Plans will be revised and will need to be aligned to higher ambitions for GHG emissions, RES and energy efficiency. In the long run, the European Union and its Member States must **strengthen and accelerate the policies** and the actions set out in national strategies.

3
The natural gas dependence index was calculated by multiplying the share of imported gas in each country by the share of natural gas on primary energy consumption. Therefore, the index evaluates the exposure of European countries in terms of both natural gas imports and the relative weight of natural gas in the energy mix.

4
The gas intensity of GDP index has been calculated dividing the quantity of gas consumed in each country by the GDP. Therefore, the index evaluates the European Countries' gas consumption necessary to produce a million of GDP.

Focusing on Italy and looking at the evolution over time, the country's energy dependence decreased **from 82.6% in 2010 to 73.5% in 2020** (-9.1 percentage points). This trend was mainly due to the evolution of the energy mix in final energy consumption during the same period (which decreased by 23.3 Mtoe), with an **increase in both renewables** (+2 percentage points) **and electrification** (+1.5 percentage points) and a **5.2 percentage points fall in petroleum products**.

FIG II.A. → **Energy dependence*** (chart on the left, % value) **and final energy consumption by fuel type in Italy** (chart on the right, % value and total)**, 2010-2020**

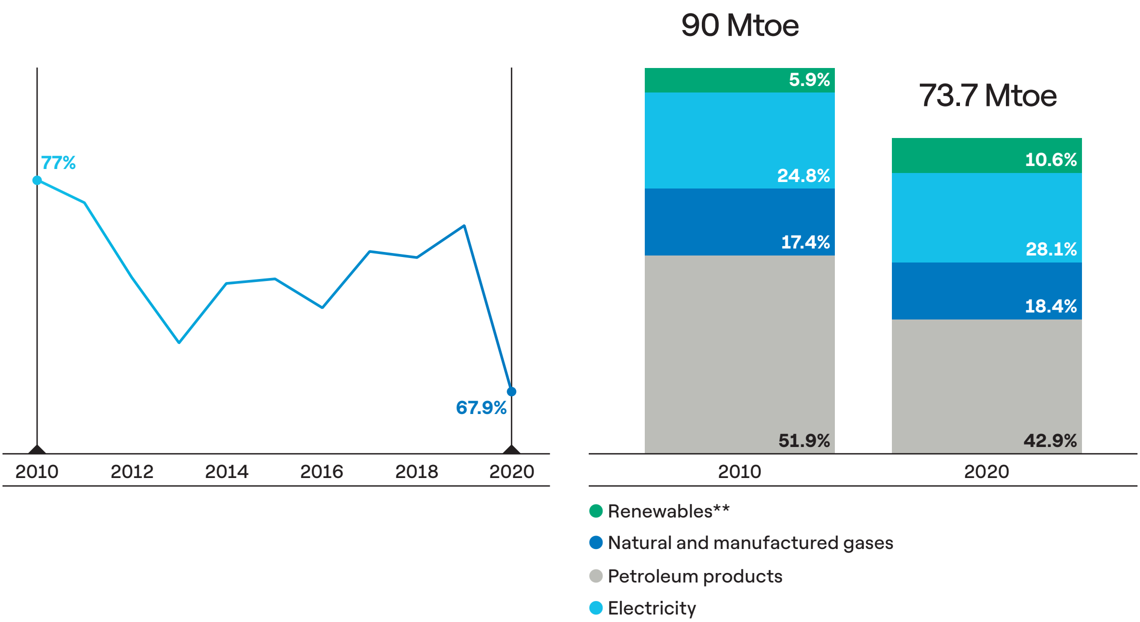


* The indicator is calculated as net imports on gross available energy.
** Renewables include biomass and waste, geothermal, solar heat and ambient heat.

Source → The European House - Ambrosetti and Enel Foundation elaboration on Eurostat data, 2022.

Just like Italy, between 2010 and 2020 Spain reduced its energy dependence by almost 10%, **from 77% to 67.9%**. During the same period, final energy consumption decreased by 16.3 Mtoe while the share of renewables in the energy mix almost doubled (from 5.9% in 2010 to 10.6% in 2020) and electrification increased by 3.3 percentage points. The share of natural gas in the energy mix increased by almost 1 percentage points but the preponderance of petroleum products fell by 9 percentage points. Overall, the share of fossil fuels declined from 69.3% to 61.3% in 2020.

FIG II.B. → **Energy dependence*** (chart on the left, % value) **and final energy consumption by fuel type in Spain** (chart on the right, % value and total), **2010-2020**



* The indicator is calculated as net imports on gross available energy.
** Renewables include biomass and waste, geothermal, solar heat and ambient heat.

Source → The European House - Ambrosetti and Enel Foundation elaboration on Eurostat data, 2022.

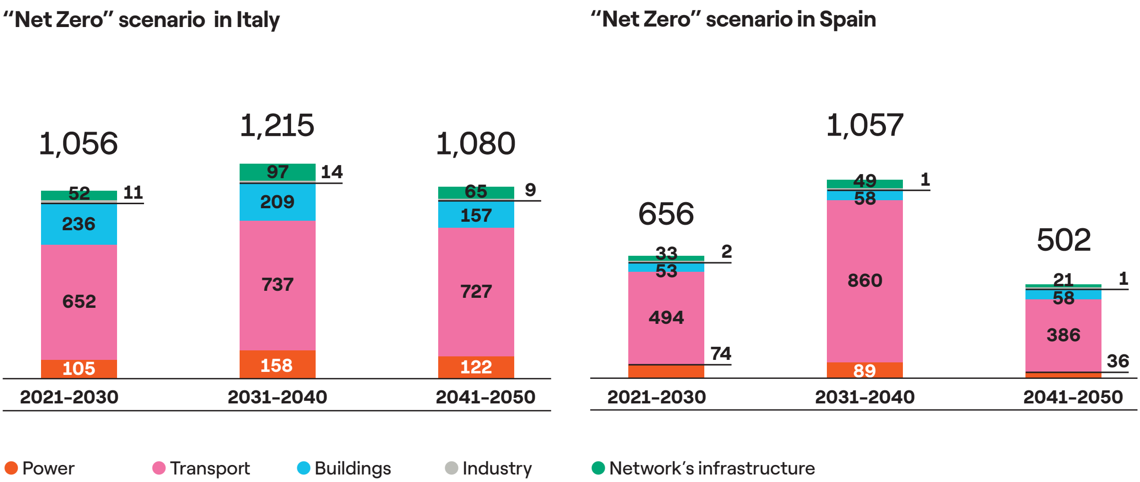
Therefore, the reduction of the country's energy dependence occurred thanks to a **combination of energy efficiency gains and/or a switch in the energy mix to promote primary production from renewable sources**.

3→ A more robust acceleration of decarbonization would require less resources than a weaker one. The "Net Zero" scenarios envisage 3,351 billion Euros and 2,215 billion Euros of investments in Italy and Spain respectively over the 2021-2050 period, 548 and 546 less than the investments needed by the "Low Ambition" scenarios in the two countries.

Two scenarios have been identified for both Italy and Spain as a starting point to assess the impact of the penetration of the various technologies on the economy and the job market in the 2021-2050 period. For Italy, the **"Low Ambition"** scenario is based on updated NECP data whilst the **"Net Zero"** scenario includes the more ambitious "Fit for 55" for 2030 and the economic and environmental impacts of COVID-19. For Spain, the scenarios correspond to the **"Low Ambition"** one (based on NECP which already integrated high ambition targets in line with "Fit for 55"), whilst the **"Net Zero"** scenario includes the Long-Term Strategy, meaning "Fit for 55" together with the new "REPowerEU" targets (higher ambition).

Overall - considering power (including power networks), transport, buildings and industry – the "Net Zero" scenario **requires fewer resources** compared to the **"Low Ambition"** scenario. In Italy, while the "Low Ambition" scenario needs around **3,899 billion Euros** of investments, the "Net Zero" scenario requires **3,351** billion, **548** billion less than the "Low Ambition", with a major role played by **transport** and a relevant share of investments to be carried out in the **2031-2040 period**. In Spain, the "Low Ambition" scenario will need **2,761 billion Euros** of investments while the "Net Zero" will encompass **2,215 billion Euros** of investments, around **546 billion Euros** less than the "Low Ambition" one.

FIG III → **Investments per sector in the "Net Zero" scenario in Italy and Spain, 2021-2030, 2031-2040 and 2041-2050** (absolute values in billion Euros)



Source → The European House - Ambrosetti and Enel Foundation elaboration, 2022.

The different assumptions underlying the scenarios explain the variations in terms of investments. For **transport**, in both countries the "Net Zero" scenario envisages fewer passenger cars up to 2050. Indeed, in the "Net Zero" scenario electric vehicle penetration is comparatively cheaper and more convenient due to falling battery costs, technological improvements, and cheaper renewable power generation, leading to a **lower total cost of ownership**. At the same time, **new business models** will develop, involving the **shared mobility paradigm, car-pooling and multi-modal transport**, encouraging a shift toward **public transportation**, the **higher utilization rate** of vehicles and an acceleration in more **sustainable behaviors** among citizens. Altogether, these considerations translate into lower investment costs in the "Net Zero" scenario both in Italy and Spain.

4→ "Net Zero" scenarios in Italy and Spain are associated with relevant social, economic, environmental and energy security benefits, in terms of value added, employment, reduction of emissions, fossil fuels expenditures and energy independence.

The impact of the investments in the two scenarios is calculated on four dimensions:
1) **Economic and social impacts**.
2) **Reduction of pollution**.
3) **Savings in fossil fuels expenditures**.
4) **Energy security and independence**.

It is also worth mentioning that the results in terms of impacts are always represented as the difference between the **"Net Zero" scenario** and the **"Low Ambition" scenario** and between the two scenarios and a **Counterfactual scenario**, that represents the current business as usual projections[5].

With regards to **economic benefits**, in both Italy and Spain, investing in **the "Net Zero" scenario produces a better** and more efficient **impact on the economy**. In fact, the **GDP/investment ratio is better** than in the "Low Ambition" scenario (1.64 vs 1.59 in Italy and 1.28 vs 1.23 in Spain). This means that the **"Net Zero" scenario** not only **requires fewer resources** than the "Low Ambition" one but, for each Euro invested, also **generates a better economic effect** (0.05 Euros more) than the "Low Ambition" scenario. As for **social benefits**, in both countries the "Net Zero" scenario creates more jobs than the "Low Ambition" scenario (**2.6 million jobs** vs 2.1 million in the "Low Ambition" one in Italy and **1.8 million** vs 1.7 million jobs in the "Low Ambition" one in Spain).

The reduction of pollution generates a positive effect on public health. The savings connected with the reduction of diseases, improved productivity and the avoidance of premature deaths made possible by the reduction of pollution in the "Net Zero" scenario amount to around **614 billion Euros** in Italy and **317 billion Euros** in Spain.

Regarding **savings in fossil fuel expenditures**, for Italy the benefit would be equal to **1,914 billion Euros** in the "Net Zero" scenario (**851 billion Euros** in the "Low Ambition" scenario) compared to a Counterfactual scenario in the 2021-2050 period. In Spain, fossil fuel savings would be equal to **1,279 billion Euros** in the "Net Zero" scenario (**702 billion Euros** in the "Low Ambition" scenario) compared to a Counterfactual scenario in the 2021-2050 period.

Lastly, in terms of energy benefits (gas intensity of GDP index and energy dependence), the "Net Zero" scenario would ensure a **significant reduction in gas intensity of GDP**, i.e. the gas consumption necessary to produce a million Euros of GDP. In this scenario, in Italy gas intensity of GDP is expected to be equal to 1.9 toe per million Euros of GDP in 2050 (vs. 34.9 in 2020 and 8.3

5
For economic and social impacts, the Counterfactual scenario indicates a scenario in which the same level of investment considered in the scenarios ("Net Zero" and "Low Ambition") was used for another project or for other production purposes, allocating the investments on the basis of the historical trend over the past 10 years. Instead, for the reduction of pollution and savings the Counterfactual scenario corresponds to the 2035 values of the "Low Ambition" scenario.

in the "Low Ambition" scenario in 2050), leading to a **94% reduction** compared to current data (vs -76% in the "Low Ambition" scenario). In Spain, gas intensity of GDP is expected to reach 1.9 toe per million Euros of GDP in 2050 (vs. 23.3 in 2020 and 10.2 in the "Low Ambition" scenario), leading to a **92% reduction** compared to current data (vs. 56% in the "Low Ambition" scenario).

Moreover, the "Net Zero" scenario would allow a further **reduction in the energy dependence index**, especially in Italy. In particular, the strong penetration of renewables in 2030 (63% of total generation) and 2050 (98% of total generation), together with electrification and energy efficiency, will reduce energy dependence to **56.7% in 2030** (vs. 68.3% in the inertial trend and 63.5% in the "Low Ambition" scenario) and **bring Italy to energy independence in 2050** (vs. 57.9% in the inertial trend and 31.3% in the "Low Ambition" scenario). As for Spain, in the "Net Zero" scenario the energy dependence index is expected to reduce **from 67.9% in 2020 to 61% in 2030** (vs. 62% in the inertial trend and 61% in the "Low Ambition" scenario) and **13% in 2050** (vs. 52% in the inertial trend and 50,1% in the "Low Ambition" scenario).

FIG IV → **Summary of the impacts of the "Net Zero" and "Low Ambition" scenarios in Italy and Spain on different indicators, 2050** (difference to Counterfactual scenario impacts, unless stated otherwise)

	Higher economic return (billion Euros)	**Net activated jobs** (millions)	**Reduction of pollution** (billion Euros)	**Savings in fossil fuel expenditures** (billion Euros)	**Improvement in the gas intensity of GDP index*** (% values)	**Improvement in energy dependence*** (percentage points)
Italy "Net Zero"	328	+2.6	614	1,914	-94%	-73.5 p.p.
Italy "Low Ambition"	188	+2.1	495	851	-76%	-42.2 p.p.
Spain "Net Zero"	223	+1.8	317	1,279	-92%	-54.9 p.p.
Spain "Low Ambition"	136	+1.7	205	702	-56%	-15.9 p.p.

***** Compared to 2020 values.
N.B. For economic and social benefits the Counterfactual scenario indicates a scenario in which the same level of investment considered in the scenarios ("Net Zero" and "Low Ambition") was used for another project or for other production purposes, allocating the investments on the basis of the historical trend over the past 10 years. For the reduction of pollution and savings the Counterfactual scenario corresponds to the 2035 values of the "Low Ambition" scenario.

Source → The European House – Ambrosetti and Enel Foundation elaboration, 2022.

5→ To accelerate the pathway towards a "Net Zero" economy, two prerequisites and five policy proposals have been identified

To foster the investments required and obtain the economic, social, and environmental benefits deriving from the decarbonization process, some outstanding issues must be addressed. To reach ambitious global climate targets, it is necessary to invest in the **electrification of final consumption** and, at the same time, to support the **massive deployment of renewable energy production and smart power networks**.

To this end, **two prerequisites** and **five policy proposals** have been identified to tackle the existing challenges. One proposal affects all the economic sectors analyzed, while the remaining four are sector-specific initiatives.

FIG V → **The two prerequisites and the five policy proposals to accelerate the pathway towards a "Net Zero" economy**

I

Ensuring **stability**, **transparency** and **consistency** of European, national and local energy policies and measures

II

Supporting **industrial production** in scaling up existing green technologies, developing new ones, and stopping fossil fuel subsidies

1

Guaranteeing a **stronger form of cooperation** and a **greater degree of harmonization** in the governance of the energy transition at the European level

2

POWER SECTOR
Simplifying **authorization procedures** for RES plants, facilitating intervention on energy **infrastructures** and promoting **demand side** management as well as deployment of **storage** facilities and **flexibility** solutions

3

TRANSPORT
Simplifying charging infrastructure installation **procedures**, strengthening **collaboration** between all the e-mobility actors, enabling **interoperability**, optimizing **grid connections time-to-market**, and promoting electric **public urban mobility**

4

INDUSTRY
Leveraging on legal frameworks to support the technological shift of industry towards greener technologies, creating **Tech Transfer Labs** for direct and indirect electrification solutions, and favoring **demand-response**

5

BUILDINGS
Defining the **phase out** of fossil fuel boilers - through a just, stable and transparent framework with regards to heat pumps - and creating a **one-stop-shop** to support the renovation of buildings

Source → The European House – Ambrosetti and Enel Foundation elaboration, 2022.

→ PREREQUISITES

I. **Ensure the stability, transparency and consistency of European, national and local energy policies and measures**, which necessarily reverberate at individual Member State level, to address long-term plans (and investments) and **design consistent remuneration mechanisms** (such as subsidies and auctions), in order to spread positive price and non-price signals to companies and final consumers ready to invest in the energy transition and to switch to green solutions.

II. **Support both European and national industrial production** in scaling up existing technologies, developing and adopting **new green solutions** and **stopping fossil fuel subsidies**. This could be achieved by strengthening the **European industrial strategy** (promoting domestic production and re-shoring of knowledge, know-how and processes) and a **resilient raw materials supply chain**, continuing to promote initiatives like the European Raw Materials Alliance, the European Battery Alliance and the European Hydrogen Alliance, and favoring financial and economic schemes like the Recovery and Resilience Facility, the Innovation Fund, the Connecting Europe Facility, the European Regional Development Fund and the Just Transition Fund.

→ CROSS-SECTORAL POLICY PROPOSAL

Guaranteeing a **stronger form of cooperation** and a **greater degree of harmonization in the governance of the energy transition** at European level, by reviewing the European Commission's current **enforcement mechanisms** towards Member States regarding decarbonization targets, facilitating the implementation of the "REPowerEU" guidelines.

→ SECTORAL POLICY PROPOSALS

POWER → Simplifying **authorization procedures for RES plants and grids** and increasing their **social acceptance** by:

- Further simplifying and digitalizing the **procedures for issuing authorization**.
- Strengthening the offices in charge of the authorization procedures with **appropriate task forces staffed** with trained and competent personnel, and designing **"go-to" renewables areas**".
- Recognizing the status of **national public interest** in the "development of renewables", as acknowledged by the Italian legislation[6].
- Directly **involving citizens** from the early stages of new projects, allowing them to participate, for example, in the capital of project companies with free or low-cost share transfers, or by making project companies pay a share of the profits generated by renewable plants, to be added to local taxes (hence guaranteeing a reduction in taxes for citizens).
- In addition, promoting **demand side management** as well as the deployment of **storage facilities** and **flexibility solutions**.

6
See art. 18 of Decree n. 77/2021 which modified art. 7 bis of the Environmental Code.

TRANSPORT → Promoting the **effective deployment of charging infrastructures** for Electric Vehicles in Italy, by:

- Simplifying and standardizing at national level the **recharging infrastructure installation and administrative procedures**, both for residential and public charging, also ensuring that new infrastructures can be installed in already existing buildings (e.g., through pre-cabling).
- Optimizing the time-to-market of grid connections, also by identifying adequate **preventive mechanisms for grid planning and development** (also pivotal for RES deployment), considering recharging infrastructure as a support for grids and focusing on flexibility, ensuring that grid infrastructure can connect and manage the increasing capacity and flows (also on core and comprehensive transport network).
- Strengthening **collaboration, integration, and cohesion between all e-mobility ecosystem actors** (players, platforms, systems, processes, and technologies), promoting interoperability, unlocking all business value and favoring the deployment of sharing mobility paradigm.
- Fostering **interoperability** (any vehicle, any contract, any payment mechanism) across charger networks.
- Promoting **innovative financial schemes** for public urban mobility (e-Buses), including leasing, Joint Purchasing Agreements between administrations, and **Public-Private Partnerships (PPPs)**.

INDUSTRY → Leveraging on legal frameworks like Emissions Trading System (ETS) (free allowances) to support the **technological shift of industry towards greener technologies** (green hydrogen), for instance by strengthening free carbon allowance schemes for greener solutions compared with the allowances already in place for less sustainable solutions. In addition, **creating national Tech Transfer Labs**, focused on direct and indirect electrification technologies, with the mission of acting as enablers of technology transfer from research institutions to industrial players (including energy companies), guaranteeing adequate collaboration at European level. Finally, favoring the deployment of **demand-response** by providing adequate **financial mechanisms** and increasing the **awareness** of industrial players.

BUILDINGS → Defining the **phase out of fossil fuel** boilers in heating, levelling tax and levies with regards to heat pumps by overcoming year-by-year renewal and ensuring a **just, stable, and transparent regulatory framework** for consumers, by:

- Optimizing **implementation procedures**.
- Devising **innovative financial schemes** inspired by European Union good practices, such as combining traditional mortgages with an *ad hoc* loan for energy efficiency technologies guaranteed by the financial institution under an agreement with an industrial player.
- Increasing **citizens' energy efficiency awareness** through the introduction of a "Household Maintenance Leaflet".
- **Creating a one-stop shop** where citizens can be guided through the renovation process, with integrated solutions and guarantees (e.g., qualified suppliers, granted permitting, access to support schemes and financing, quality control).

Par

The reference context of the current path to achieving the "zero emissions" target by 2050 in Italy and Spain, and its implications on energy independence

Part 1

Key Messages

1 → The trend in global CO_2 emissions – which in 2021 reached an all-time negative record with 36.3 billion tonnes – highlighted more than ever the need to **rethink the current energy system** in order to keep global warming under the 1.5°C threshold by the end of the century, as established in the Paris Agreement in 2015.

2 → The European Union has set the goal of becoming **"climate neutral" by 2050** in its Climate Law, one of the first legislative proposals following the Green Deal. The Climate Law includes also the intermediate steps necessary to achieve net zero emissions in 2050: in order to keep the pace with the 2050 final goal, in 2030 GHG emissions are expected to decrease by 55% with respect to 1990 levels. Furthermore, in July 2021 the European Commission launched the package of proposals called "**Fit for 55**", which includes the Climate Law's GHG emissions reduction target, a review of both the EU Directive on renewables (from **32%** to **40%** share of renewable energy sources in overall final consumption) and the Directive on energy efficiency (considering the target of +36% improvement in energy efficiency in final energy consumption); moreover, the

package aims at reducing GHG emissions in Effort Sharing Regulation sectors by 40%, and strengthening EU Emission Trading Scheme, among others.

3 → Under the Governance of the Energy Union Regulation, Member States had to present their own **national plans and strategies to pursue the decarbonization of their economies by 2050**, in order to align their GHG emissions reduction, RES deployment and energy efficiency improvement goals with the European Union's. These plans represent the roadmap each country must follow to quickly achieve a significant decarbonization of its economy.

4 → In January 2020 Italy adopted the **National Energy and Climate Plan (NECP)**, which includes national 2030 decarbonization objectives: a 33% reduction of GHG emissions for non-ETS sectors by 2030, with respect to 2005 levels; 30% share of RES in gross final energy consumption; 43% reduction in final energy consumption, improving energy efficiency. Moreover, NECP includes an estimated 43% reduction of GHG emissions in ETS sectors. However, these targets are not enough to keep the pace either with the EU target of 55% GHG emissions reduction by 2030 or with carbon neutrality by 2050. To achieve this goal, Italy defined its **Long-Term Strategy** for GHG emissions reduction. Its targets include an **84/87% reduction of GHG emissions** with respect to 1990 levels in 2050; an **85/90% renewable energy share in gross final energy consumption**, to be achieved

through the massive contribution of renewable energy sources to electricity generation (95/100%) and a 49% decrease in energy demand with respect to 2005 levels.

5 → **Spain** published its "Plan Nacional Integrado de Energía y Clima 2021-2030" in January 2020, which sets its 2030 targets: 23% reduction of GHG emissions with respect to 1990 levels by 2030; the achievement of 42% of renewable energy sources in end use by 2030 and a 74% share of RES in electricity generation; 39.5% reduction in final energy consumption, improving energy efficiency. Instead, in order to achieve 2050 national carbon neutrality, Spain defined its **Estrategia de Decarbonisación a Largo Plazo 2050**, which aims at reducing GHG emissions by **90%** with respect to 1990 levels, increasing the renewable energy share in gross final energy consumption up to **97%**, to be achieved through the **100%** deployment of renewable energy sources into electricity generation and a decrease in energy demand by 44% with respect to 2005 levels, with a 50% reduction in primary energy consumption.

6 → In order to assess the current path of Italy and Spain in achieving these targets, a gap analysis has been carried out. With regard to **RES**, based on the current trends, Italy is still far from reaching the 30% target in 2030, with a gap of nearly 8 percentage points. The situation is even worse looking at 2050, where the gap is 60.7 percentage points. In terms of **ener-**

gy efficiency, Italy is not performing well: this leads to a difference of 35.1 Mtoe in 2050 compared to the policy scenarios. Also, in terms of **GHG reduction** Italy is underperforming in the period 2021-2030 with regard to the target set under the policy scenario. Moreover, between 2030 and 2050, in the light of more ambitious targets in the long term – namely, reducing gross GHG emissions by 84/87% compared to 1990 levels – the gap broadens further to around 151.2 Mt CO_2-eq. in 2050.

7 → With regard to Spain, in terms of **RES**, despite the ambitious target set at the national level, projecting the inertial trend from 2015 to 2020 it results that Spain will be able to achieve the goal of renewable energy share in gross final energy consumption equal to **97%** and, ultimately, overperforming with a value of 106.4% in 2050. Regarding **energy efficiency**, as for Italy, the gap between the inertial trend and the policy scenario is broadening as time goes by. The current scenario would lead the energy efficiency trajectory in an opposite direction compared to the trend needed to reach policy targets at 2030, 2040 and 2050. With regard to **GHG reduction**, **Spain** reports an inertial trend that is underperforming with respect to the path outlined in the policy scenarios by 2030. From 2030 onwards the gap between GHG reductions in policy scenarios and the inertial trend further deepens, reaching a difference of 136.9 Mt CO_2-eq. in 2050 (a bit lower than the one reported for Italy).

8 → The current energy crisis, with the surge of prices in international energy markets, and the outbreak of the Russia-Ukraine conflict, has brought to light the EU's vulnerability and energy dependence on fossil fuel imports. Europe is **57% dependent on energy imports** and over the 20-year period 2000-2020 this share remained almost unchanged, if not increased by about one percentage point. In 2020 Italy imported the **73.5%** of its total gross available energy, and Spain **67.9%**, both above the European average.

9 → Focusing on natural gas, Europe relies on imports of natural gas for **23%** on average. Italy ranks second (just behind Malta) for imported gas in the gross available energy mix (**41.2%**), while Spain's gas imports account for **26.1%**. Considering just imports from Russia, Italy is the 4th most exposed country to the **threat of Russian gas supply shortage**, as it accounts for **19%** of the total available energy. Russian gas imports to Spain account only for 3%, since Spain has a broader range of commercial partners. Lastly, it is important to mention that Italy is also among the countries that **consume more gas per million Euros of GDP** with a value of 34.9 toe per million Euros of GDP, thus highlighting a structural dependence of the economy.

10 → In order to tackle the energy emergency issue, the European Commission recently proposed the **"RE-PowerEU" plan**, with the aim of increasing the resilience of the energy system and eliminating Russian gas imports from the European mix by 2027. The set of short-term measures are expected to offset the **155 billion m^3** imported in 2021 by diversifying commercial partners for gas imports, deploying renewable energy sources faster and applying energy efficiency measures.

11 → Although the solutions proposed in the Plan are fundamental to address a gas shortage threat in the short run, they are not as effective in pursuing long-term decarbonization goals set by the European Union. In the long run, the European Union and its Member States have to strengthen and accelerate the policies and the actions set out in the national strategies. Besides decarbonization goals, national strategies aim at eliminating fossil fuels from the economies of EU Member States, which implies a **reduced reliance on fossil fuel imports** from foreign countries, less exposure to the volatility of international energy market prices and a stronger energy supply security. Focusing on Italy, the decarbonization process managed to reduce energy dependence from 83% to 73.5% between 2010 and 2020, mainly thanks to an increasing deployment of RES. But if Italy were able to pursue the decarbonization targets entailed in the "Fit for 55" package (which will be included in the revision of NECP by 2023) and

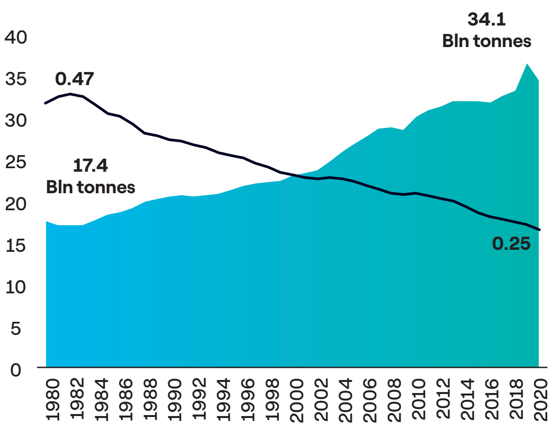
in its Long-Term Strategies, it would rely on energy imports for just **36.4%** of its gross available energy in 2050. If Spain did the same, its energy dependence would fall sharply to **13%** of its total energy needs, as current fossil fuel imports will be outweighed by nationally produced renewable energy.

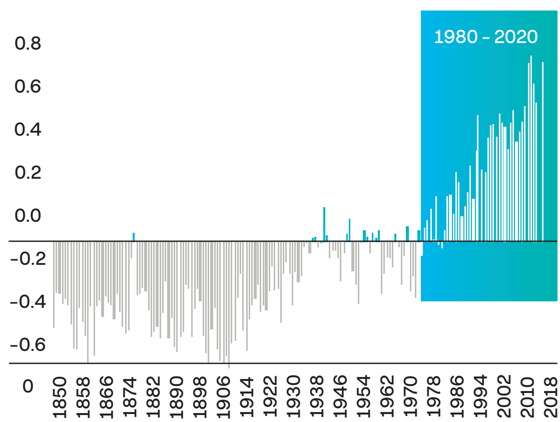
1.1

The path to decarbonization: opportunities and challenges for a climate neutral Europe in 2050

Over the past 30 years, despite an improvement in carbon intensity (i.e., the amount of CO_2 emitted per unit of GDP), CO_2 emissions have steadily increased in the world, from 20.3 billion tonnes in 1990 to 34.1 billion tonnes in 2020 (+68.3%). The year 2021 marked a new (negative) record of 36.3 billion tonnes of CO_2 emitted[1]. This growth between 2020 and 2021 marks **the highest level ever reached in history**, also due to the acceleration of the economy in the post-pandemic period, which more than compensated the decline induced by the pandemic between 2019 and 2020. In this context, coal accounted for more than 40% of the overall growth of global CO_2 emissions in 2021, reaching an all-time high of 15.3 billion tonnes. Overall, this dynamic has had and is having severe negative implications for **global warming**.

FIG 1 → **CO_2 emissions and carbon intensity** (left graph, Bln tonnes of kg CO_2 per GDP in US Dollars, 1980-2020) **and global temperature anomalies** (right graph, °C, 1850-2020) **at global level**





Source → The European House - Ambrosetti and Enel Foundation elaboration on data of European Environment Agency, International Energy Agency and Climatic Research Unit, 2022.

1
Source: International Energy Agency, *"Global Energy Review: CO_2 emissions in 2021"*, 2022.

To contain this trend, the **Paris Agreement** was signed in 2015. It aims to keep global warming "well below 2°C", preferably below 1.5°C, by the end of the century. Reaching, or even exceeding, this limit would have serious and irreversible environmental effects, with the risk of endangering the entire planet and ecosystems.

However, the world is not going in the right direction in the fight against climate change. Suffice it to say that 2019 was the second warmest year on record, with an average increase in global temperature of **about 1.1 degrees compared to the pre-industrial period**. The planet is therefore not very far from reaching the critical 2°C threshold of maximum global warming set in the Paris Agreement.

To achieve the much-needed decarbonization, a paradigm shift of the energy system is necessary. To this end, the European Union has set itself the goal of becoming "**climate neutral**" by 2050 and has progressively increased its commitment toward this objective culminated with the launch of the **European Green Deal**. The plan is designed to attract **at least 1 trillion Euros** in public and private investment over the next 10 years. About half of the funds are expected to come from the EU budget, while an additional 114 billion Euros will be mobilised through co-financing by Member States, to which approximately 300 billion Euros of private and public investment should be added. To accompany the most vulnerable areas in the transition process, the Just Transition Fund was also established, with an initial endowment of 17.5 billion Euros, of which 7.5 billion from the Multiannual Financial Framework and 10 billion from the Next Generation EU.

The European Climate Law enshrines the target set out in the European Green Deal of achieving European carbon neutrality by 2050, including also the intermediate steps necessary to reach it: by 2030, European GHG emissions must be reduced by 55% with respect to 1990 levels. Furthermore, in July 2021 the European Commission confirmed its will to accelerate the energy transition process through the package of proposals called "**Fit for 55**". The new package, together with the Next Generation EU, represents a strong acceleration toward the energy transition, introducing more ambitious targets for 2030, included the Climate Law's GHG emissions reduction target of **-55% with respect to 1990 levels**. The package entails a review of the EU Directive on Renewables, with a more ambitious **target share of 40% of renewable energy sources** in overall gross final consumption (+8% compared to the previous goal), a review of the Directive on Energy Efficiency with a renewed target of **+36% energy efficiency improvement in final energy consumption**[2] by 2030 **and 40% GHG emissions reduction in non-ETS sectors** (including transport, buildings and small and medium industries). The package offers medium-term policy measures aimed at delivering the transformations required across Europe to reach a **net zero economy by 2050**.

2
Overall, the EU must collectively ensure a reduction in energy consumption of at least 9% by 2030, compared to projections made under the EU's 2020 reference scenario.

FIG 2 → **The main measures introduced by the European Union in favour of a sustainable development model, 2015-2022**

Introduction of the **Circular Economy Action Plan** that identifies the Circular Economy as the priority strategy to relaunch European competitiveness with 54 actions

Adoption of the **EU strategy for plastics in the Circular Economy** with limits on the use of single-use plastics

Presentation of the **European Green Deal** with 4 objectives for the EU:

- Climate neutrality **by 2050**
- Reduction of **pollution**
- Supporting European companies to become leaders in **sustainable production and technologies**
- Support for a **just and inclusive transition**

Adoption of the **Ecodesign Working Plan**

Adoption of **10 directives** implementing **Ecodesign** legislation

Source → The European House - Ambrosetti and Enel Foundation elaboration on the European Commission, 2022.

Mar 2020

Presentation of the **New Circular Economy Action Plan** by the European Commission

May 2020

Presentation of the **Next Generation EU** plan to support the post-COVID EU recovery with **30%** of the financial resources dedicated to the sustainable transition

Jul 2021

"Fit for 55" package with proposals on energy and climate from the European Commission

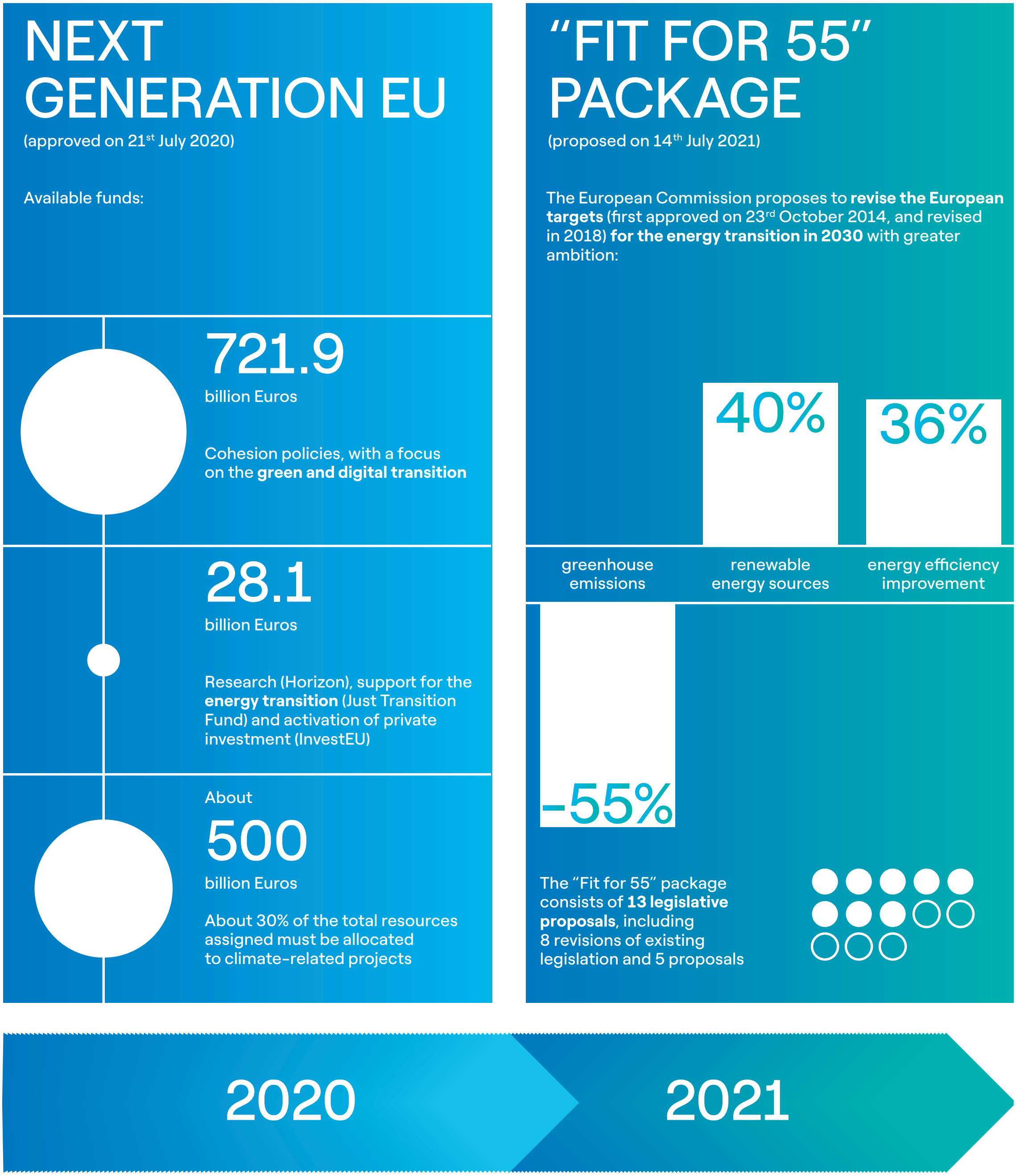
Mar 2022

Presentation of the **"REPowerEU" plan** to make Europe independent from Russian fossil fuels well before 2030, in light of Russia's invasion of Ukraine

End of 2022

By the end of 2022 Member States are expected to **adopt "Fit for 55" and revise their national strategies in 2023 at most**

FIG 3 → Summary vision of Next Generation EU and "Fit for 55" package



Source → The European House – Ambrosetti and Enel Foundation elaboration on European Commission data, 2022.

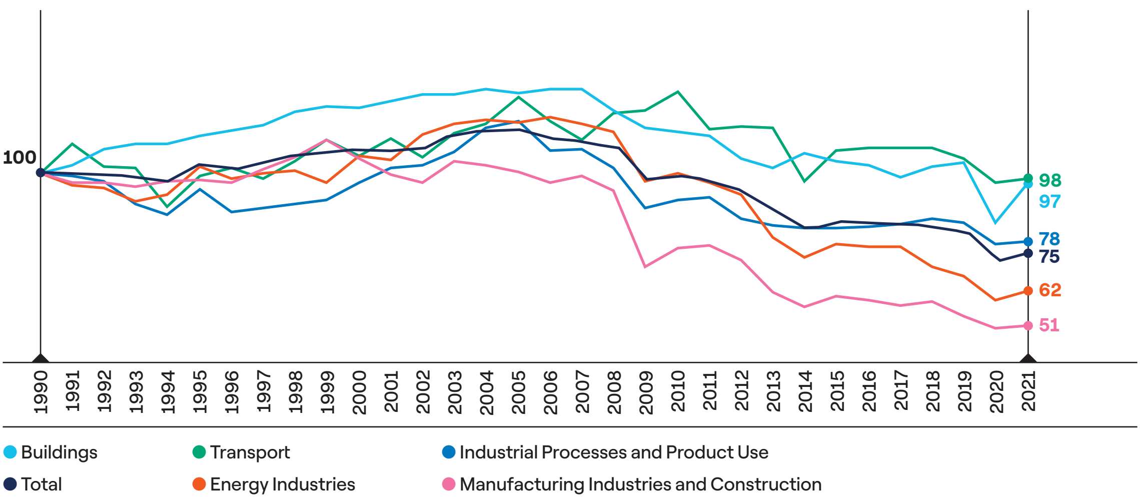
The "Fit for 55" package consists of **revisions** to existing directives and regulations[3] and some **new instruments** (such as the carbon border adjustment mechanism or the ETS for transport and buildings) with the ultimate objective to implement measures at different levels and promote decarbonization in different sectors. This increased ambition is the first step towards putting the European Union on the path to **climate neutrality by 2050** and aligning it with the global objectives of the Paris Climate Agreement.

1.1.1 DECARBONIZATION IN ITALY AND SPAIN: NATIONAL PLANS AND STRATEGIES

ITALY → In the light of the decarbonization targets set at the European level, described in the previous paragraph, the individual Member States must also come to terms with the characteristics of their energy systems and set their own targets.

In Italy, between 1990 and 2019 **GHG emissions** decreased by **19.4% from 519 to 418 million tonnes of carbon dioxide equivalent (Mt CO_2-eq)**[4]. In addition, due to the COVID-19 crisis, between 2019 and 2020 GHG emissions further decreased by **-10.6%**, reaching 373.5 Mt CO_2-eq. In 2021, preliminary estimates consider an **increase of 4.8% in GHG emissions** with respect to the previous year, due to the recovery of economic activities after the COVID-19 outbreak[5].

FIG 4 → **GHG emissions trends by sector in Italy, 1990-2021** (1990=100)



N.B. The final balance of sectorial GHG emissions 2021 is estimated by applying the GHG contribution share per sector on total 2020 GHG emissions, computed on the total 2021 GHG emissions.

Source → The European House – Ambrosetti and Enel Foundation elaboration on European Environmental Agency and ISPRA, 2022.

3
Such as renewable energy, energy efficiency, ETS, climate effort sharing, energy taxation, CO_2 emissions performance standards, deployment of alternative fuel infrastructure, LULUCF regulation, energy performance of buildings and new framework to decarbonize gas markets, promote hydrogen and reduce methane emissions.

4
Excluding emissions and removals from Land Use, Land Use Change and Forestry (LULUCF).

5
Source: Istituto superiore per la ricerca e la protezione ambientale (ISPRA).

Within this scenario of overall emissions decline, the **buildings and the transport sectors** are the only two recording an increase of **+3.3%** and **+4.7%** in GHG emissions respectively over the period 1990-2019. Then, in 2020, GHG emissions in the transport sector fell by 19% with respect to 2019, but was still responsible for the **22.4%** of total GHG emissions at national level, being the main polluter. Within this sector, road transport accounted for **92.1%** of total GHG emissions and **20.6% of national GHG emissions**.

On the contrary, between 1990 and 2019 **energy industries sector** decreased its GHG emissions by **33%** (and almost 40% with respect to 2005 levels), despite gross national electricity generation increased from 216,891 to 293,853 GWh throughout the same period. In 2020, GHG emissions further decreased by **10.9%**, down 40.6% with respect to 1990 levels. This partial decarbonization of the sector was made possible by the increase in the RES share in electricity generation, which reached 33.4% (considering electricity generated by hydro, solar PV, wind and geothermal sources) of total electricity generated in 2019, and further increased up to **35.4%** in 2020[6].

Despite the decline in GHG emissions, the reduction experienced so far is not enough to achieve the ambitious long-term European goals. In this regard, in 2020, the **National Energy and Climate Plan (NECP)** defined Italy's **objectives for GHG emissions reduction by 2030**, aligned with EU directives. The main targets of the NECP are:

- **33% of GHG emissions reduction for non-ETS sectors** (transport, residential, tertiary, industry not included in the ETS sector, agriculture and waste) **by 2030**, with respect to 2005 levels (NECP considers also a scenario projection that leads to a **43% reduction in GHG emissions in ETS sectors**, including energy industries, energy-intensive industrial sectors and aviation).
- **30% of RES share in gross final energy consumption by 2030** (22% of RES in the gross final consumption of energy in the transport sector) and **55% share of RES in electricity generation**.
- **43%** decrease in primary energy consumption and **39.7% in final energy consumption**, with respect to the PRIMES 2007 reference scenario.

However, Italy's NECP targets and policy initiatives need to be revised and updated in the light of the heightened EU ambitions to **reduce net GHG emissions by 55% by 2030 with respect to 1990 levels**, which is the main goal of the "**Fit for 55" package** (described in paragraph 1).

In order to pave the way for revised 2050 targets, in accordance with the European Governance Regulation, Italy presented in January 2021 its **Long-Term Strategy for GHG Emissions Reduction (LTS)**, which was reviewed by the European Commission on 11 February 2021[7]. The strategy included NECP scenarios projected at 2050 to build up a counterfactual **Reference scenario** to be compared to the **new Decarbonization scenario**, which instead includes the heightened decarbonization ambitions needed to keep up with EU carbon neutrality objectives.

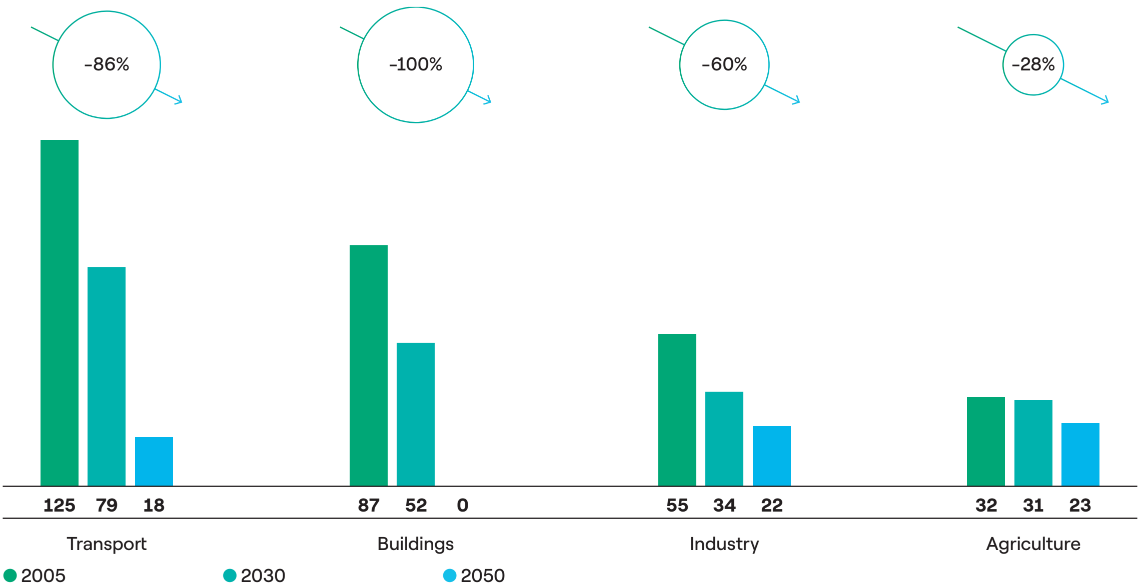
The **2050 projections** set out in the Decarbonization scenario, which involve a stronger technological development and a faster replacement of traditional oil products and gas with RES compared to the Reference scenario, include:

6
Source: Terna, 2022.

7
It is worth mentioning that the Italian Long-Term Strategy lacks 2040 milestones.

- An **84/87%** reduction of gross GHG emissions with respect to 1990 levels.
- An **85/90%** renewable energy share in gross final energy consumption, to be achieved through the massive contribution of RES to electricity generation (**95/100%**)[8]; electrification of final energy consumption is expected to reach the **55%** of the total mix.
- A **49%** decrease in energy demand with respect to 2005 levels, down to roughly 70 Mtoe in 2050.

FIG 5 → **GHG emissions projections in the Decarbonization scenario by sector in Italy, 2005, 2030 and 2050** (Mt CO_2-eq.)



N.B. 2030 targets reflect NECP data.

Source → The European House – Ambrosetti and Enel Foundation elaboration on Italian Long-Term Strategy for GHG Emissions Reduction, 2022.

In the Italian long-term strategy, the **power sector** is expected to reduce its emissions to 30 Mt CO_2-eq. in the Reference scenario and, even further, to 18 Mt CO_2-eq. in the Decarbonization scenario, due to a higher penetration of RES in the sector. Electricity generation will play a pivotal role in the Italian economy's decarbonization, since electricity will be massively used in final cosumptions (in the Decarbonization scenario, in 2050 national electricity demand is expected to jump to **650 TWh**, compared to 301 TWh in 2020) and will enable further GHG emission reductions (alternative fuels like hydrogen and e-fuels, or direct heat generation without CO_2 emissions).

8
The range depends on different assumptions on intermittent renewable energy generation potential and the scope of development of flexibility in the power grid in coming years.

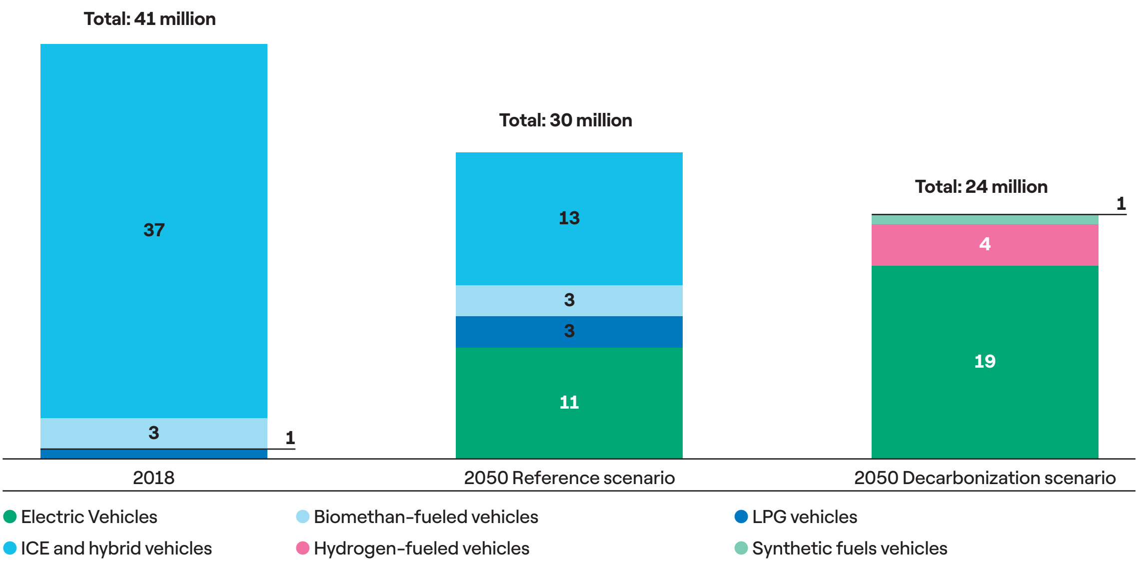
The fundamental role played by the national electricity system depends on 3 conditions:

- An increase in national electricity generation and its complete decarbonization, achievable through a **tenfold increase in installed solar PV power capacity** between 2020 and 2050 (which in 2020 generated 24,942 GWh) and an **additional installed wind power capacity of 40/50 GW** in the same timespan.
- The ability to handle a huge quantity of variable RES, and the required **flexibility** of the grid (for instance, through the creation of distributed storage systems throughout the grid, in the order of 30/40 GW and a total accumulated energy of 70/100 TWh).
- Grid infrastructure development.

In addition, in the Italian LTS, the Decarbonization scenario forecasts the achievement of zero net carbon emissions in the transport sector, which requires **-92% of emissions** in 2050 compared to the 2015 level, from 520 to 98 Mt CO_2-eq.. Decarbonization of the transport sector is related to a **higher penetration of electric vehicles**. In particular, low-carbon vehicles will represent 83% of the total, of which 63% will be electrified vehicles. Moreover, almost **80% of the total car fleet** in 2050 is expected to be electrified (19 million vehicles out of the total 24 million), with 4 million circulating hydrogen-fuelled vehicles.

Not only. According to the strategy, in 2050 **76% of total heavy duty transport** has to be electrified, although 18% is expected to be still fossil-fueled; the remaining estimated 6% will be fuelled by hydrogen and biofuels. Depending on their technological development, batteries, biofuels and hydrogen will play a key role for long range and heavy duty fleet decarbonization.

FIG 6 → **Total vehicles fleeet by energy vector in 2018 and in Reference and Decarbonization scenarios in Italy, 2018 and 2050** (millions of units)



Source → The European House – Ambrosetti and Enel Foundation elaboration on Italian Long-Term Strategy for GHG Emissions Reduction, 2022.

When it comes to building sector, the Italian LTS considers a reduction in final energy demand of 41% by 2050 with respect to 2015 level, and the massive electrification of final energy demand (66%). Specifically for the **residential sector**, electrification is expected to reach the **53%** in energy carrier mix, recording a **+34% of final use electrification** with respect to 2022. The remaining 47% will still be based on natural gas and biomass. In particular, space heating electrification will increase from 3.6% to 36.3% between 2022 and 2050, water heating from 17.4% to 50.3% and cooking from 24.4% to 66.7% in the same period[9].

Finally, the Decarbonization scenario under Italian LTS forecasts a 5% reduction in energy demand for the industrial sector and **-50/-60% fossil fuel reliance**, mainly thanks to the switch to alternative fuels like hydrogen, bioenergy and synthetic fuels (in the long-run, gas is expected to cover 10% of industry's total energy demand). Moreover, in order to achieve the sector's decarbonization, the strategy relies on circular economy measures, carbon capture and storage technologies (potentially useful to absorb combustion and process incompressible emissions of industries like cement, but their actual usage depends on the development of production processes based on hydrogen and variable renewable energy, which may avoid the application of CCS technologies) and **electrification of energy consumption up to 52/54%** of the total.

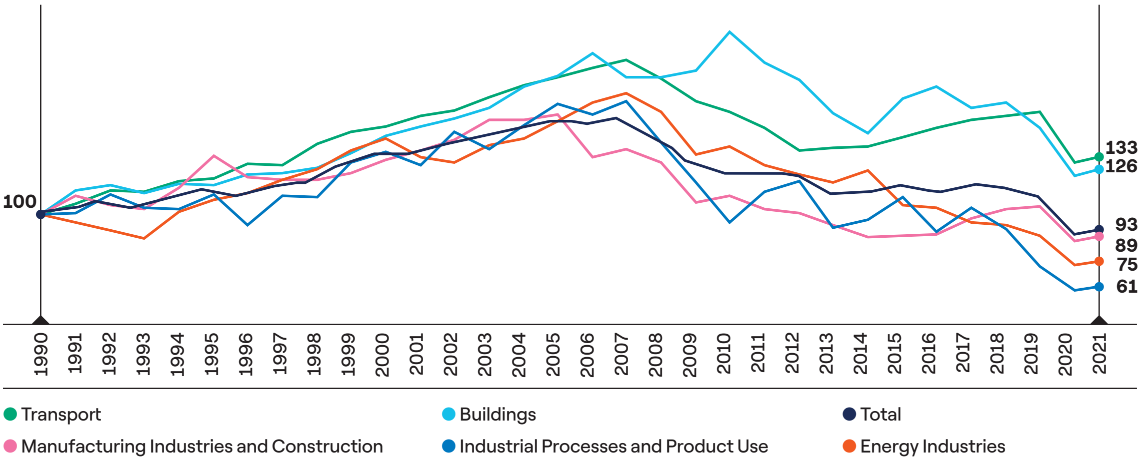
SPAIN → In Spain, unlike Italy, GHG emissions increased between 1990 and 2019, varying **from 290 Mt CO_2-eq. to 314.5 Mt CO_2-eq**. (+8.5%). Due to the COVID-19 crisis, in 2020 GHG emissions plummeted to 258.2 Mt CO_2-eq. (**-17.9% between 2019 and 2020**). The Basque Centre for Climate Research and the Observatorio de la Transición Energética y la Acción Climática estimated a **+4% in Spanish GHG emissions in 2021 with respect to 2020**, due to the gradual economic recovery after COVID-19.

Focusing on the period 1990-2019, the overall increase in Spanish GHG generation was mainly driven by the transport sector: its GHG emissions increased by **+55.8%** over 30 years, varying from 58.6 to 91.4 Mt CO_2-eq. and increasing its contribution to national GHG emissions **from 20.2% in 1990 to almost 30%** in 2019. In particular, this increase was driven by the rise in **road transport** GHG emissions, which in 2019 contributed to the **92.4%** of the sector's total emissions. The **buildings sector** also increased its GHG emissions between 1990 and 2019, recording a **+47%**. However, the residential sector's share in buildings sector overall GHG emissions decreased, from 78.2% in 1990 to 55.5% in 2019.

On the contrary, GHG emissions in the energy industry recorded the strongest decrease, with a **28.8%** reduction compared to 1990 (from 78.9 to 58.1 Mt CO_2-eq.). As for Italy, in Spain gross national electricity production increased, but the increasing share of RES in the energy carrier mix (**37.6%** in 2019) and energy efficiency improvements in electricity generation led to a strong decrease in the sector's emissions. However, in 2019 the sector was the second main polluter after transport sector, accounting for **18.5% of national emissions**.

9
Source: Electrify Italy.

FIG 7 → **GHG emissions trends by sector in Spain, 1990-2021** (1990=100)



N.B. The final balances of sectorial GHG emissions for 2020 and 2021 are estimated by applying the GHG contribution share per sector on total 2019 GHG emissions, computed on the total 2020 and 2021 GHG emissions.

Source → The European House – Ambrosetti and Enel Foundation elaboration on European Environmental Agency, 2022.

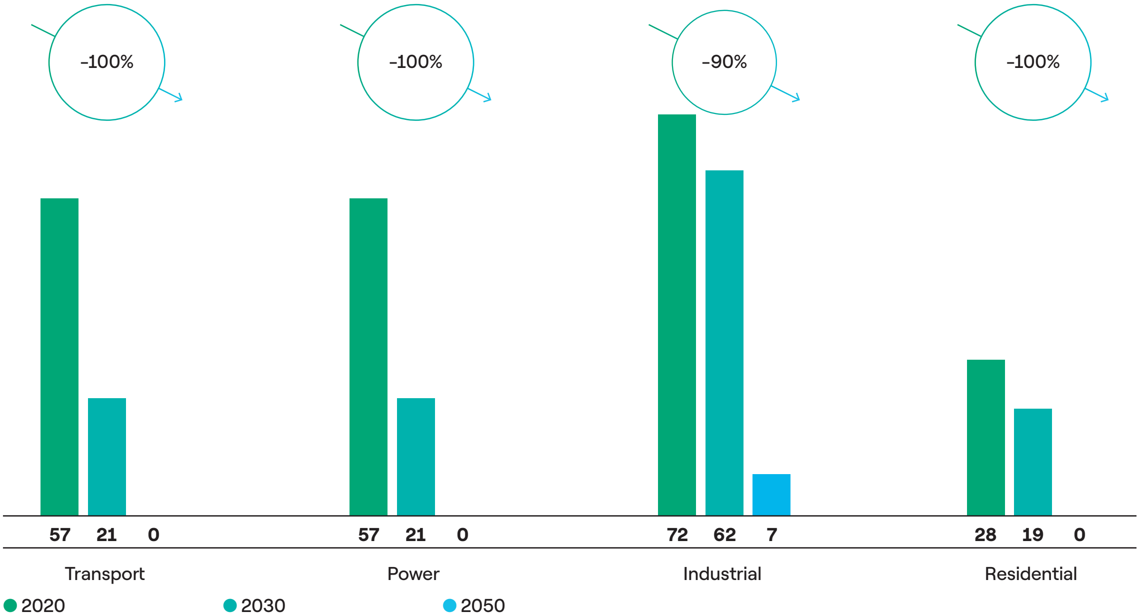
Spain, as described for Italy, presented its own 2030 targets in its "**Plan Nacional Integrado de Energía y Clima 2021-2030**", published on 20 January 2020, in order to keep up with European 2030 and 2050 decarbonization targets. The main targets include:

- **23% of GHG emissions reduction** with respect to 1990 levels by 2030 (with ETS sectors contributing with -61% GHG emissions with respect to 2005 levels, while non-ETS sectors decreasing their emissions by 39%).
- The achievement of a **42% share of RES in end uses of energy by 2030** (28% of RES penetration in the transport sector) and **74% share of RES in electricity generation**.
- **39.5%** reduction in final energy consumption, improving energy efficiency, and a 34% decrease in primary energy consumption with respect to 2017 levels.

In the long run, the **Spanish "Estrategia de Decarbonisación a Largo Plazo 2050"**, set out in November 2020 and verified by the European Commission – which noted the lack of GHG emissions reductions for industrial subsectors – on 11 December 2021, expects the following **2050 objectives**:

- A **90%** reduction in gross GHG emissions with respect to the 1990 level.
- A **97%** renewable energy share in gross final energy consumption, to be achieved through the **100%** deployment of RES into electricity generation; electrification of final energy consumption will reach roughly 50% in 2050 Decarbonization scenario.
- A **44%** decrease in energy demand with respect to 2005 levels, with a **50%** reduction in primary energy consumption.

FIG 8 → **GHG emissions projections in the Decarbonization scenario by sector in Spain, 2020, 2030 and 2050** (Mt CO_2-eq.)



Source → The European House – Ambrosetti and Enel Foundation elaboration Estrategia de Decarbonisación a Largo Plazo 2050, 2022.

In Spain, long-term RES penetration targets are **higher** than the Italian ones. Spain expects a **97%** share of RES in final energy consumption, of which **79%** RES share of final consumption both in the transport sector and building heating and cooling sector and **100%** of electricity generated from renewable energy.

Spanish transport sector is expected to reduce its GHG emissions by 30% by 2030 (according to NECP), through a 28% renewable energy vectors penetration in vehicles. In order to reduce the sector's GHG emissions to 2 Mt CO_2-eq. by 2050 (with a 97.7% reduction with respect to 2020 levels), the long-term strategy expects a huge process of electrification of private cars and penetration of renewable gases and green hydrogen, which is considered a fundamental vector for the sector's decarbonization.

80% of the building stock in Spain is made up of low energy buildings: for this reason, the Spanish LTS expects fast energy efficiency measures and **electrification of final uses, including electrification of 81% of the residential sector's final energy demand** (driven by RES penetration in heating and cooling systems) and **91% for the services sector**.

Finally, the Spanish LTS to reduce **GHG emissions in the industrial sector** to 7 Mt CO_2-eq. by 2050 is mainly based on the reduction of energy intensity in processes, raw material recycling, and decarbonization of energy vectors in the sector, through electrification, and reliance on biomass and hydrogen.

FIG 9 → **European, Italian and Spanish targets and scenario projections to reach net zero economy, 2030 and 2050**

	Europe	Italy	Spain
2030	**-55%** GHG emissions **40%** RES in final energy consumption **-36%** final energy consumption	**-43%** GHG emissions in ETS sectors and **-33%** GHG emissions in non-ETS sectors **30%** RES in final energy consumption **55%** RES in electricity generation **-39.7%** final energy consumption	**-23%** GHG emissions in ETS sectors and **-39%** GHG emissions in non-ETS sectors **42%** RES in final energy consumption **74%** RES in electricity generation **-43%** final energy consumption
2050	**0 net GHG emissions** (European Union carbon neutrality at 2050)	**-84/87%** GHG emissions **85/90%** RES in final energy consumption **95/100%** RES in electricity generation **-49%** final energy consumption	**-90%** GHG emissions **97%** RES in final energy consumption **100%** RES in electricity generation **-44%** energy consumption

N.B. Italian and Spanish GHG objectives are gross values.

Source → Elaboration by The European House – Ambrosetti and Enel Foundation of data of European Commission, Italian and Spanish NECPs and Italian and Spanish Long-term Strategy, 2022.

→ DECARBONIZATION IN ITALY AND SPAIN: GAP ANALYSIS

Starting from the targets and strategic guidelines set in the current national plans and strategies for Italy and Spain, a **gap analysis** was carried out for the main energy transition levers: **renewable energy sources**, **energy efficiency** and **reduction of GHG emissions** with respect to two different dimensions:

- **Policy targets**. The 2030, 2040[10] and 2050 policy targets were mapped to evaluate the gap between current trends and targets.
- **Investments**. The level of investment needed to achieve the 2030, 2040 (when available) and 2050 targets was mapped, and the distance with the current level was assessed.

10
In absence of official data, the policy target in 2040 was calculated assuming a linear trend between the policy target in 2030 and the policy target in 2050.

The goal of this analysis was to understand the extent to which Italy and Spain are close to effectively becoming **carbon neutral**, reaching the target set in their national plans with a particular focus on 2030, 2040 and 2050.

To carry out this assessment, the focus was placed on the **current national plan and long-term strategies in Italy and Spain**. In the absence of elements suggesting a change of trajectory in the future, current trends were taken in account by implementing a projection of historical data and, therefore, assuming a constant pace[11].

Following the analysis done in the 2020 Study "*European Governance of the Energy Transition*" by The European House – Ambrosetti and Enel Foundation, the current trends were compared with the targets set by national plans. The following paragraphs present the simulation for both Italy and Spain, with a particular focus on the **2030**, **2040** and **2050** milestones for GHG emissions, share of renewables on final energy consumption and energy efficiency.

→ GHG EMISSIONS

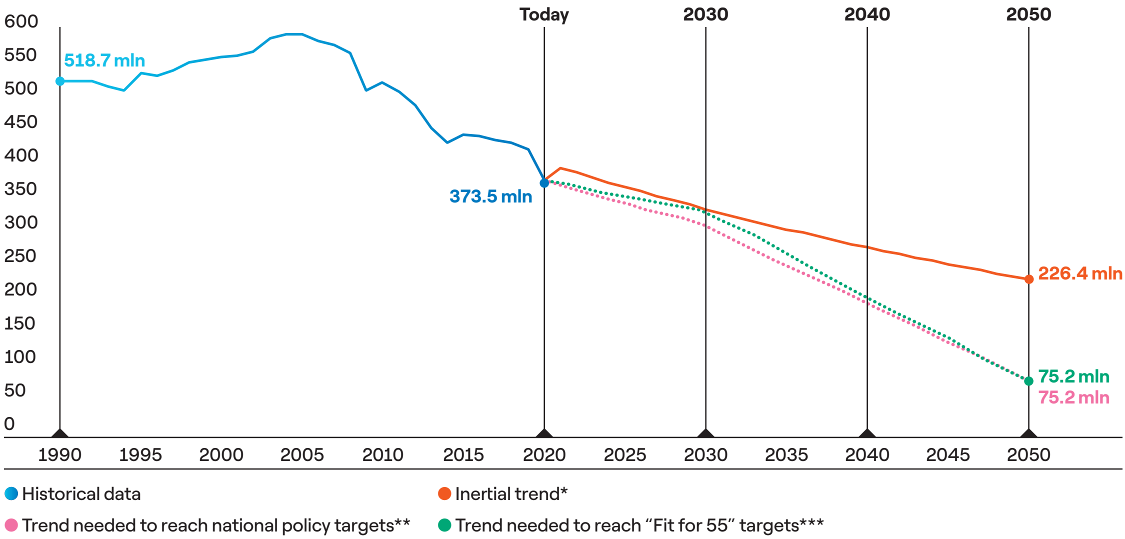
Although Italy has performed well in recent years with regard to greenhouse gas emissions compared to other European countries (even though the country accounts for 11.4% of the EU's total GHG emissions[12], it has reduced emissions at a faster pace than the EU average since 2005, falling by around 28% between 2005 and 2019), the downward trend is definitely not enough to keep the pace with either the 2050 targets or the more ambitious 2030 GHG emissions reduction entailed in the "Fit for 55" package.

In particular, in the period 2021-2030, by projecting the CAGR between 2005 and 2019, the values recorded in terms of GHG reductions were worse than the ones expected in the policy scenario in the Italian NECP (330.3 Mt CO_2-eq. vs. 328 Mt CO_2-eq.). In addition, it is also important to mention that in 2030, under the increased ambition set by "Fit for 55" package, the Italian GHG goal looks even more challenging than the one reported in the NECP (306.3 million tonnes CO_2). Lastly, between 2030 and 2050, in the light of the more ambitious targets in the long term – namely, reducing GHG emissions by 84/87% compared to 1990 levels – **the gap broadens**, with a distance of around 151.2 Mt CO_2-eq. in 2050.

11
The projecting CAGR, used to elaborate the inertial trend, voluntarily stops at 2019 in order not to consider the exogenous shock arising in 2020 following the pandemic.

12
Source: European Parliament, "*EU progress on climate action – how are the Member States doing?*", 2021.

FIG 10 → **GHG gross emissions in Italy, 1990-2050**[E] (Mt CO_2-eq.)

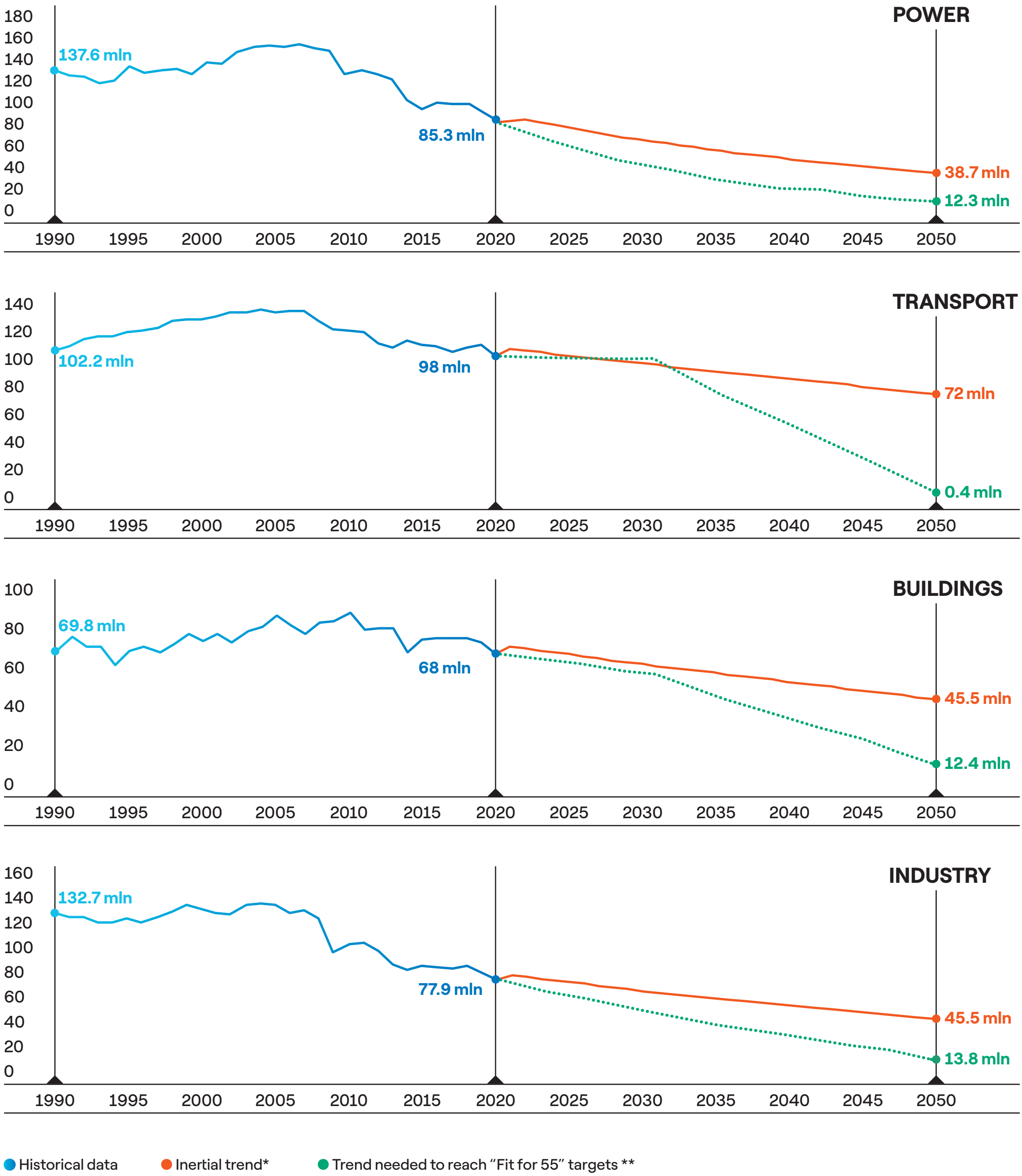


* The inertial trend was been calculated by projecting the CAGR from 2009 to 2019.
** The policy targets are the ones reported in the 2030 National Energy and Climate Plan and the 2050 Long-Term strategies.
*** The "Fit for 55" targets in 2030 were estimated by projecting the same percentage increase estimated at European level.

Source → The European House - Ambrosetti and Enel Foundation elaboration on European Environment Agency, NECP and long-term strategy, 2022.

Examining closely the expected reduction trends in sectorial GHG emissions in Italy, considering an inertial trend built on GHG emissions trends registered between 1990 and 2020, in 2050 the transport sector is expected to be **the main polluter**, with 72 Mt CO_2-eq. (-26.5% with respect to 2020), followed by the building and industry sectors (45.5 Mt CO_2-eq., -33.1% and -41.6%, respectively, compared to 2020 levels). Instead, following the trend in GHG emissions reduction necessary to achieve the goals set out in the "Fit for 55" package, the transport sector is expected to be fully decarbonized (-99.6% in 2050, compared to 2020), while the buildings sector and industrial sector GHG emissions will shrink to 12.4 and 13.8 Mt CO_2-eq., respectively. The power sector will account for 12.3 Mt CO_2-eq. in 2050.

FIG 11 → **GHG gross emissions in Italy by sector, 1990-2050[E]** (Mt CO_2-eq.)



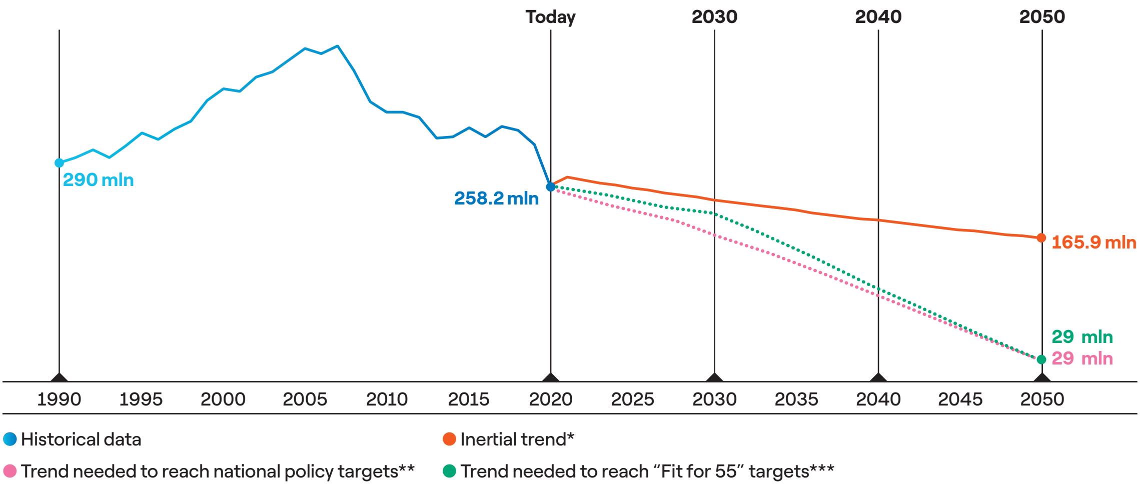
* The inertial trend was calculated by projecting the CAGR from 2009 to 2019.
** The "Fit for 55" targets were estimated starting from the energy mix in 2030, 2040 and 2050 reported in the national long-term strategy.

Source → The European House - Ambrosetti and Enel Foundation elaboration on Eurostat data, 2022.

Spain dramatically cut GHG emissions between 2005 and 2019, reporting a **27%** decline and performing better than the EU average (slightly below the Italian performance). However, looking at a broader horizon, the interpretation changes. In fact, considering the last 30 years, it is undeniable that Spain could have done more: GHG emissions reduced by only 11%.

Looking forward, **Spain** shows an inertial trend that, just like Italy, **underperforms** with respect to the national policy scenario by 2030 (232.5 Mt CO_2-eq. vs. 223.3 Mt CO_2-eq.). From 2030 onwards, as for Italy, the gap between GHG reductions in policy scenarios and the inertial trend further deepens, reaching a difference of 136.9 Mt CO_2-eq. in 2050 (a bit lower than the one reported for Italy).

FIG 12 → **GHG gross emissions in Spain, 1990-2050[E]** (Mt CO_2-eq.)

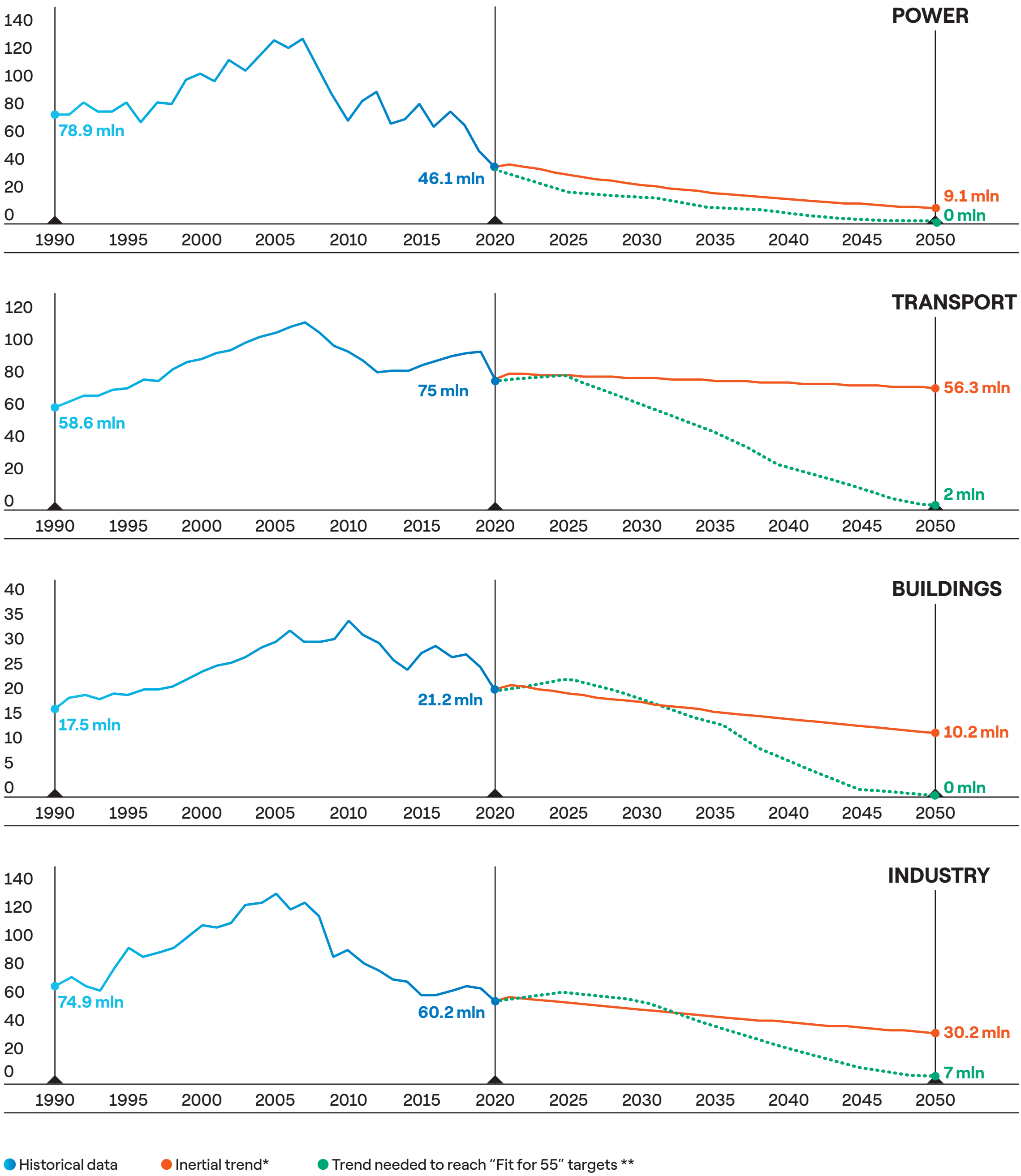


* The inertial trend was calculated by projecting the CAGR from 2009 to 2019.
** The policy targets are the ones reported in the 2030 National Energy and Climate Plan and 2050 Long-Term strategies.
*** The "Fit for 55" targets in 2030 were estimated by projecting the same percentage increase estimated at European level.

Source → The European House - Ambrosetti and Enel Foundation elaboration on European Environment Agency, NECP and long-term strategy, 2022.

Considering each sector's GHG emissions trend projections to 2050 in Spain, following the inertial trend built on the trajectories observed between 1990 and 2019, the transport sector is expected to continue to be **the main polluter** in 2050, with 56.3 Mt CO_2-eq. (-24.9% with respect to 2020), while the GHG emissions contribution of industry and buildings will decrease by 49.8% and 51.9%, respectively; the power sector's emissions is expected to record the largest decrease (-80.2%). But, in order to keep up with GHG emissions reduction goal set out in the "Fit for 55" package and the national long-term strategy, in 2050 transport sector should contribute with 2 Mt CO_2-eq. only, while the buildings and power sectors have to be fully decarbonized. Finally, the industry sector's residual GHG emissions will amount to 7 Mt CO_2-eq.

FIG 13 → **GHG gross emissions in Spain by sector, 1990-2050[E]** (Mt CO_2-eq.)



* The inertial trend was calculated by projecting the CAGR from 2009 to 2019.
** The "Fit for 55" targets were estimated starting from the energy mix in 2030, 2040 and 2050 reported in the national long-term strategy.

Source → The European House - Ambrosetti and Enel Foundation elaboration on Eurostat data, 2022.

GHG emissions in Italy and Spain under the effort-sharing legislation

EU effort-sharing legislation covers emissions from sectors not included in the ETS, such as **transport, buildings, agriculture, and waste**.
For the Effort-Sharing Regulation (ESR) covering the 2021-2030 period, Italy must reduce its emissions by **33%** against 2005 levels. Italy has remained consistently within its allocated emission allowances and estimates that its planned measures will result in the country slightly exceeding the 2030 target.
Spain, under the ESR for the 2021-2030 period, has committed to reducing non-ETS emissions by **26%** compared with 2005. However, Spain plans to overachieve this target and reduce emissions by 39%, to reach its 2030 target of reducing total emissions by 23% compared to 1990.

The European Commission validated this ambitious target and noted that Spain's NECP sets a comprehensive set of measures to meet this objective.
However, the European Commission's intends to revise the Effort-Sharing Regulation to adapt it to the heightened ambitions after the adoption of the "Fit for 55" package: an option proposed is to set the target of GHG emissions reduction from ESR sectors to **40%** between 2021 and 2030, with a parallel coverage of ESR and new emissions trading on the transport and building sectors; another option is a 35% GHG emissions reduction, but the transport and building sectors will be left out of the ESR scope.

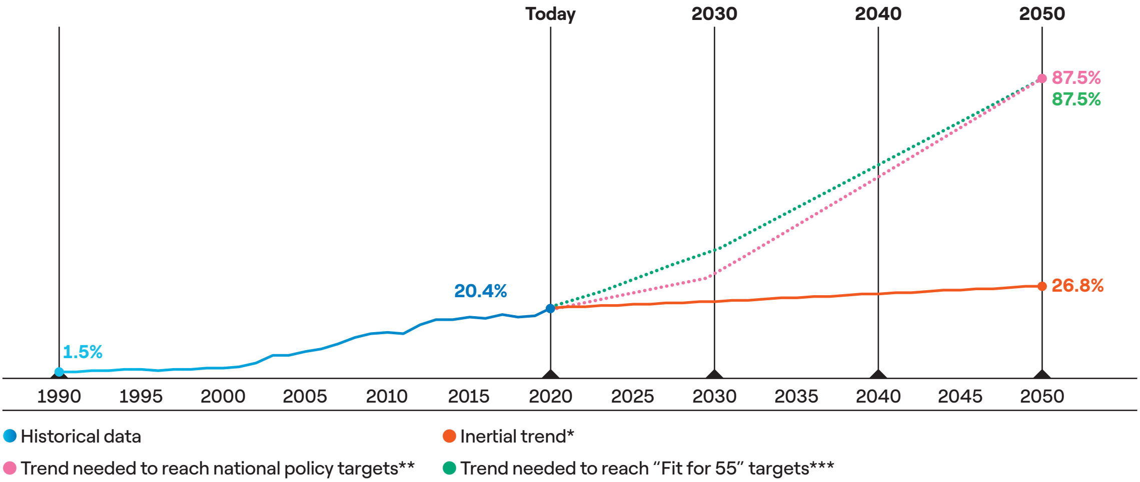
Source → The European House - Ambrosetti and Enel Foundation elaboration on European Parliament Research Service, 2022.

→ **RENEWABLE ENERGY SOURCES**

In the current National Plan, Italy expects to triple its production of solar energy and to double its production of wind energy by 2030. A crucial driver will be the **phasing out of coal in electricity production** and an estimated 55% penetration of renewable sources in final electricity consumption by 2030. Focusing attention on the share of renewable energy sources in final energy consumption, it is clear that Italy **is still far from reaching the 30% target in 2030**, with a gap of nearly 8 percentage points compared to the national policy target.

The situation is even worse looking at 2040 and 2050. In particular, looking at 2050, the gap is equal to **60.7 percentage points**. The increase in the gap as the horizon time increases can be explained by the ambitious goal to achieve a value of renewable energy on gross final energy consumption equal to 87.5% by 2050 (almost three times the value estimated in 2030).

FIG 14 → **Share of renewables on final energy consumption in Italy, 1990-2050ᴱ** (% values)



* The inertial trend was calculated by projecting the CAGR from 2009 to 2019.
** The policy targets are the ones reported in the 2030 National Energy and Climate Plan and 2050 Long-Term strategies.
*** The "Fit for 55" targets in 2030 were estimated by projecting the same percentage increase estimated at European level.

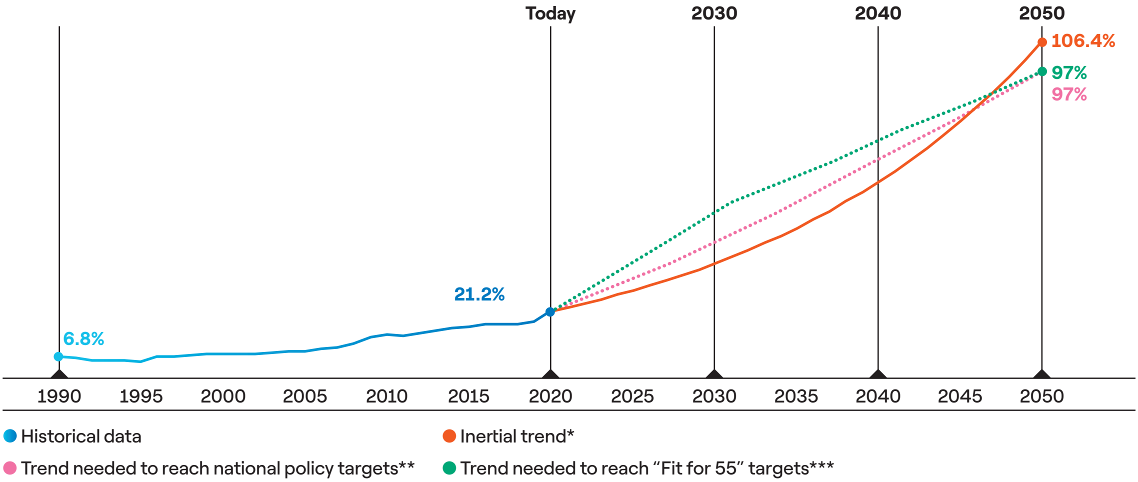
Source → The European House - Ambrosetti and Enel Foundation elaboration on Eurostat data, 2022.

Looking forward to 2030, Spain has set a target of share of renewable energy in the energy mix to **42%**, starting from a 2020 target of a 20% (**+22 percentage points**, vs. +9.6 percentage points increase in Italy in the same period). In the EU, Spain is **the most ambitious country** with regard to growth expectations of this indicator, behind only Denmark (which raised the target of share of renewable energy from 30% in 2020 to 55% in 2030).

With regards to Spain, **RES** projection suggests that the distance from the policy scenario is already marked in the short-term, with a gap of **15 percentage points** compared to the national policy target at 2030 and of **53.5 percentage points at 2050**[13]. However, including in the analysis also year 2020 (year in which there was a significant increase in the penetration of renewables in Spain, also due to regulatory enhancement), even though Spain won't achieve the policy target in the short-term (with a gap of 5.7 percentage points in 2030), it will overperform it in 2050 with a value of 106.4% (vs. 97% given by the national policy and "Fit for 55" targets).

13
The projection is based on the 2015-2019 trend so to take into account the evolution of RES prior to the exogenous shock caused by COVID-19.

FIG 15 → **Share of renewables on final energy consumption in Spain, 1990-2050[E]** (% values)



* Inertial trend has been calculated by projecting CAGR from 2015 to 2020.
** Policy targets refers to the ones reported in 2030 National Energy and Climate Plan and 2050 Long-Term strategies.
*** "Fit for 55" targets in 2030 have been estimated by projecting the same percentage increase estimated at European level.

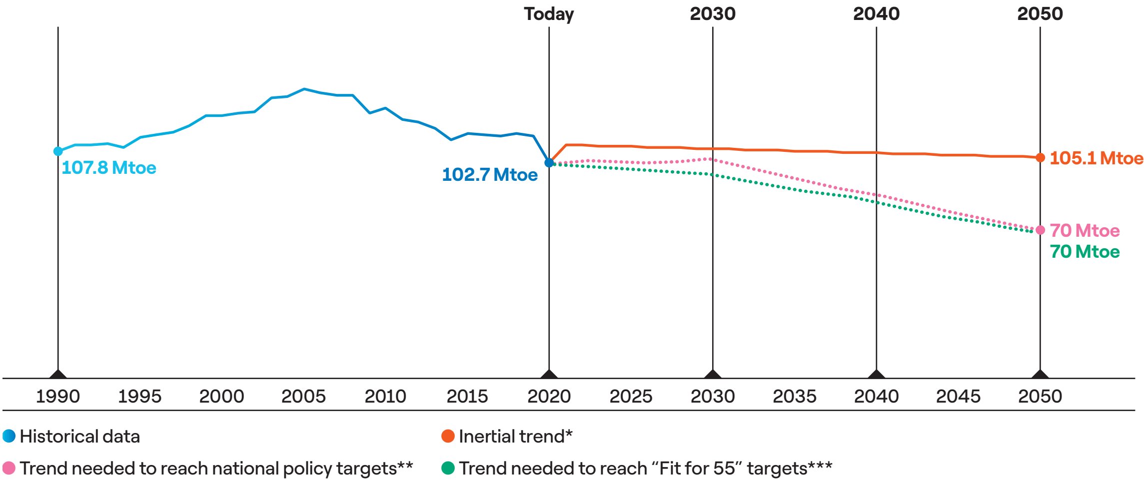
Source → The European House - Ambrosetti and Enel Foundation elaboration on Eurostat data, 2022.

→ **ENERGY EFFICIENCY**

Italy has been experiencing relevant energy efficiency gains over the years. In addition, the country intends to pursue a reduction of 43% for primary energy consumption and 39.7% for final energy consumption by 2030 with respect to the PRIMES 2007 reference scenario. With regard to final energy consumption, this ambition is reflected, in absolute terms, in a target of **103.8 Mtoe** of final energy consumption. New measures to promote sustainable mobility and full implementation of the National Fund for Energy Efficiency will contribute to achieving this target.

However, it is worth noting that Italy is **not performing well**. In fact, looking at the 2030, 2040 and 2050 targets, the inertial trend signals worse results compared to the policy scenario and the increased ambition deriving from the goal set in the "Fit for 55" plan. This leads to a difference of 35.1 Mtoe in 2050.

FIG 16 → **Energy efficiency in Italy, 1990-2050[E]** (Mtoe)

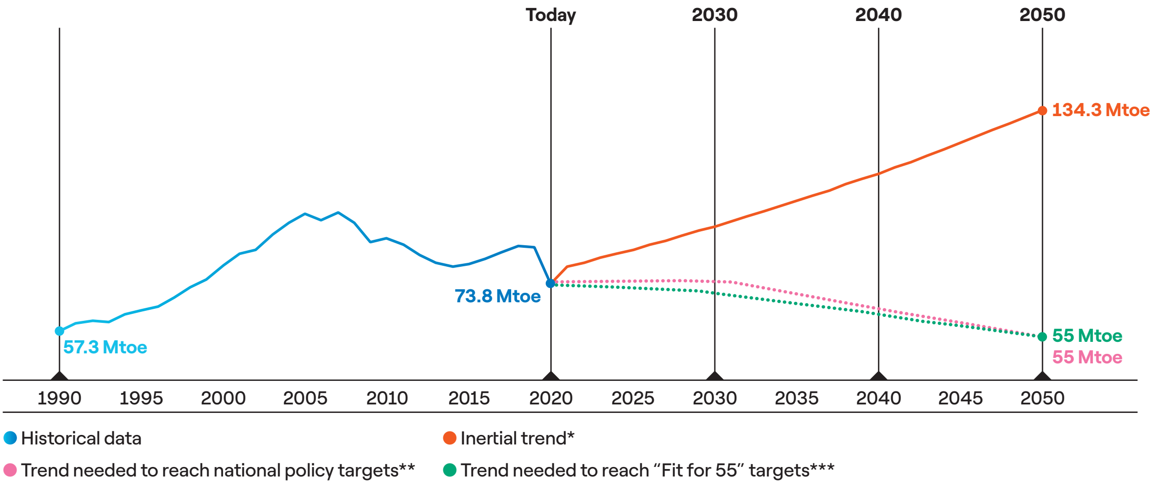


* The inertial trend was calculated by projecting the CAGR from 2009 to 2019.
** The policy targets are the ones reported in the 2030 National Energy and Climate Plan and 2050 Long-Term strategies.
*** The "Fit for 55" targets in 2030 were estimated by projecting the same percentage increase estimated at European level.

Source → The European House – Ambrosetti and Enel Foundation elaboration on Eurostat, NECP and long-term strategy, 2022.

In Spain the National Energy and Climate Plan estimates a target for energy efficiency improvement equal to 39.5%, which translates into a level of primary and final energy consumption equal to 98.5 Mtoe and 73.5 Mtoe, respectively, by 2030. As can be seen from the figure below, the current scenario would lead energy efficiency trajectory in an **opposite direction** compared to the trend needed to reach policy targets at 2030, 2040 and 2050. However, the use of autonomous and electric vehicles will bring about significant efficiency gains in the transport and mobility sector, providing a considerable support in respecting policy targets.

FIG 17 → **Energy efficiency in Spain, 2005-2050**[E] (Mtoe)



* The inertial trend was calculated by projecting the CAGR from 2009 to 2019.
** The policy targets are the ones reported in the 2030 National Energy and Climate Plan and 2050 Long-Term strategies.
*** The "Fit for 55" targets in 2030 were estimated by projecting the same percentage increase estimated at European level.

Source → The European House – Ambrosetti and Enel Foundation elaboration on Eurostat, NECP and long-term strategy, 2022.

Overall, the analyses show that both Italy and Spain are **behind schedule on their policy targets**, especially in the **long term**. In particular, the most critical energy levers appear to be the share of renewable energy sources for Italy and the energy efficiency indicators for both of them.

These delays associated with renewables deployment, energy demand reduction and GHG emissions reduction can be linked to a **gap in the deployment of investments** associated with the energy transition. In Italy, the NECP estimates **186 billion Euros of additional investments** in the energy transition in comparison with the current policy scenario across the time span 2017-2030. In particular, the **buildings and renewables** sectors require most of the additional investments to reach the 2030 policy targets set in the NECP, i.e., 99 and 38 billion Euros, respectively.

In Spain, the National Energy and Climate Plan estimates the total investments needed to achieve the objective of the plan to be equal to **241.4 billion Euros for 2021–2030**, of which the additional investments are equal to **196 billion Euros** compared to the current policy scenario. In particular, the areas that will require most of the additional investments are:

- **Renewables** with 38% of the total (91.8 billion Euros).
- **Energy efficiency** with 35% of the total (83.5 billion Euros).
- **Networks and electrification** with 24% of the total (58.6 billion Euros).

In addition to this, the Spanish long-term strategy provides an estimate of the total investments needed across the period 2031-2050, equal to **500 billion Euros** (of which **300 billion Euros** are additional investments as a consequence of the implementation of the strategy).

The **investment deficit** is relevant at the European level as well. In particular, as seen in the "*European Governance of the Energy Transition*" Study by The European House – Ambrosetti and Enel Foundation, the power grid sector is receiving the highest percentage rise in average annual investments in the period 2021-2030, from 24 billion Euros in the period 2011-2020 to 58 billion Euros in the period 2021-2030 in the -55% GHG scenario (+141.7%). Special attention has been given to the transport sector, which on average invested the most each year over the period 2011-2020 (492 billion Euros), but it still needs an increase in annual investments of +26.4% over the next 10 years according to the -55% GHG scenario. Overall, it is necessary to earmark **3,564 billion Euros in additional investments** to reach the more ambitious target of -55% GHG emissions between 2021 and 2030. Looking at the period 2031-2050, the additional annual investment, compared to the baseline scenario, is estimated to be equal to around **214.2 billion Euros**[14].

14
Source: The European House - Ambrosetti and Enel Foundation, "*European governance of the energy transition, enabling investments*", 2021.

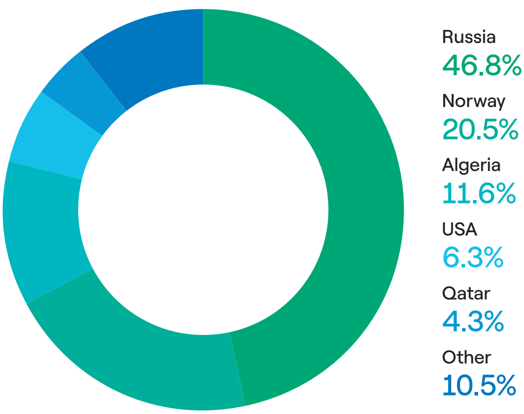
1.2

Energy dependence in Europe, Italy and Spain: the current situation, the energy crisis and the diversification strategy

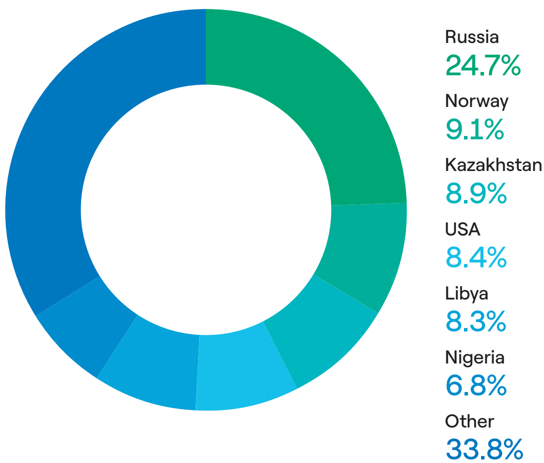
Further to the climate threat, the need to rethink our energy system has been made even more pressing by the **current energy crisis** triggered by the Russia-Ukraine conflict, which has highlighted the need to dramatically improve **Europe's energy independence**. Europe[15] is **58%** dependent on energy imports[16] and over the 20-year period 2000-2020 this share has remained almost unchanged, if not increased by about one percentage point. Moreover, the import is poorly diversified geographically, with Russia accounting for almost **47%** of extra-EU natural gas imports and about **25%** of oil imports.

FIG 18 → **Extra-EU natural gas imports** (left graph) **and extra-EU oil imports** (right graph) **from the main trading partners, first half of 2021** (% values)

Extra-EU natural gas imports



Extra-EU oil imports



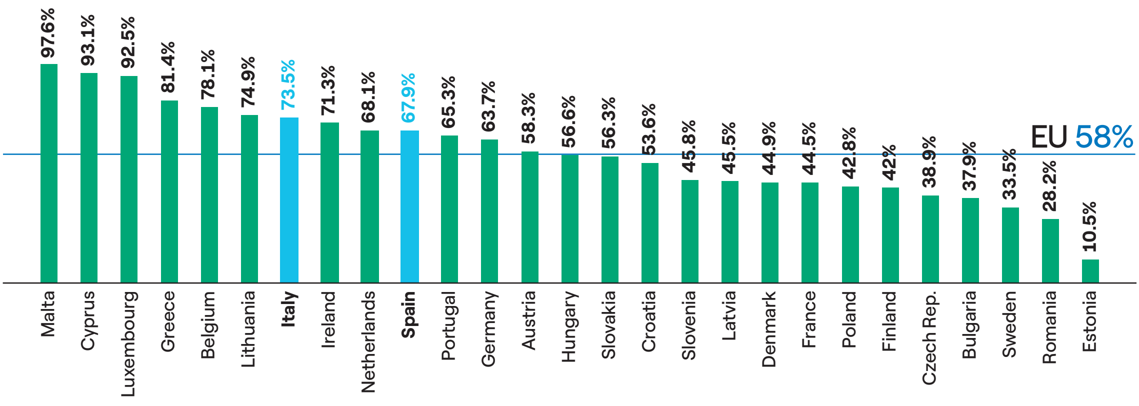
Source → The European House – Ambrosetti and Enel Foundation elaboration on Eurostat data, 2022.

15
Europe refers to the entire European Union.

16
Source: Eurostat data, 2022.

Within this context, Italy is **among the countries with the least energy autonomy, importing 73.5% of its gross available energy**. Spain too reports a high dependence on energy imports, with a value of around 68% (around 5 percentage points less than Italy). Overall, there are several countries which are still highly dependent on energy imports, such as Lithuania (74.9%), Belgium (78.1%), Greece (81.4%), Luxembourg (92.5%), Cyprus (93.1%), and Malta (97.6%). The lowest energy dependence rates in 2020 are reported in Estonia (10.5%), Romania (28.2%), Sweden (33.5%), and Bulgaria (37.9%).

FIG 19 → **Dependence on energy imports for European countries, 2020** (% values)



N.B. The indicator is calculated as net imports on gross available energy.

Source → The European House – Ambrosetti and Enel Foundation elaboration on Eurostat data, 2022.

The risk – in terms of both physical security and economic affordability – connected to a high level of import dependency coupled with low import diversification has become once again evident when, starting in May 2021, Russia reduced its supplies to European countries by 25%, peaking at 40% in January 2022, causing an **increase in natural gas spot prices** in European markets. In particular, the TTF (Title Transfer Facility) index, the reference market in Europe for natural gas, recorded, according to Bloomberg data, an average price in January 2022 of **83.94 Euros per MWh** (**+366% compared to January 2021**), reaching its peak at the beginning of March 2022 (**227.2 Euros per MWh**).

In the first quarter of 2022, in Italy, the price of electricity and gas **increased by 131% and 95% respectively**, compared to the same period of 2021. In Spain, the cost of electricity for households in March 2022 was **ten times higher** than a year before; in Germany, on March 2022 households paid on average **52% more for energy** compared to the previous year, while in the UK, the **price cap on energy bills for households has increased by 54%** from 1 April 2022; in France, government measures limited energy bills for households to a 4% increase, which would have otherwise increased between 35% and 45% compared to 2021. Considering companies, in January 2022 in Italy the net electricity price reached the second highest value in Europe (225 Euros/MWh), right after Spain (243 Euros/MWh), but over 6% more than in France and 34% higher than in Germany[17].

Low energy independence, especially in the contingency of worsening international relations, causes **large-scale economic impacts**. It is worth noting that, if current energy prices persist, the additional cost of importing gas and oil to Europe would be equivalent to an economic shock of 550 billion Euros[18].

From the business point of view, the rebounds are already visible, with energy-intensive sectors that have announced **shut-downs and a downward revision of their production plans**. The surge of energy prices for companies has eroded operating revenues, which will inevitably reduce the supply on the market of strategic materials, as many already decided to suspend operations for several weeks or reduce output to avoid losses from operating under these extremely high energy prices. The limitation of production will in turn have cascading effects on the manufacturing and construction industries, which could lack fundamental materials.

1.2.1 EUROPEAN DEPENDENCE ON NATURAL GAS AND THE IMPORTANCE OF RUSSIA AS A COMMERCIAL PARTNER

Many European countries in recent decades have increased the consumption of natural gas, while shifting from the use of petroleum products and coal. Gas relevance can be measured by looking at the composition of the **energy mix**. In particular, analysing the total energy supply in the major European countries, it is possible to highlight some differences in terms of the weight of natural gas on their energy systems.

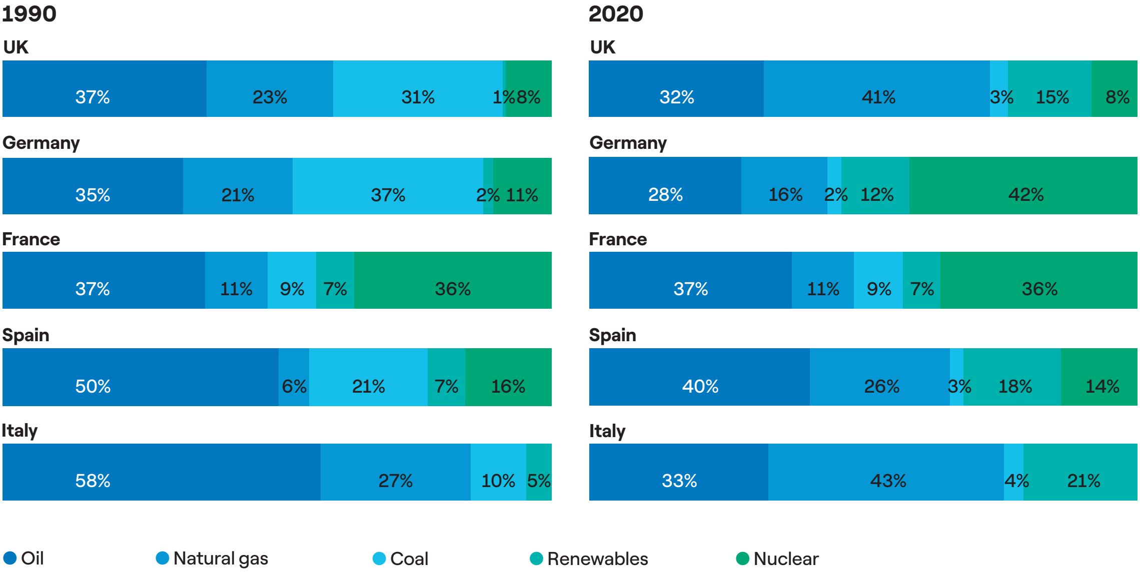
In Italy, for instance, the energy demand relies heavily on **fossil fuels**, even though the long-term trend signals a gradual downsizing, with coal and oil down by 32.2 percentage points between 1990 and 2020 in terms of share on the total energy supply. In this category, **natural gas relevance grew by 16.1 percentage points**, recording the highest growth together with renewable energy sources (+16.1 percentage points between 1990 and 2020). Overall, in Italy in 2020 natural gas accounted for **43.3%** of the total energy supply.

Looking at Spain, what first comes to mind is its lower **dependence on fossil fuels**, both in 1990 (77.3% of the total energy supply) and in 2020 (68.4% of the total energy supply). In particular, focusing our attention on natural gas, Spain reported a value almost **5 times lower than Italy in 1990** (5.5% in Spain vs. 27.2% in Italy). However, this difference decreased by almost three times in 2020: natural gas relevance on the total energy supply grew by 20.2 percentage points between 1990 and 2020 in Spain, reaching a value of **25.7%**.

17
Source: Istituto per gli Studi di Politica Internazionale (ISPI).

18
Source: JP Morgan analysis.

FIG 20 → **Evolution of the energy mix in the major European countries, 1990 and 2020** (% values)



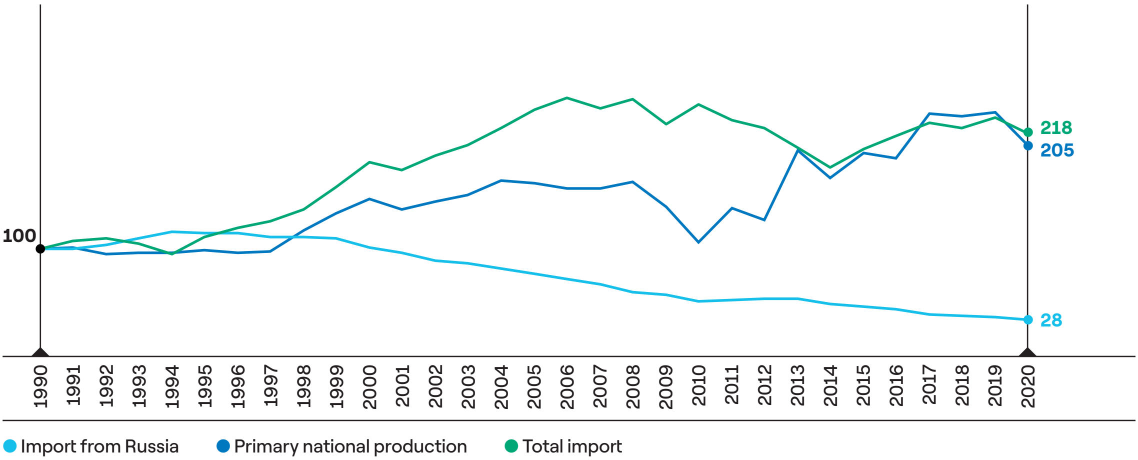
N.B. The energy mix is calculated starting from the total energy supply by source provided by the IEA.

Source → The European House – Ambrosetti and Enel Foundation elaboration on IEA data, 2022.

As Figure 20 shows, **Italy has the highest share of natural gas in the energy mix among the major European countries**. In the whole European Union the centrality of natural gas finds a parallel only in **Netherlands**, a gas producing country, where it reached a value of 45.4% in 2020. Another dimension to look at to properly assess dependence on natural gas, together with the relative weight on the energy mix, is the **percentage of imports**.

In 2020 Italy imported **73.5% of its total energy supply**, showing a high energy dependency on foreign countries. In the same year, the Italian energy mix was dominated by **natural gas**, which accounted for **43%** of the total energy supply, with an internal gross consumption of 71 billion m^3. Out of this huge amount of gas, just 7% was produced in Italy, while the remaining **93% was imported by foreign countries**. Compared to 1990, **imported gas more than doubled**, from 30,470 million m^3 to 66,393 million m^3 (+118%), while nationally produced gas fell by **72%**.

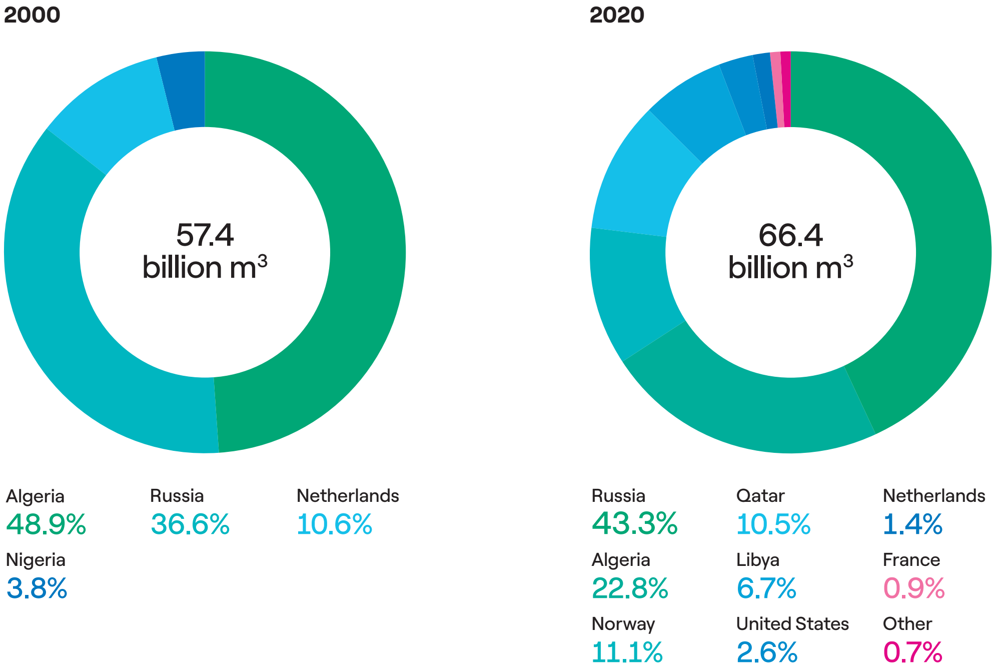
FIG 21 → **Trends in total amount of natural gas imported in Italy, imported from Russia and nationally generated, 1990-2020** (1990=100)



Source → The European House – Ambrosetti and Enel Foundation elaboration on Energetic and Mining Analyses and Statistics of Ministry of Ecological Transition and Eurostat, 2022.

Even though most natural gas imports to Italy are still concentrated in the hands of a few players (Russia and Algeria alone account for 66.1% of the total), over the last 20 years the number of Italy's commercial partners has increased, thanks also to the **strong growth in LNG imports**. In fact, while in 2000 there were only **4** suppliers of natural gas (Algeria with 48.9%, Russia with 36.6%, Netherlands with 10.6% and Nigeria with 3.8%), in 2020 **the number of main suppliers doubled**, with new players such as Norway (11.1%), Qatar (10.5%), Libya (6.7%) and United States (2.6%).

FIG 22 → **Natural gas imports to Italy by source of origin, 2000 and 2020** (% values and total amount of imported natural gas)

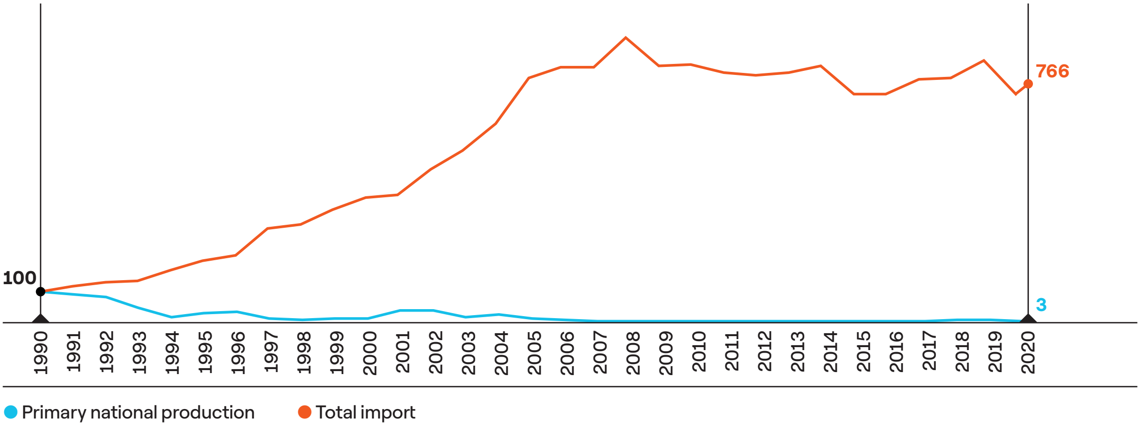


N.B. In 2020, "Other" Nigeria (0.3%), Trinidad and Tobago (0.2%), Belgium (0.1%), Croatia (0.05%), Azerbaijan (0.02%), Denmark and UK (0.002%).

Source → The European House – Ambrosetti and Enel Foundation elaboration on Eurostat data, 2022.

Although Spain depends less on international markets to cover its energy needs compared to Italy, with energy imports making up **67.9% of its total energy supply**, the issue of energy dependency is still relevant. In particular, in 2020 its total energy supply came from imported oil products for 40% and from natural gas for 26%.

FIG 23 → **Trends in total amount of gas imported and gas nationally generated in Spain, 1990-2020** (1990=100)



Source → The European House – Ambrosetti and Enel Foundation elaboration on Eurostat, 2022.

The country started importing amounts of Russian natural gas from 2018 on. Overall, Spain's main partners for gas imports are Algeria (which accounted for 29.1% of total gas imports in 2020), the United States (15.6%) and Nigeria (12.1%)[19]. Russia accounts for only 10.4% of the natural gas imported.

In addition, over the last 20 years, **Spain was able to diversify natural gas imports even more than Italy**: while in 2000 there were 7 suppliers (Algeria with 60.3%, Norway with 13.4%, Nigeria with 10.9%, Trinidad and Tobago with 5%, Libya with 4.6%, Qatar with 1.7% and United Arab Emirates with 0.9%), in 2020 the number of suppliers rose to 17, growing by **nearly 2.5 times**.

19
Source: Eurostat, 2022.

FIG 24 → **Natural gas imports to Spain by source of origin, 2000 and 2020** (% values and total amount of imported natural gas)

2000

Algeria 60.3%
Norway 13.4%
Nigeria 10.9%
Trinidad and Tobago 5%
Libya 4.6%
Not specified 3.1%

2020

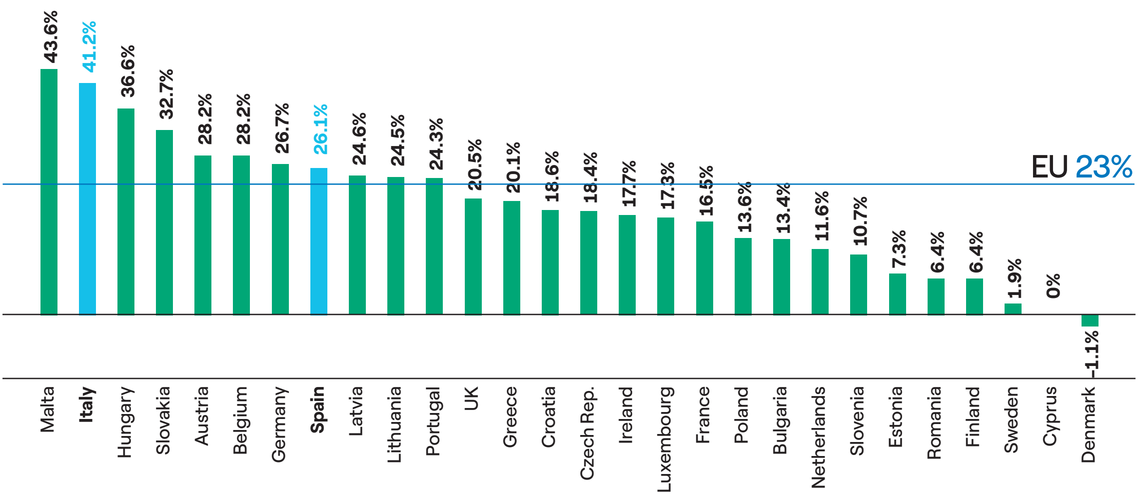
Algeria 29.1%
United States 15.6%
Nigeria 12.1%
Russia 10.4%
Qatar 8.8%
Trinidad and Tobago 6.6%
France 6.1%
Norway 5%
Other 6.2%

N.B. In 2020, "Other" includes Equatorial Guinea (2.9%), Angola (1.1%), Peru (0.5%), Portugal (0.5%), Argentina (0.5%), Egypt (0.3%), Cameroon (0.3%), Belgium (0.2%), UK (0.1%).

Source → The European House – Ambrosetti and Enel Foundation elaboration on Eurostat data, 2022.

Therefore, looking together at the dependence on imported natural gas and the weight of natural gas in the energy system, **Italy is an *unicum* in Europe**, together with Malta. In fact, Italy depends on imported natural gas for **41.2%** of its gross available energy, and thus to cover its national energy demand. Spain relies less on natural gas imports from foreign countries, which account for **26.1%**. Overall, both countries' dependence on gas imports is above the European average of 23%.

FIG 25 → **Natural gas dependence index in EU27 and UK, 2020 or last year available** (% values)

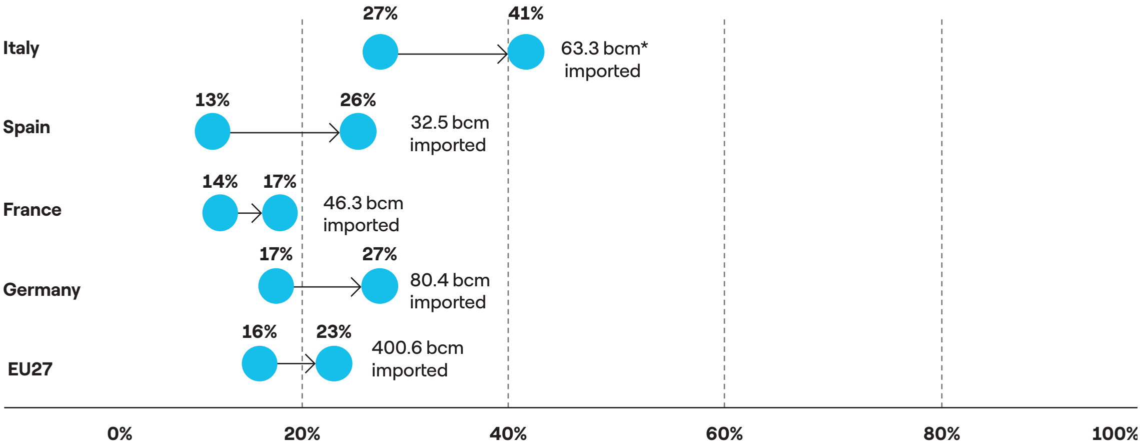


N.B. The natural gas dependence index was calculated by multiplying the share of imported gas in each country by the share of natural gas on primary energy consumption. Therefore, the index evaluates the exposure of European countries in terms of both natural gas imports and the relative weight of natural gas in the energy mix.

Source → The European House – Ambrosetti and Enel Foundation elaboration on Eurostat and ENEA data, 2022.

Considering the historical trend in the period 2000-2020, Italy reported the highest **increase in the natural gas dependence index (+14 percentage points)**, while Spain increased its reliance on imports by **13 percentage points** during the same period, as well as France; Germany's dependence on imported gas increased by 10 percentage points, recording the highest amount in absolute values imported in 2020. Both Italy's and Spain's dependence increases are above the European average (+7 percentage points).

FIG 26 → **Variation in the natural gas dependence index in selected European countries and EU27, 2000-2020** (% values)

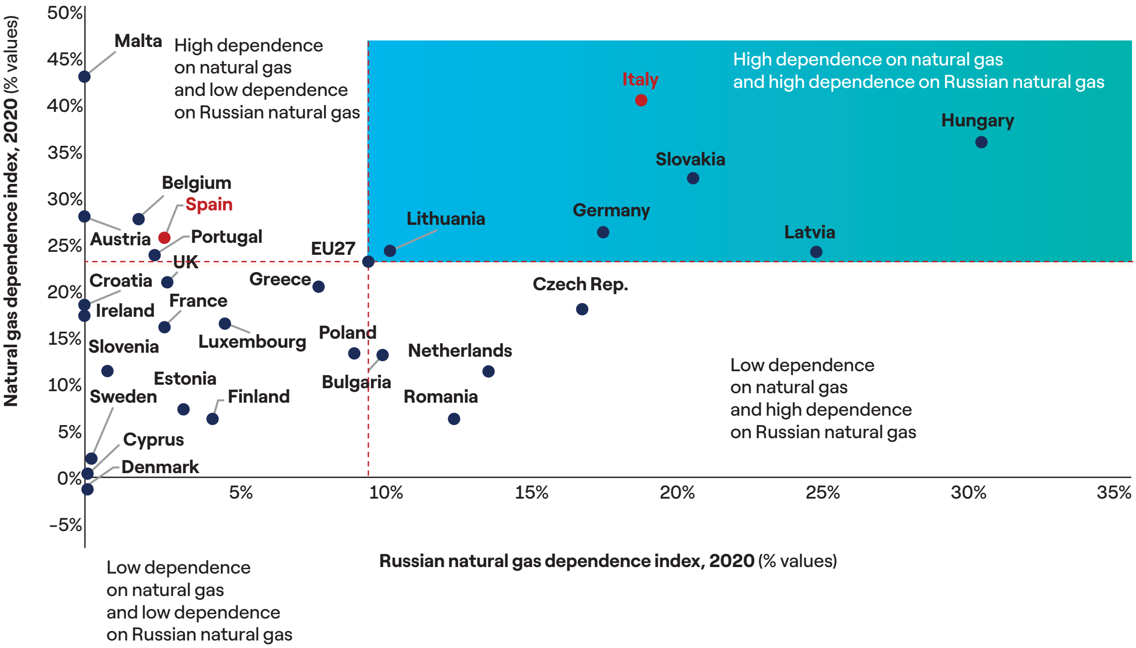


***** Bcm stands for billion m³.
N.B. The natural gas dependence index was calculated by multiplying the share of imported gas in each country by the share of natural gas on primary energy consumption. Therefore, the index evaluates the exposure of European countries in terms of natural gas imports and the relative weight of natural gas in the energy mix.

Source → The European House – Ambrosetti and Enel Foundation elaboration on Eurostat and ENEA data, 2022.

Focusing on Russian gas imports to European countries, **Italy is among the Member States with both high dependence on natural gas imports (41.5%)**, as seen previously and **high dependence on Russian natural gas imports**, together with Slovakia, Latvia and Hungary. Although Spain has a high dependence on natural gas imports as well, its reliance on Russia as a commercial partner is less significant, as its Russian natural gas dependence index is equal to 3%.

FIG 27 → **Russian natural gas dependence index** (x axis) **and natural gas dependence index** (y axis) **in EU27 and UK, 2020** (% values)

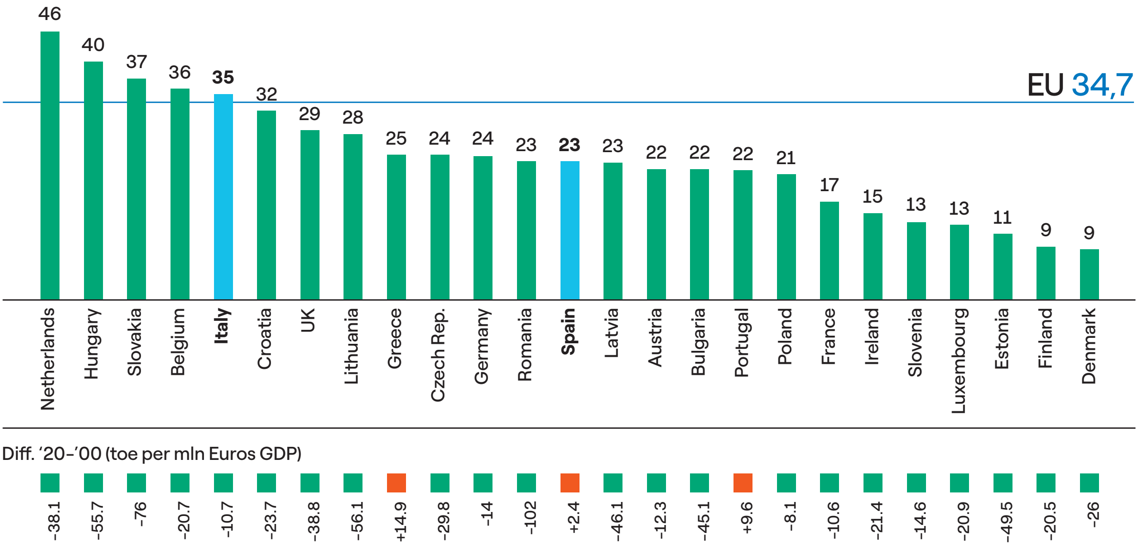


N.B. The natural gas dependence index was calculated by multiplying the share of imported gas in each country by the share of natural gas on primary energy consumption; the Russian natural gas dependence index was calculated by multiplying the share of imported gas from Russia in each country by the share of natural gas on primary energy consumption.

Source → The European House – Ambrosetti and Enel Foundation elaboration on Eurostat and ENEA data, 2022.

In addition, **Italy is also among the countries that consume more gas per million Euros of GDP with a value of 34.9 toe per million Euros of GDP**, thus highlighting a structural dependence of the economy. At the same time, it is also interesting to note that in the past 20 years Italy registered a lower reduction of gas consumption per million Euros of GDP than in most of the other European countries. With regard to Spain, **the gas intensity of GDP index indicates a lower dependence on gas**, registering a value of 23.3 toe per million of GDP. A point of attention, however, comes from the evolution over time: from 2000 to 2020, in fact, the gas intensity of GDP index increased by 2.4 toe per million Euros of GDP.

FIG 28 → **Gas intensity of GDP index in EU27 Countries, UK and Europe, 2020** (absolute values, toe per mln Euros of GDP)



N.B. The gas intensity of GDP index has been calculated dividing the quantity of gas consumed in each country by the GDP. Therefore, the index evaluates the European Countries' gas consumption necessary to produce a million Euros of GDP.

Source → Source: The European House – Ambrosetti and Enel Foundation elaboration on BP data, 2022.

Potential markets to draw on to further diversify Italian supplies

To cope with the emergency arising from the Russia-Ukraine conflict, **Italy is intensifying trade relations** to increase independence from Russian gas.
In particular, already in 2021, Algeria supplied Italy about 22.6 billion m^3 of natural gas, **a value 1.5 times higher than that recorded only in 2020**. The Trans Adriatic Pipeline (TAP), which connects Azerbaijan to Italy and which in 2021 supplied about 10 billion m^3, could double its capacity.
Alongside these short-term solutions, Italy will be able to count on the development of renewables in the next 3 years, during which it is planned to install about **60 GW of RES**. This strategy could represent the **structural solution to guarantee greater energy security and independence***.

* Source: "*La soluzione strutturale all'emergenza caro energia*", 25 February 2022.

Source → The European House - Ambrosetti and Enel Foundation elaboration on data provided by Ministero della Transizione Ecologica and Elettricità Futura, 2022.

1.3

Decarbonization and energy independence: European solutions to overcome the energy crisis

In order to address the energy crisis and the threat of Russian gas shortage, determined by the geopolitical tensions between Europe and the Russian Federation after the invasion of Ukraine, the European Commission recently proposed the "**REPowerEU**" plan. The plan aims to increase the resilience of the energy system and to eliminate Russian gas imports from the European mix by 2027. Gas accounts for about 32.3% of final energy consumption in Europe, and 83.6% of the total available gas in Europe is imported from foreign countries, among which Russia represents the main partner, providing 38.7% of the total gas imported in 2020.

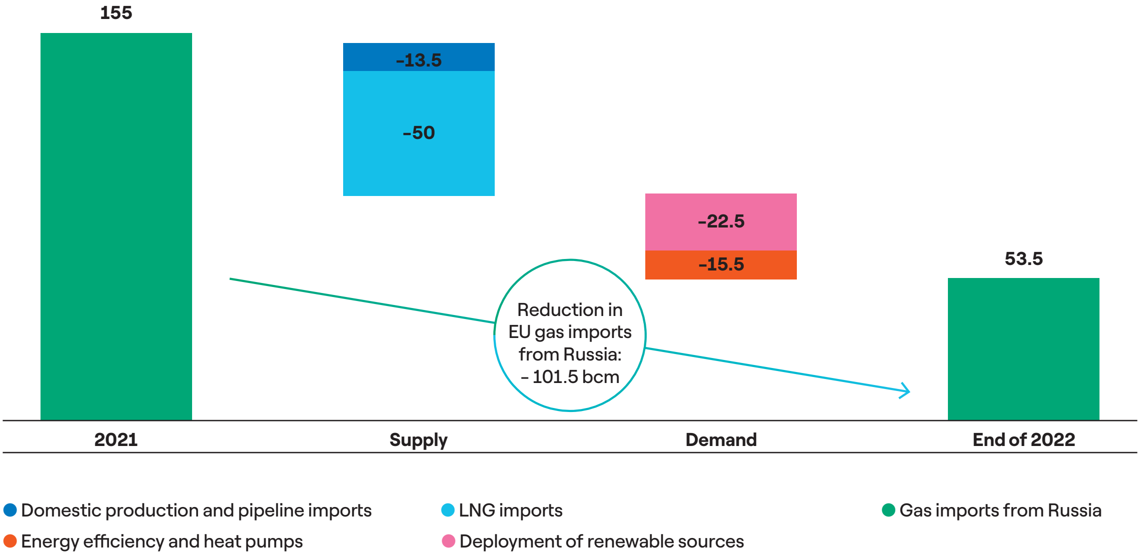
The actions outlined at European level with the "REPowerEU" plan will have an effect not only in the short term, but also in the medium one. Analysing the impact of each proposal in terms of savings on Russian gas, it is possible to estimate that, within a year, European Union could replace **more than half of the amount of gas imported in 2021**.

FIG 29 → Main levers to reduce dependence on Russian fossil fuel imports included in "REPowerEU" plan

Accelerate Clean Energy Transition	Diversify energy sources	Save energy
RES in **final energy consumption** from 40% set "Fit for 55" to **45%** in 2030	**Biomethane action plan**, with a new target of **35 bcm/year** by 2030 (almost doubling the one set out in "Fit for 55" of 18 bcm)	**Increase in long-term energy efficiency**, shifting from 9% to **13%** of the binding Energy Efficiency Target under the "Fit for 55" of European Green Deal legislation
Dedicated EU Solar Strategy to double solar photovoltaic capacity by 2025	**Hydrogen accelerator**, setting a target of **10 million tonnes** of domestic renewable hydrogen production and 10 million tonnes of imports by 2030	**Short-term behavioural changes** which could cut gas and oil demand by **5%**
Solar Rooftop Initiative, which mandates to install solar panels on new buildings	Creation of the **EU energy platform** to enable common purchase of gas, LNG and hydrogen	**Fiscal measures** to encourage energy savings
Tackle slow and complex permitting to accelerate major renewable projects		

Source → The European House – Ambrosetti and Enel Foundation elaboration on "REPowerEU" plan, 2022.

FIG 30 → **European Union gas imports reduction from Russia by the end of 2022** (billion m^3)



Source → The European House - Ambrosetti and Enel Foundation elaboration on "REPowerEU": Joint European Action for more affordable, secure and sustainable energy, 2022.

A 10-Point Plan to Reduce the European Union's Reliance on Russian Natural Gas

On 3 March 2022, International Energy Agency (IEA) published its own strategy to reduce European reliance on Russian gas in a 10-point strategy, which, if implemented by the end of the year, are expected to decrease Russian gas demand in Europe by one third with respect to the 155 bcm of gas imported in 2021, while reducing GHG emissions. The set of initiatives consists in:

1. Signing no new supply contracts with Russia (some long-term contracts are expiring by the end of 2022, which will reduce the contractual minimum take-or-pay levels for Russian imports).

2. Replacing Russian supplies with gas from alternative sources (increasing non-Russian pipeline imports, building LNG infrastructure and thus supply will bring about additional 30 bcm from non-Russian sources).

3. Introducing minimum gas storage obligations to enhance the market and to ensure optimal use of all available storage capacity in the EU.

4. Accelerating the deployment of new wind and solar projects (an additional 35 TWh of RES generation would bring gas use down by 6 bcm over 2022).

5. Maximising generation from existing dispatchable low-emission sources: bioenergy and nuclear (an additional 70 TWh of power generation from existing dispatchable low-emission sources, reducing gas use for electricity by 13 bcm).

6. Adopting short-term measures to shelter vulnerable electricity consumers (controlling the surge in energy bills due to the skyrocketing of natural gas prices would protect vulnerable groups).

7. Considering end use sectors: **Speeding up the replacement of gas boilers with heat pumps** (with an estimated reduction in gas use by 2 bcm in one year).

8. Accelerating energy efficiency improvements in buildings and industry (reducing gas consumption for heat by close to an additional 2 bcm in a year, lowering energy bills, enhancing comfort and boosting industrial competitiveness).

9. Encouraging a temporary thermostat adjustment by consumers (turning down the thermostat for building heating by just 1°C would reduce gas demand by some 10 bcm a year).

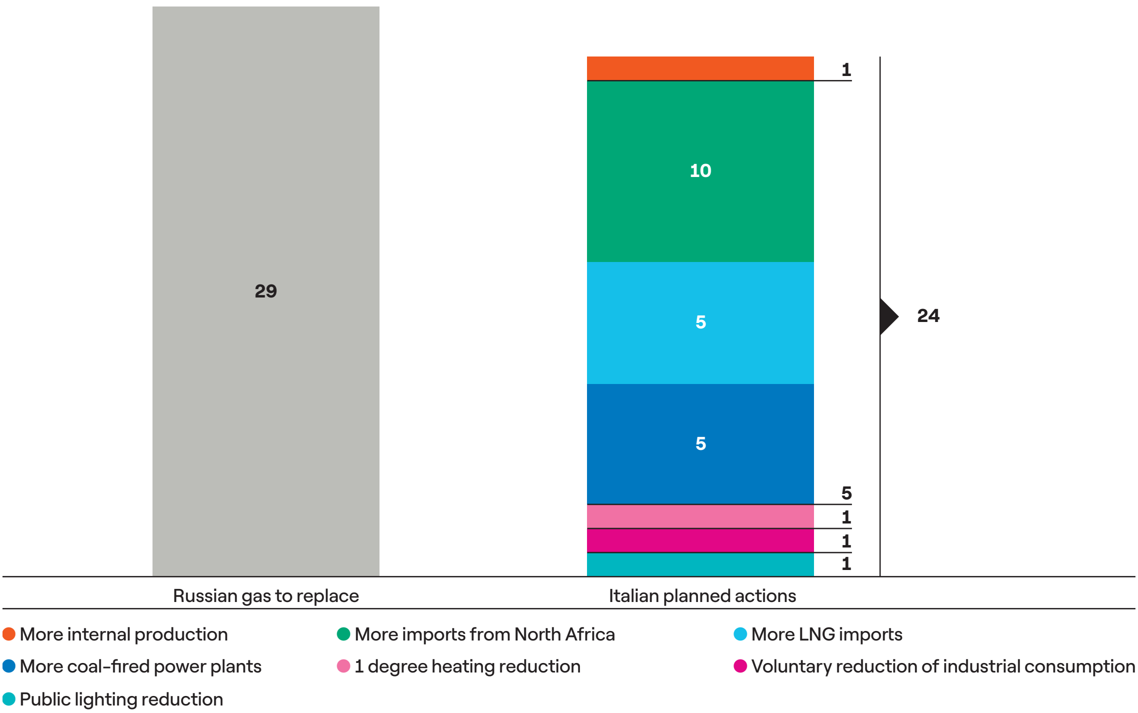
10. Finally, the cross-cutting initiative of **stepping up efforts to diversify and decarbonize power system sources** (a major near-term push on innovation can, over time, loosen the strong links between natural gas supply and Europe's electricity security. Real-time electricity price signals can unlock more flexible demand, in turn reducing expensive and gas-intensive peak supply needs).

Source → The European House – Ambrosetti and Enel Foundation elaboration on *"A 10-Point Plan to Reduce the European Union's Reliance on Russian Natural Gas"* by IEA, 2022.

1.3.1 ENERGY DEPENDENCE IN ITALY AND SPAIN: CHALLENGES, OPPORTUNITIES AND INITIATIVES FOR INCREASING THE ENERGY SECURITY

ITALY → To cope with the energy emergency, countries that depend heavily on Russian gas are debating on how to replace it with other sources, considering **solutions both in the short and long term**. Starting with short-term initiatives, on the eve of the war, Italian Prime Minister Mario Draghi announced the possibility of reopening 7 coal-fired power plants that would be able to cover 15% of national energy demand in the short term (although the Minister of Ecological Transition already rejected this scenario, stating that at most, the two functioning plants would be operated at full load). But this measure is only one piece of a broader framework of actions, which sees – among other things – a reduction in public lighting, a voluntary reduction in industrial consumption, a 1°C reduction for heating, greater LNG imports, greater imports from North Africa and greater domestic production, in order to diversify gas imports and commercial partners. The ultimate goal of this set of actions is to replace Russian gas as much as possible within 12 months. According to the data provided by the Italian Government, the country will be able to **replace already 24 billion m³** in a year (out of 29 billion m³, representing the total amount of Russian gas directed to Italy in 2021).

FIG 31 → **Detail of the Italian plan to replace Russian gas within 12 months** (billion m³)



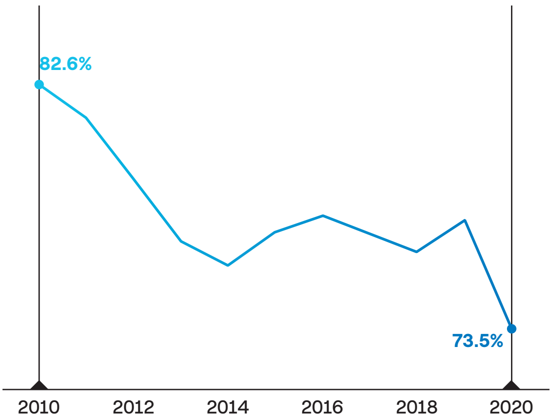
N.B. The greater imports from North Africa fluctuate between 5 and 10 billion m³. In this Figure the more optimistic scenario is assumed, meaning 10 billion m³.

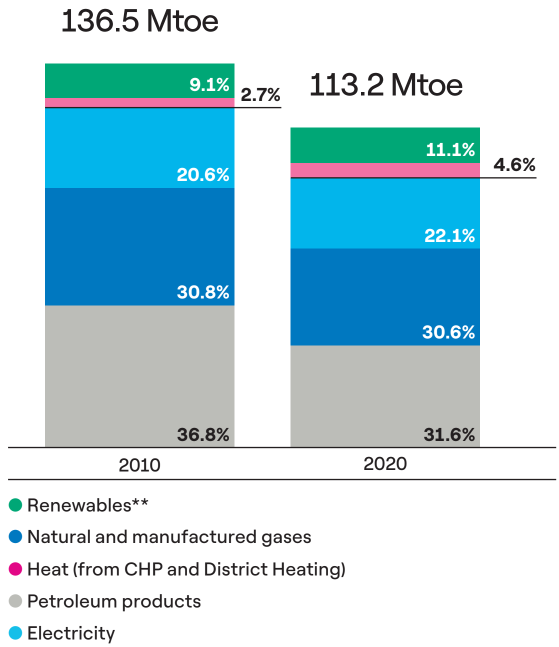
Source → The European House – Ambrosetti and Enel Foundation elaboration on Italian Government data, 2022.

The current Russia-Ukraine conflict has put the issue of energy dependency even more under the spotlight. It is indeed a crucial theme to face, which calls for a strong relationship with **decarbonization objectives**, **electrification** and **deployment of renewables**.

With regard to Italy, looking at the evolution over time, the country's energy dependency decreased by almost 10% over 10 years, **from 82.6% in 2010 to 73.5% in 2020**. During the same period, the energy mix in final energy consumption (which decreased by 23.3 Mtoe) changed, with an increase of both renewables (+2 percentage points) and electrification (+1.5 percentage points) while petroleum products fell by 5.2 percentage points. As explained earlier, the increase in RES penetration in final energy consumption and the energy production mix is correlated to the decrease in energy imports from abroad and, thus, the increase in energy security.

FIG 32 → **Energy dependence*** (chart on the left, % value) **and final energy consumption by fuel type in Italy** (chart on the right, % value and total)**, 2010-2020**



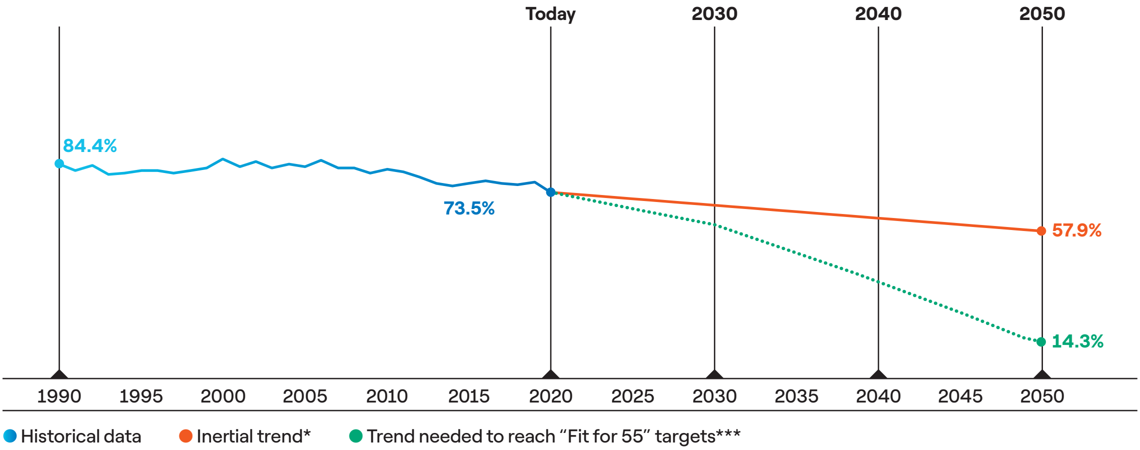


* The indicator is calculated as net imports on gross available energy.
** Renewables include biomass and waste, geothermal, solar heat and ambient heat.

Source → The European House - Ambrosetti and Enel Foundation elaboration on Eurostat data, 2022.

This dynamic occurred thanks to a **combination of energy efficiency gains and a switch in the energy mix to promote primary production from renewable sources**. However, in Italy it is necessary to push further towards energy independence. Indeed, projecting the trend of the last 15 years (2005-2019), in 2050 the country will be still relying on energy imports from third parties for almost 58%. On the contrary, looking at the more ambitious goal set by the "Fit for 55" target and projecting it to 2050, it is possible to see that **reaching the decarbonization targets will allow Italy to also obtain a greater reduction in energy dependence**, reaching **14.3% in 2050** (-43.6% percentage points vs. inertial trend).

FIG 33 → **Energy dependence in Italy, 1990-2050ᴱ** (% values)

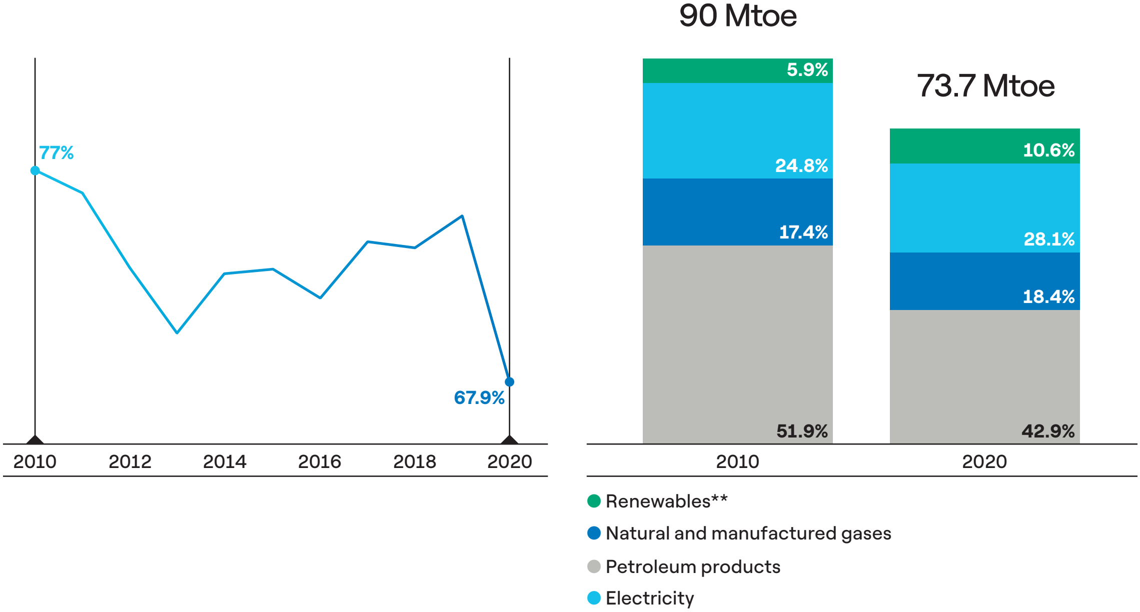


* The inertial trend was calculated by projecting the CAGR from 2005 to 2019.
** The policy target in 2030 was the one provided by the European Commission. The "Fit for 55" targets in 2040 and 2050 was estimated by projecting the same trend occurred between 2020 and 2030 and up to 2050.

Source → The European House – Ambrosetti and Enel Foundation elaboration on European Commission data, 2022.

SPAIN → Just like Italy, between 2010 and 2020 Spain reduced its energy dependence by almost 10 percentage points, **from 77% to 67.9%**. During the same period, final energy consumption decreased by 16.3 Mtoe while the share of renewables in the energy mix almost doubled (from 5.9% in 2010 to 10.6% in 2020) and electrification increased by 3.3 percentage points. The share of natural gas in the energy mix increased by almost 1 percentage points but the preponderance of petroleum products fell by 9 percentage points. Overall, the share of fossil fuels declined from 69.3% to 61.3% in 2020.

FIG 34 → **Energy dependence*** (chart on the left, % value) **and final energy consumption by fuel type in Spain** (chart on the right, % value and total)**, 2010-2020**

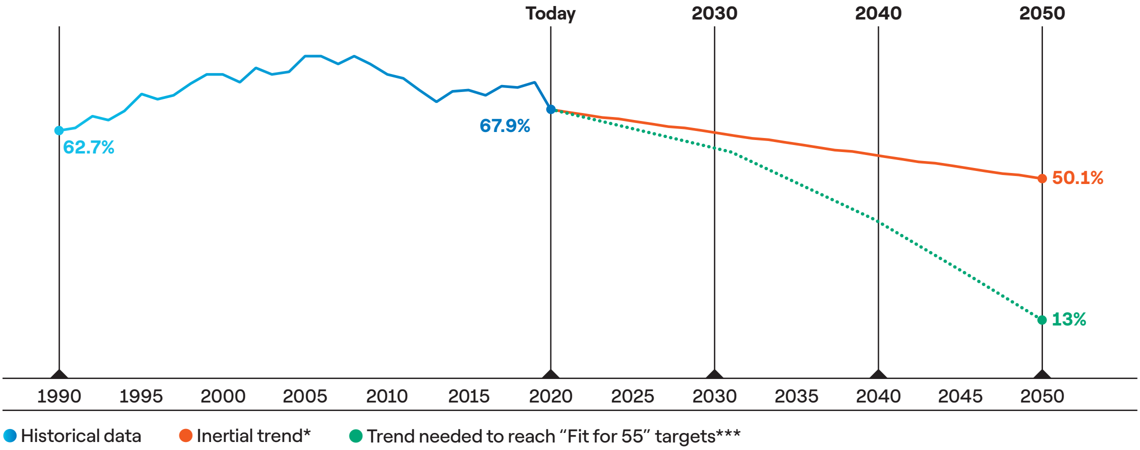


* The indicator is calculated as net imports on gross available energy.
** Renewables include biomass and waste, geothermal, solar heat and ambient heat.

Source → The European House - Ambrosetti and Enel Foundation elaboration on Eurostat data, 2022.

With regard to Spain, first of all, it is important to mention that – unlike Italy, **in the national Long-Term Strategy expressly sets a target related to energy dependence**, equal to **13%** by 2050. Not only: it also illustrates intermediate objectives in 2030 (61% coming from Spanish NECP) and 2040 (39%). By projecting the trend of the last 15 years, in 2050 Spain will still be importing **half of the total energy**. However, by examining the national objectives depicted in the national Long-Term Strategy together with the increased ambition set by the "Fit for 55" (2020-2030), it is clear that the country will be able to drastically reduce its energy dependence, reaching a value of 13% in 2050 (-37.1 percentage points vs. the inertial trend).

FIG 35 → **Energy dependence in Spain, 1990-2050[E]** (% values)



* The inertial trend was calculated by projecting the CAGR from 2005 to 2019.
** The policy target in 2030 was the one provided by the European Commission, while the 2040 and 2050 objectives are taken from the Spanish long-term strategy.
*** The "Fit for 55" targets in 2030 were estimated by projecting the same percentage increase estimated at European level.

Source → The European House - Ambrosetti and Enel Foundation elaboration on European Commission and long-term strategy data, 2022.

1.3.2 LONG-TERM SOLUTIONS TO ADDRESS ENERGY DEPENDENCE WHILE PURSUING DECARBONIZATION TARGETS

Overall, it is important to outline that many of the initiatives included in the European Commission's "RePowerEU" plan to address energy security in the most effective way by the end of 2022 just represent an expansion and diversification of EU's energy partners/suppliers, pushing on LNG imports from USA, Qatar, Egypt, West Africa, and increased pipeline imports from Azerbaijan, Algeria, Norway.

At the same time, "RePowerEU" mentions several times that the **acceleration on "Fit for 55" package targets would address both the energy crisis in the short term, and the pursuit of long-term decarbonization targets in 2050**. In particular, the document specifies that "Fit for 55" provided for the doubling of the EU's photovoltaic and wind capacities by 2025 and tripling by 2030, saving 170 billion m³ of annual gas consumption by 2030.

Not only: doubling the objective of "Fit for 55" for biomethane would lead to the production of 35 billion m³ per year by 2030 and an additional 15 million tonnes of renewable hydrogen (besides the 5.6 already considered in "Fit for 55") can replace 25/50 billion m³ per year of Russian gas imports by 2030.

To conclude, the implementation of both “Fit for 55” proposals, together with more renewable gases and energy efficicency measures to jointly deliver at least the equivalent of the 155 billion m^3 of the 2021 Russian gas imports. The **renewal of 2030 national strategies and plans**, which will include the increased ambitions of the Climate Law and “Fit for 55” package will represent the practical **action plan to achieve European energy independence from Russian gas and energy security**, while **keeping the pace with long-term decarbonization targets**.

Par

Energy solutions and technologies to achieve a “zero emissions“ economy by 2050 in Italy and Spain

t 2

Key Messages

1 → This Part aims at presenting an overview of the solutions and technologies that are and could be employed to **achieve a "zero emissions" economy by 2050**, with a focus on Italy and Spain. The sectors analyzed have been identified according to their contribution to total CO_2 emissions: electricity and heat generation (that account for **44%** of CO_2 emissions at global level), transport (25%), industry (20%) and buildings (9%).

2 → Renewables account for **41.1%** and **44.1%** of the total electricity generated in Italy and Spain. However, especially in Italy, natural gas and coal still have a significant role in the mix, determining the emissions of the sector. In Spain, natural gas share in final energy consumption is significant, as well as in electricity generation.

3 → Most of the transport sector's emissions are caused by road transport (94.8% in Italy and 88.4% in Spain), followed by air transport, with a lower share. The main alternatives to Internal Combustion Engines (ICEs) for the decarbonization of road transport are Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs), and Fuel Cell Electric Vehicles (FCEVs).

4 → Industry decarbonization must address the "**hard to abate**" sectors (manufacturing of rubber and plastic products, coke and refined petroleum products, cement, basic metals and fabricated metal products, and chemicals and chemical products), contributing to 78% of the CO_2 emissions of the manufacturing sector in Italy and 82% in Spain. Key pathways for decarbonization include the fuel switch from fossil fuels, the electrification of processes and heat generation, as well as sector-specific solutions (e.g., Green Hydrogen-based Direct Reduced Iron).

5 → Electricity accounts for **48%** of the final energy demand in **non-residential buildings** in the EU27+UK, while the same value for the **residential sector** is currently lower than **25%**. From a technological perspective, the most common solutions for space and water heating in residential buildings are gas and oil boilers, while **electric heat pumps** represent the main sustainable and efficient alternative.

6 → There is a **fairly wide range of decarbonization technologies that are well established**: hydropower, onshore wind, solar PV, geothermal, solar thermal and nuclear are, in fact, "mature" technologies, meaning that they have reached a sizeable deployment and only incremental innovations are expected. On the other hand, technologies such as power-to-gas appear to be in the "early adoption" stage, meaning that some designs have reached the markets, but **some level of support is required to scale them up**.

Finally, solutions such as coal with CCUS, biomass with CCUS, ocean and tidal energy are technologies in the "demonstration" phase.

7 → The "lifecycle assessment" of GHGs produced by renewable energy sources are the lowest of all energy technologies available today. In particular, **wind and hydro are the best technologies available on the market from an environmental point of view**, charachterized by the lowest GHG emission intensity during the lifecycle of electricity production (around 26 tonnes of CO_2-eq. for every GWh of energy generated vs. around 500 tonnes of CO_2 for every GWh of energy generated by natural gas plants)[1].

8 → **An energy system powered by clean energy technologies has evident benefits for the economy and the environment**, as well as the benefits in terms of improving air quality and circular economy performance. In addition, electrification and electricity generation with renewables allows to reduce the weight of fossil fuels in the energy mix thus increasing energy independence. However, renewable technologies need more specific materials than fossil fuels counterparts for construction, such as **minerals and rare earths**. Hence, the transition to a clean energy system leads to **new energy trade patterns, countries and geopolitical considerations**.

1
In the literature there are multiple sources related to GHG emissions intensity during the lifecycle of electricity production. Hence, the values reported in this Study might differ from the ones shown in other reports.

9 → After having analyzed the pros and cons of the technologies, **two scenarios have been identified for both Italy and Spain as a starting point to assess the impact of the penetration of the various technologies on the economy and the job market in the 2021-2050 period**. For Italy, the **"Low Ambition" scenario** is based on updated NECP data, whilst the **"Net Zero" scenario** includes the higher ambition set by "Fit for 55" for 2030 and the economic and environmental impacts of COVID-19. For Spain, the scenarios correspond to those of the Long-Term Strategy, given their already high ambitions.

10 → Considering the power sector in Italy, RES installed capacity in the "Net Zero" scenario will be higher than in the "Low Ambition" scenario (**+31 GW and +87 GW of RES capacity installed than in the "Low Ambition" scenario, in 2030 and 2050 respectively**) and will entail a higher installed capacity of flexible sources (meaning batteries and power-to-gas, +19 GW in 2050 than in the "Low Ambition" scenario). In Spain, the "Net Zero" scenario envisions an **additional 10 GW** of installed RES capacity in the 2020-2050 period if compared to the "Low Ambition" scenario, and additional 13 GW of installed capacity of flexible sources for the same period.

11 → The electric solutions for **road transport** are already present in the mass-market with performances close to or better than those of ICEs (e.g., in terms of costs and range), but further improvements can still

be expected in the next few years. Full-electric buses are already competitive with diesel buses both in Italy and Spain (in terms of Total Costs of Ownership) thanks to the reduction of initial costs of buses and batteries made possible by economies of scale, while for Light Commercial Vehicles some market barriers still need to be overcome. For heavy-duty and long-distance transport, key issues for electric solutions in the short-to-medium term are constituted by range and charging times. With regard to **environmental impact**, the increased penetration of RES in the energy mix will enable further improvements: for example the life cycle emissions advantage of **BEVs** with respect to gasoline vehicles is expected to increase from 66%/69% to around 74%/77%, and up to 81% with BEVs entirely powered by RES. For the sector's decarbonization in Italy and Spain, the two key drivers will be constituted by the shared mobility paradigm (that will lead to a lower number of cars circulating) and by the deployment of electric vehicles, first of all BEVs, which in the "Net Zero" scenario will account for **90%** of the passenger car fleet, both in Italy and Spain, but also **FCEVs** (8%). In the "Low Ambition" scenario, on the contrary, BEVs will account for 85% of the fleet and FCEV for 2%, and ICEs will still be present with a share of 9%.

12 → Within **industry**, and in particular with regard to process emissions, some technological solutions are already mature and present in the market, though not in all sectors (i.e., cement) and temperature levels

(i.e., higher temperatures). For example, **low-temperature heat pumps are already cost-competitive with gas appliances and by 2030 also low-to-medium temperature heat pumps will be so**. On the contrary, for **medium-to-high and ultra-high** temperatures, other paths will have to be pursued, including **indirect electrification** (fuel-switching). Considering the decarbonization of the industry sector, in Italy is foreseen a significant reduction in energy demand in both "Low Ambition" and "Net Zero" scenarios. This improvement is mainly related to the substitution of gas, oil, and coal technologies with electrified ones (plus hydrogen). In particular, **72% of industrial energy demand will come from electricity** in 2050 in the "Net Zero" scenario. In Spain, the result is quite similar when compared to Italy: Spanish industry will see a **25%** reduction in energy demand in the "Net Zero" scenario by 2050, with a final value of **14.9 Mtoe** (vs. 18.1 in the "Low Ambition" scenario). Overall, such result is linked to the strong penetration of electrification technologies.

13 → Most of the solutions for the **decarbonization** of buildings are mature and already present in the market: the key to their large-scale deployment is strictly dependent on **financial convenience** (namely investment costs and energy prices for electricity), but also on the **overall interventions** on heating systems of existing buildings. Given the current energy demand of the building sector, another key action to carry out is the **renovation of buildings**: thermal insulation re-

duces energy demand and building refurbishment allows for more radical modification and adaptation of Heating, Ventilation and Air Conditioning (HVAC) (heating, ventilating and air conditioning) systems, favoring the installation of heat-pumps. With regard to heating technologies, **electric heat pumps** offer lower levelized cost of heat among the different heating options. Moreover, electric technologies are the **most environmentally sound**: thanks to their efficiency, they can drastically reduce energy demand, as well as CO_2, NO_x and PM_{10} emissions. When fed with renewable electricity the emissions are reduced to zero. On the contrary, biomass boilers are the highest particulate emitters, while gas boilers produce the highest CO_2-eq. emissions over the entire lifetime. The deployment of **heat pumps** will be the key driver for the decarbonization of the sector: at least 50 million of them should be installed in Italy by 2050 and 16.4 million in Spain, enabling overall reductions in the final energy demand. On the contrary, in "Low Ambition" scenarios gas boilers will still be relevant, with a share on the final energy demand of **27%** in Italy and **24%** in Spain, thus hindering the sector's decarbonization.

14 → According to literature, there are some technologies that have a **cross-cutting** impact on multiple markets and sectors. In particular, **4 cross-sectoral solutions** which might help to achieve the "Net Zero" target by 2030, 2040 and 2050 have been identified: Power-to-X, smart grids, energy storage and demand response.

15 → **Electricity** emerges as the essential energy vector to achieve “Net Zero“ targets in 2050. In addition to this, the inclusion of **green hydrogen** as a new innovative energy vector, together with bio-energies, will lead to an increase in the share of renewable energy carriers in 2050. Hence, direct electrification will be complemented by **indirect electrification**, thanks to green hydrogen and Power-to-X technologies, in order to decarbonize hard-to-abate sectors.

2.1

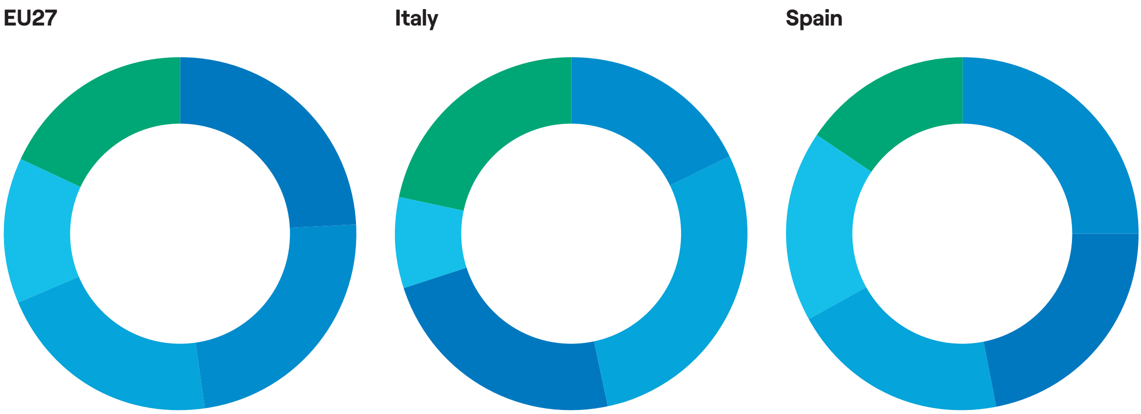
An overview on the current state of the sectors contributing to reach the “Net Zero“ target by 2030, 2040 and 2050

This Part aims at presenting an overview of the **solutions and technologies** that can be employed — and could in the near future — to achieve a **“zero emissions“** economy by 2050, with a focus on Italy and Spain. The technologies will then be compared on the basis of different indicators and dimensions to assess their potential role in the decarbonization path towards 2050.

The analyses are structured on a **sectoral basis**, in particular: **electricity generation**, **transport**, **industry**, and **buildings**. In addition, solutions with **cross-sectoral application** have also been considered (Power-to-X, smart grid, energy storage, demand response). This structure follows a typical division made in the literature, as these are the most emission-intensive sectors.

Focusing the attention at European level, in line with the data registered worldwide, **energy production**, **transport, and buildings** sectors contributed to the vast majority of GHG emissions (**82%**). As for Italy and Spain, this value is equal to **78%** and **85%**, respectively.

FIG 1 → **GHG emissions by sector in EU27, Italy and Spain*, 2019** (% values)



EU27

Energy supply 24.3%
Transport 23.5%
Industry 21%
Buildings 13.2%
Other** 18%

Italy

Energy supply 17.8%
Transport 29.1%
Industry 23.3%
Buildings 8.2%
Other** 21.6%

Spain

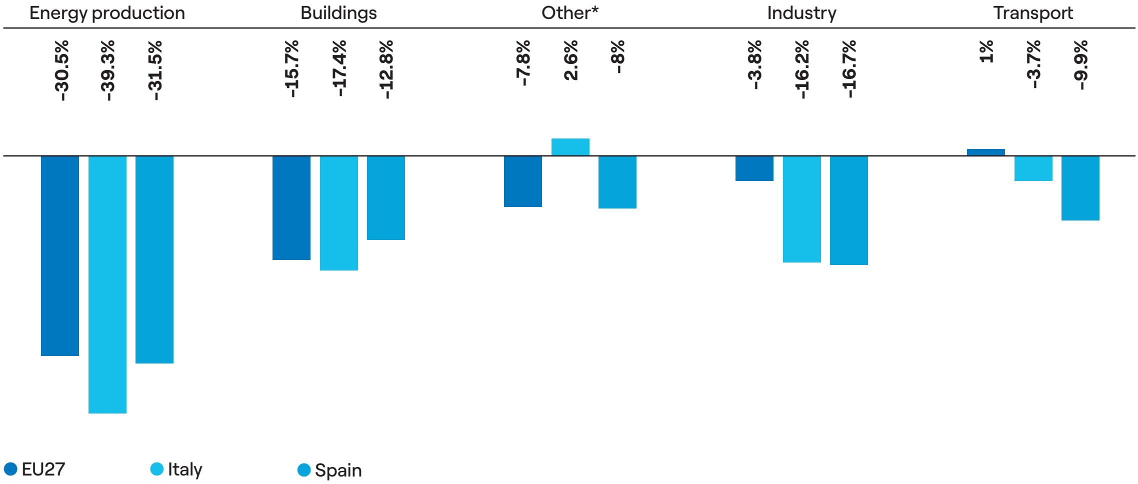
Energy supply 21.9%
Transport 25.2%
Industry 20%
Buildings 17.5%
Other** 15.4%

* Excluding land use, land use change, and forestry (LULUCF).
** Agriculture, waste management, indirect CO_2.

Source → The European House - Ambrosetti and Enel Foundation elaboration on Eurostat data, 2022.

Taking in consideration the 2009-2019 decade, **transport is the only sector that increased its emissions in Europe**, recording a +1%. On the contrary, all the other sectors reported a decrease, which ranges from -30.5% in the energy production sector to -3.8% in the industry sector. A similar trend occurred both in Italy and Spain, where the energy sector had the most significant decline (-39.3% in Italy and -31.5% in Spain).

FIG 2 → **Variation of GHG emissions by sector in EU27, Italy and Spain, 2009-2019** (% values)

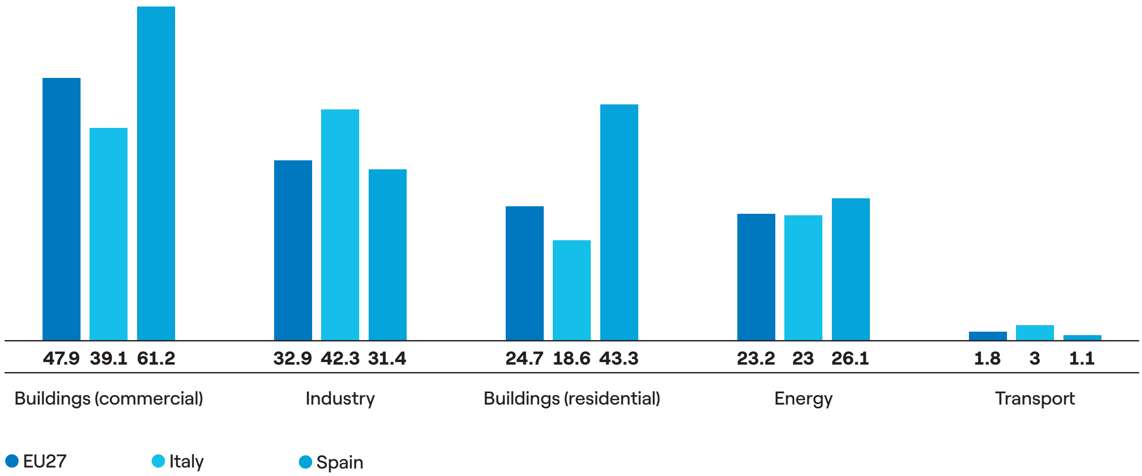


* Agriculture, waste management, indirect CO_2.

Source → The European House - Ambrosetti and Enel Foundation elaboration on Eurostat data, 2022.

Transport is also the sector with the lowest share of electrification in final energy consumption in Europe (1.8%), Italy (3%) and Spain (1.1%). On the other hand, commercial buildings are the most electrified sector both in Europe (47.9%) and in Spain (61.2%), while for residential buildings Italy has the lowest electrification rate (18.6%). Regarding Italy, the highest share of electrification is reported in the industry sector, with a value of 42.3% (vs. 32.9% in Europe and 31.4% in Spain).

FIG 3 → **Share of electricity in final energy consumption by sector in EU27, Italy and Spain, 2020** (% values)



Source → The European House - Ambrosetti and Enel Foundation elaboration on Eurostat data, 2022.

Besides the aforementioned sectors, agriculture accounts for approximately 10% of the European Union's total GHG emissions in 2019 and around 3.3% of total final energy consumption. In Italy, it accounts for the 9.4% of total emissions, and between 1990 and 2020 it recorded an 11.4% decrease, while in Spain, in 2019, the sector accounted for 12.5% of total emissions. The penetration of green technologies, such as solar photovoltaic, has a great potential in the sector and is pivotal for to achieve the carbon neutrality target, as well as the development of technologies related to the Land Use, Land-Use Change and Forestry (LULUCF) sectors, and the exploitation of natural carbon sinks to reduce GHG emissions. At the EU level, the LULUCF sector acts as a CO_2 sink (mainly forests), offsetting about 7% of GHG emissions from the other sectors, and its potential increasing significance has led European institutions to define specific "accounting rules" to assess the impact of land-related mitigation actions.

2.2

Existing decarbonization pathways for Italy and Spain

As a first step, an **in-depth analysis of the current measures** adopted at the national level, for both Italy and Spain, was carried out. To do so, the main objectives of the national plans were analyzed.

In particular, for both Italy and Spain, the **two scenarios** reported in the national strategies were considered as a starting point:

- **Reference scenario**, which is aligned with the NECP (the Italian PNIEC) target for up to 2030 and then extends such targets up to 2050. The Reference scenario, in particular, focuses on the objectives set by the NECP, projecting the consequent virtuous energy-environmental trends until 2050. It adopts exogenous dynamics of GDP and population in line with the most recent available sets present in national databases and integrates the effects of climate change (including the potential temperature increasing and its consequences, such as on crop yields and fire frequency).
- **Decarbonization scenario**, which is based upon the NECP target for up to 2030 and then, based on national long-term strategies, aims at achieving **"Net Zero" emissions by 2050**. In particular, the Decarbonization scenario reported in the national strategies is built starting from the emission gap that is still present in 2050 in the Reference scenario: the exercises to identify combinations, synergies and criticalities of the potential levers that can be activated to achieve climate neutrality by 2050 are based on the addressing of this gap. The identified levers can be traced back to three main types: i) a dramatic reduction in energy demand, connected in particular to a drop in consumption for private mobility and consumption in the residential buildings (thanks to the efficiency enabled by electrification); ii) a radical change in the energy mix in favor of renewables, combined with a deep electrification of end-uses and the production of green hydrogen, to be used as it is or transformed into other fuels, including for the decarbonization of non-electrical uses; iii) an increased absorption guaranteed by forest areas obtained through sustainable management, restoration of degraded surfaces and interventions of reforestation.

It is worth mentioning that both the Reference and Decarbonization scenarios do not take into account the impact, which is still difficult to quantify, of the **health emergency linked to COVID-19**. In addition to the short and medium negative production shock period, the effects of the health crisis on the decarbonization process will vary according to a multiplicity of factors, such as the possible acceleration of economic recovery measures (both at European and national level) or a structural change in habits and methods of citizens' work (for instance, a greater use of remote working).

On top of what is mentioned above, it is also important to highlight that such scenarios **do not consider the increased ambition of the "REPowerEU" plan published in May 2022 in response to the disruption of the global energy market caused by Russia's invasion of Ukraine**, whose impacts on the global economy and energy prices, in turn, are not considered.

Such limitations – meaning the absence of the economic and environmental impacts of COVID-19 and the higher ambition set by "Fit for 55" and "REPowerEU" – have been the rationale at the basis of the analysis of levers and solutions for achieving the goal of a zero-emission economy by 2050, in light of recent developments. This assessment has been instrumental to the implementation of new and more ambitious scenarios, to be included in the impact analysis model[2]. In fact, both the Italian and Spanish scenarios, provided in the respective national plans, though designed to reach a net zero economy by 2050, do not consider the increased ambition of the "Fit for 55" targets by 2030.

Thus, in the following pages an analysis of the **state of the art and development opportunities** for the technologies for decarbonization in each sector has been elaborated. The final goal of the analysis is to define a more ambitious scenario which includes the new targets set by the European Union, also identifying the pros and cons of each technology deployment in the different economic sectors, the investment needed to decarbonize the power, building, transport and industrial sectors and the different degrees of technological penetration considering the scenarios included in the analysis.

2
The impact analysis model will be analyzed in detail in Part 3 of this Report.

2.3

Analysis of the sectoral technologies and definition of the Study's scenarios

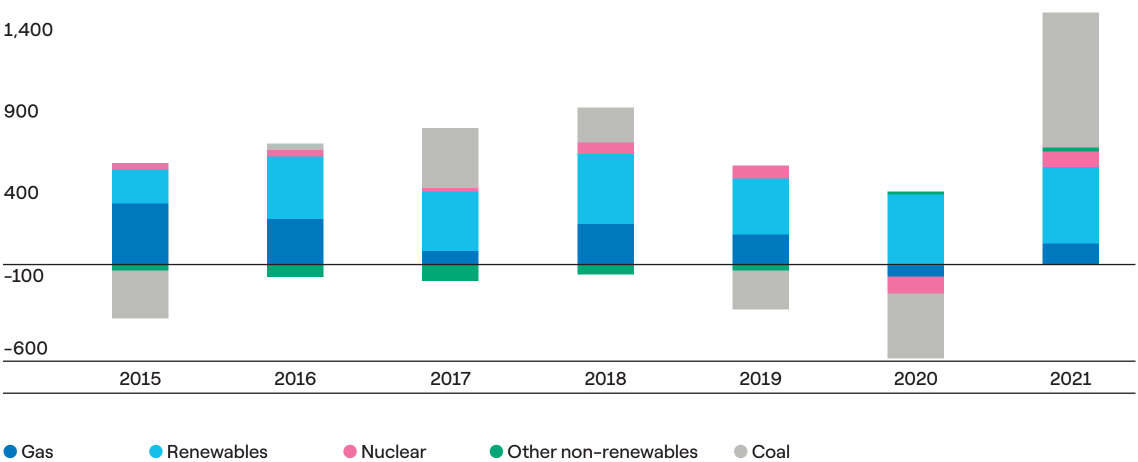
→ **POWER**

Power: state of the art

According to IEA data, the electricity and heat generation sector accounts for **almost half of CO_2 emissions at global level** (**44%**). After declining in 2019 and 2020, global electricity sector emissions grew by around **7%** in 2021, reaching a record level.

This significant growth was triggered by the global electricity demand, which in 2021 grew by nearly **6%**, after having recorded a decline in 2020 due to the spread of the pandemic, with the largest rise since the recovery from the financial crisis in 2007-2008. As a consequence, the global electricity generation grew significantly between 2020 and 2021, mainly met by an increase in electricity generation from **coal**.

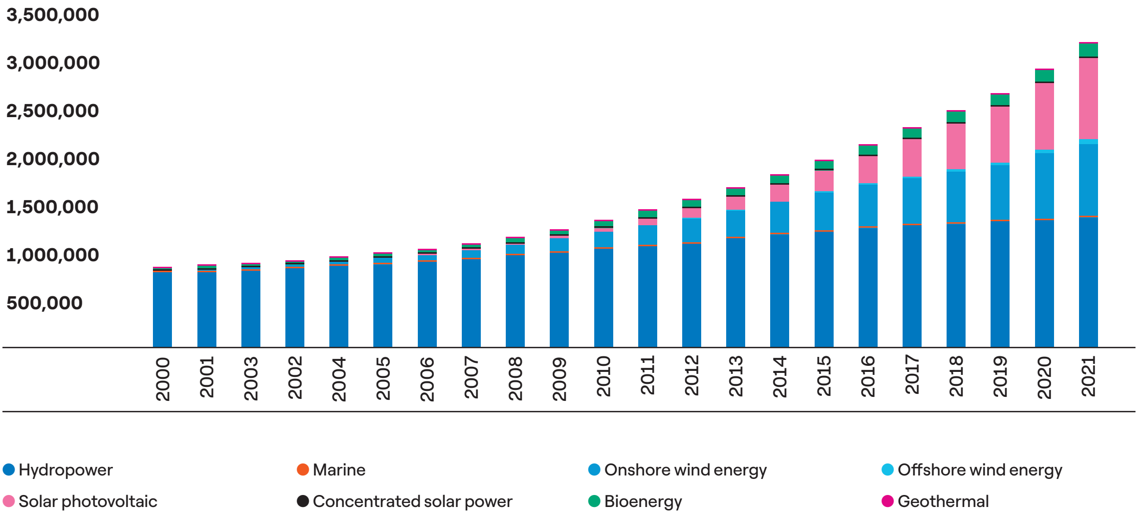
FIG 4 → **Global changes in electricity generation year by year, 2015-2021** (TWh)



Source → The European House - Ambrosetti and Enel Foundation elaboration on IEA data, 2022.

Looking at capacity, according to IRENA, the amount of renewable electricity capacity added in 2021 grew by 9% to reach about 3 TW. Within this context, **China recorded the highest increase**, accounting for **46%** of worldwide renewable capacity additions. Outside China, the **European Union was the second largest market in terms of increased capacity**, surpassing the previous record set in 2011. In particular, solar PV alone accounted for the majority of the European Union's installed capacity additions last year, due to project acceleration in Spain, France, Poland and Germany. Overall, at the global level, **solar and wind** continued to dominate new generating capacity: together, both technologies contributed to **88%** of the share of all new renewable capacity in 2021. More in detail, solar capacity led with a **19%** increase, followed by wind energy, which increased its generating capacity by 13%.

FIG 5 → **Trends in renewable energy at a global level, 2000-2021** (installed capacity, MW)



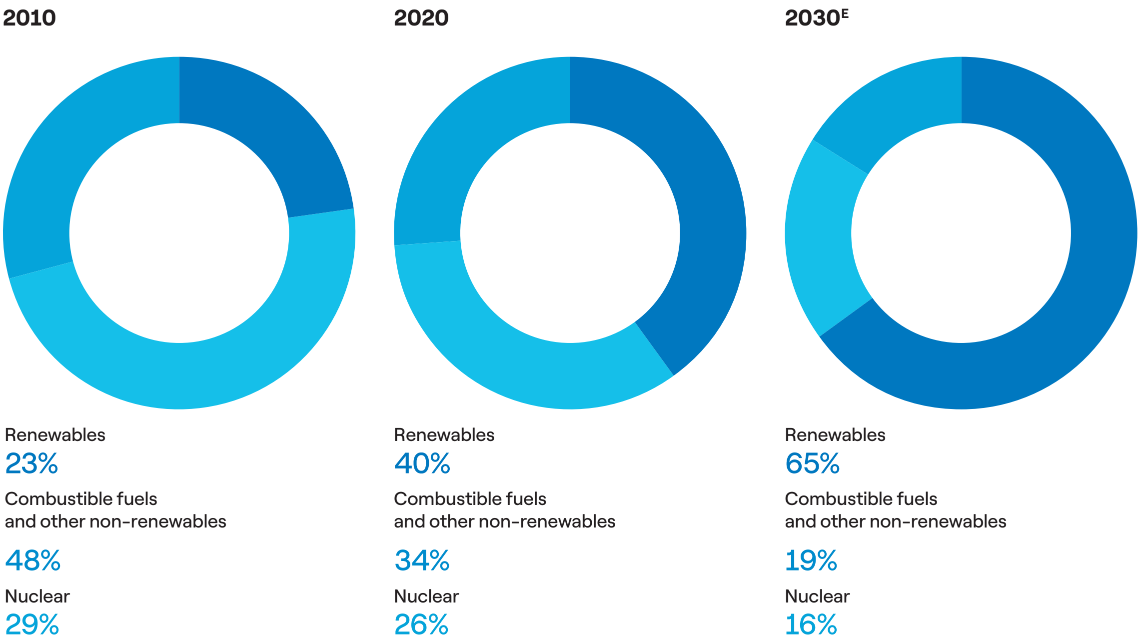
Source → The European House - Ambrosetti and Enel Foundation elaboration on IRENA data, 2022.

In Europe, the relative **weight of renewable energy sources** on gross electricity generation grew **from 22.8% in 2010 to 39.9% in 2020**. In particular, among the renewable energy sources, the share of gross electricity generated from **solar and wind** out of the total electricity increased considerably: from 0.8% in 2010 to 5.4% in 2020 for solar power (+4.6 percentage points) and from 4.7% in 2010 to 14.8% in 2020 for wind power (+10.1 percentage points). Looking forward, according to the results of the E3Modelling of the European Union[3], between 2020 and 2030, the contribution of RES to gross electricity generation in Europe is expected to grow from 39.9% in 2020 to 65% in 2030 (+25.1 percentage points).

3
Source: *""Fit for 55" MIX scenario. Summary report: Energy, transport and GHG emissions"*, European Union, July 2021.

In parallel, there was a **significant decrease in the relevance of fossil fuels**, which decreased from 48.3% in 2010 to 34.4% in 2020[4]. Another reduction was registered, though on a smaller scale, in the share of electricity generated from nuclear power plants, which showed a decrease of more than 3 percentage points in the same period (from 28.9% in 2010 to 25.7% in 2020). Looking ahead, by 2030 the significance of fossil fuels and nuclear will decrease further, reaching 18.6% and 16.3% of gross electricity generation, respectively[5]. **The combined share of these two sources** (35%) **will be less than that ensured by RES** (65%).

FIG 6 → **Gross electricity generation by type of source in the European Union 2010, 2020 and 2030** (% values)



N.B. 2030 data are computed based on the increased ambition set by the "Fit for 55" scenario.

Source → The European House - Ambrosetti and Enel Foundation elaboration on EU E3Modelling data, 2022.

4 *Ibidem*.

5 In this case, the scenario taken into account at European level for 2030 is given by PRIMES and is aligned with the objectives of the "Fit for 55".

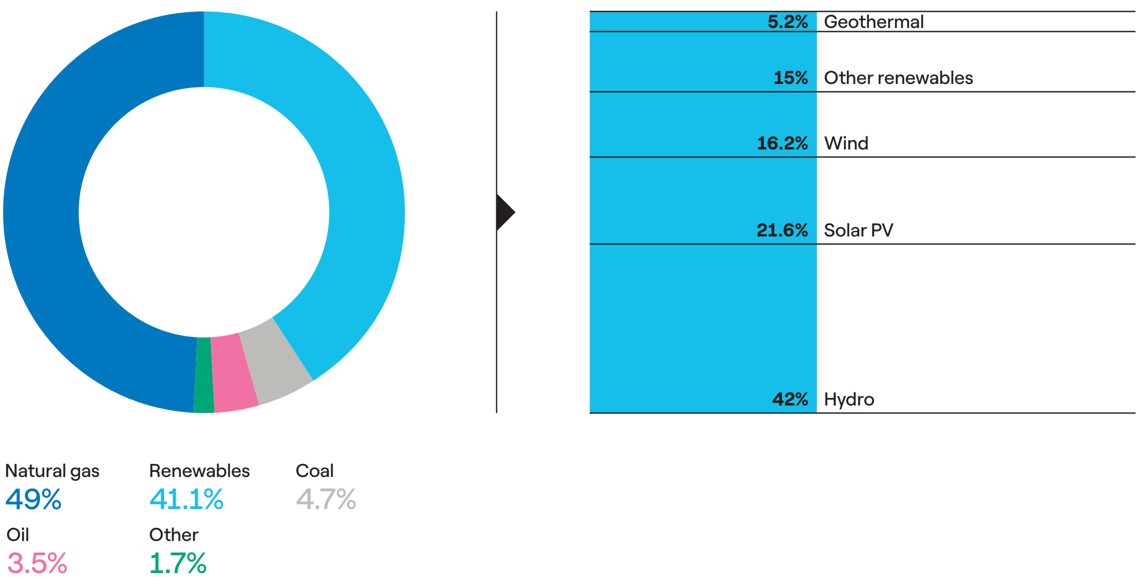
The "paradigm shift" in the EU's green electricity transition

From 2019 to 2021 **more than half** (52%) of the new renewable generation **replaced gas power** (as a result of soaring prices in second half of 2021), and **one third replaced nuclear**, while only **one sixth replaced coal**. In particular, the largest drops in fossil gas compared to 2019 were in the Netherlands (-17 TWh, -24%) and Spain (-15 TWh, -18%), the two countries with the strongest growth in renewable generation (primarily wind and solar). However, prior to this, from 2011 to 2019, **more than 80% of new renewables replaced coal**.

Source → The European House - Ambrosetti and Enel Foundation elaboration on European Electricity Review, 2022.

Focusing on Italy and Spain, it is possible to note how considerable – yet not sufficient - progress has been made in recent years with reference to renewable energy sources. Looking at the composition of the Italian electricity generation in 2020, it is possible to see a **relevant contribution determined by RES**, accounting for **41.1%** of the total electricity generated, after natural gas only, which accounts for **almost 50%**. In this context, **hydropower** is the most relevant renewable technology, accounting for 42% of the electricity generated from RES. A considerable share of the total electricity generated from RES also comes from solar PV and wind, which together account for nearly 40%.

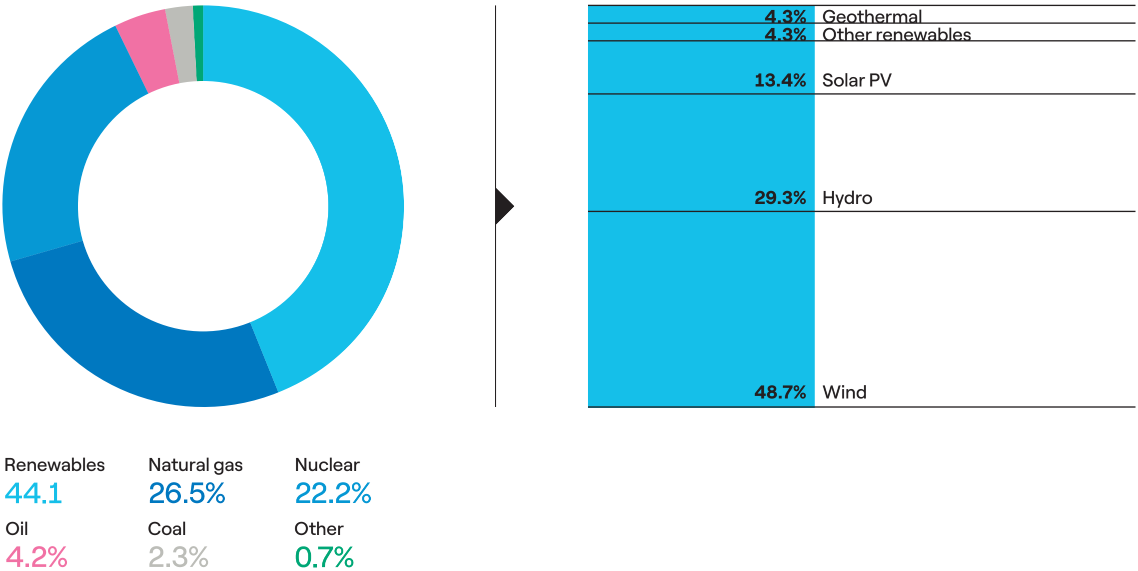
FIG 7 → **Electricity generation by source in Italy** (% value) **and focus on renewables** (% value)**, 2020**



Source → The European House - Ambrosetti and Enel Foundation elaboration on IEA data, 2022.

Looking at the composition of the Spanish electricity generation in 2020, **RES are the most relevant source**, accounting for **44.1%** of the total (17.6 percentage points more than the second source for contribution, that is natural gas with 26.5%). In particular, **wind technology** is the most developed solution, contributing to **almost 50%** of the electricity generated by RES in 2020, followed by hydropower and solar PV technologies, which together amount to 42.7%.

FIG 8 → **Electricity generation by source in Spain** (% value) **and focus on renewables** (% value)**, 2020**

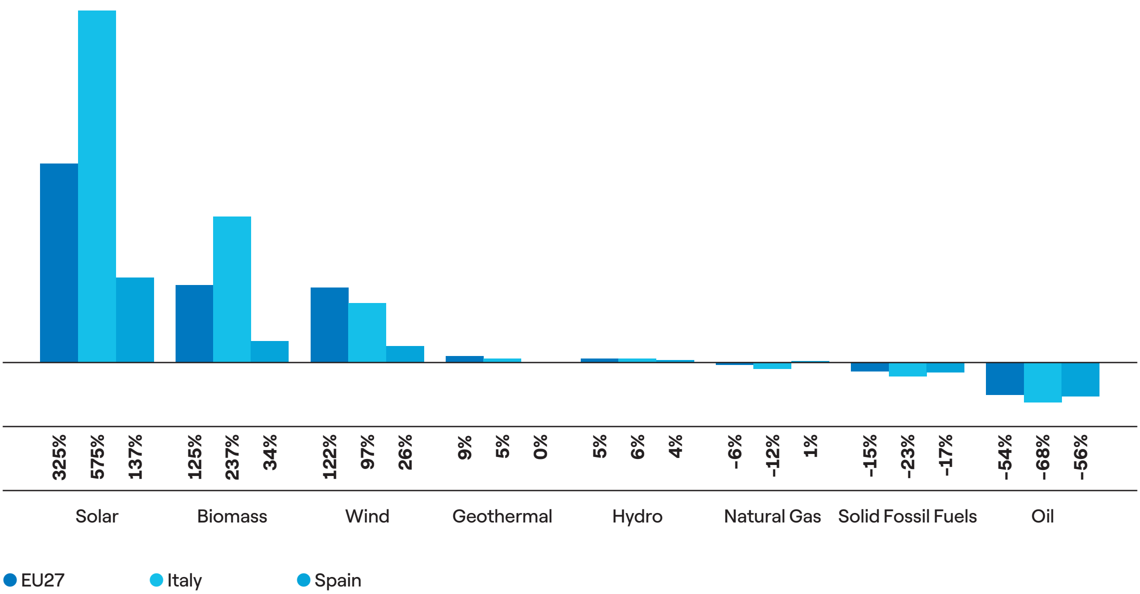


Source → The European House – Ambrosetti and Enel Foundation elaboration on IEA data, 2022.

Looking at the capacity added between 2010 and 2020, the push towards renewable energy sources in the power sector is even more evident. In particular, with regard to Italy, between 2010 and 2020 the net installed power capacity of RES plants increased **from almost 30 GW in 2010 to nearly 61 GW in 2020** (recording an average annual growth rate of +7.4%)[6], with wind power and solar recording an increase of 97% (from 5.8 GW in 2010 to 11.4 GW in 2020) and 575% (from 3.1 GW in 2010 to 21 GW in 2020), respectively. In Spain, the net installed power capacity of RES grew **from almost 43 GW in 2010 to nearly 56 GW in 2020** (recording an average annual growth rate of 2.7%), with wind power and solar recording an increase of 26% (from 20.7 GW in 2010 to 26 GW in 2020) and 137% (from 4.6 GW in 2010 to 11 GW in 2020), respectively.

6
Source: European Union, *""Fit for 55" MIX scenario. Summary report: Energy, transport and GHG emissions"*, July 2021.

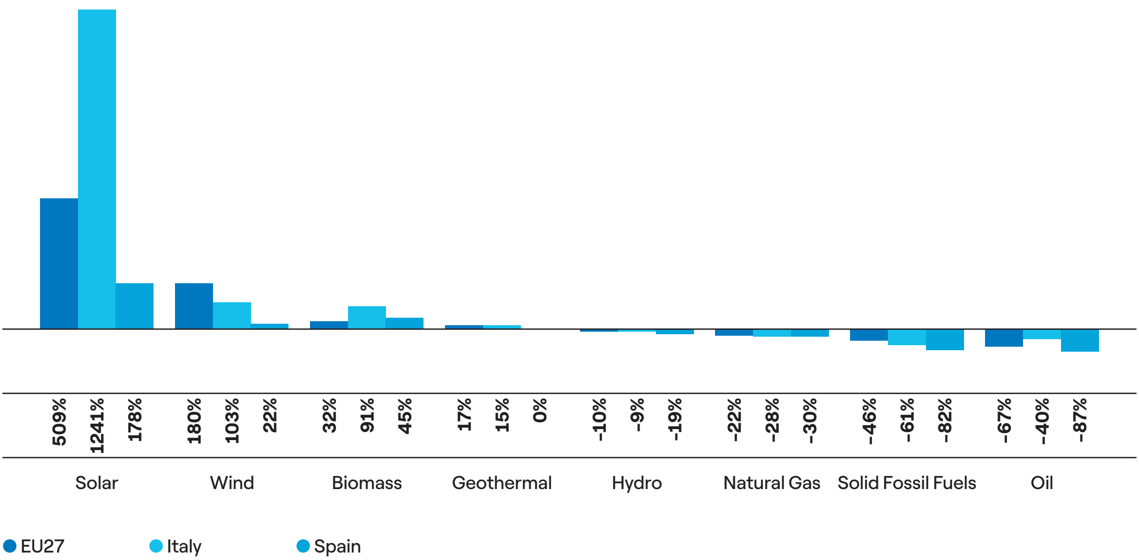
FIG 9 → **Evolution of installed power capacity per plant type in EU27, Italy and Spain, 2010 and 2020** (% value)



Source → The European House - Ambrosetti and Enel Foundation elaboration on E3Modelling data, 2022.

Looking at electricity generation, the **strong acceleration in renewables** emerges even stronger. Suffice it to say that, between 2010 and 2020, Italy increased the generation of electricity from **solar** by **1,241%** (from 1,906 GWh in 2010 to 25,568 in 2020). Significant increases were recorded also for wind (+103%, from 9,126 GWh in 2010 to 18,561 in 2020) and biomass (+91%, from 11,586 GWh in 2010 to 22,179 in 2020). At the same time, **fossil fuels technologies** decreased their relevance in terms of electricity generation, declining overall by **35%** between 2010 and 2020 (-61% solid fossil fuels, -40% oil, -28% natural gas). As for Spain, though to a minor extent, renewables recorded relevant increases: +178% of solar (from 7,186 GWh in 2010 to 19,992 in 2020) and +22% of wind (from 44,271 GWh in 2010 to 53,964 GWh in 2020). Lastly, as for Italy, electricity generation from fossil fuels dropped by **47%** between 2010 and 2020 (-82% solid fossil fuels, -87% oil, -30% natural gas).

FIG 10 → **Evolution of power generation per plant type in EU27, Italy and Spain 2010 and 2020** (% value)



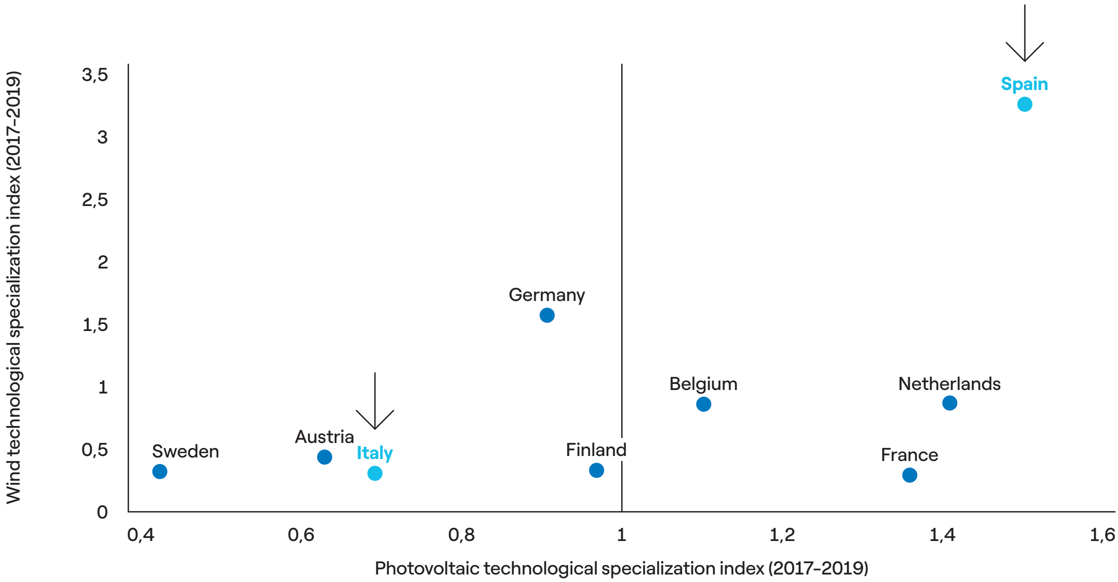
Source → The European House - Ambrosetti and Enel Foundation elaboration on E3Modelling data, 2022.

As can be seen from the figures above, renewable energy sources already play a key role in the electricity generation structure of both Italy and Spain. However, Italy and Spain, and more generally the European Union, lack a structured industrial cluster that can compete with global counterparts in green technology manufacturing. Moreover, according to a recent report published by ENEA[7], Italy is lagging behind other European countries in terms of **patenting green technologies** and, hence, it is more difficult for the country to put in action supply chains by leveraging innovation. In fact, analyzing the **ratio between the global share of patents that a country has in a specific technology and the share of patents it has in all technologies**[8], Italy is not well positioned compared to its major peers, such as Spain, which is specialized in several aspects of green technologies. In other words, Italy risks being dependent on other countries, for instance in terms of photovoltaic and wind technologies.

7
Source: ENEA, *"Analisi trimestrale del sistema energetico italiano"*, III trimestre 2021.

8
The indicator assumes values above 1 when a country is specialized in a certain technology.

FIG 11 → **Wind specialization index** (vertical axis) **and photovoltaic specialization index** (horizontal axis) **in selected European countries, average 2017-2019**



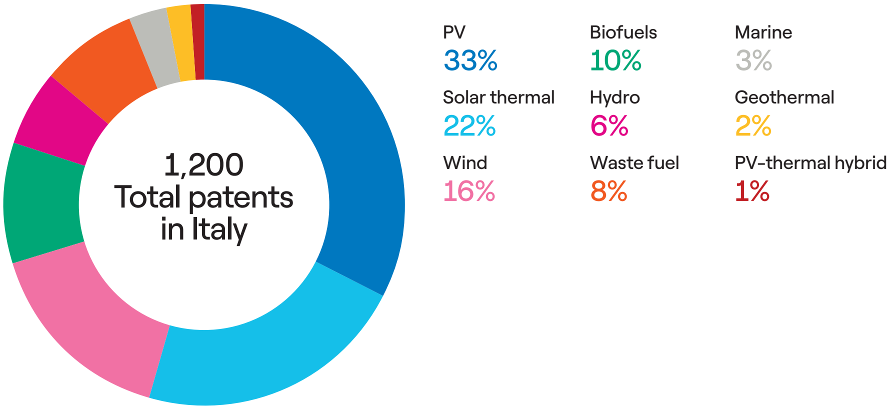
N.B. The specialization index is calculated as the ratio between the global share of patents that a country has in a specific technology and the share of patents it has in all technologies. The indicator assumes values above 1 when a country is specialized in a certain technology.

Source → The European House – Ambrosetti and Enel Foundation elaboration on ENEA data, 2022.

Analyzing all renewable technologies, Italy is well positioned[9] in **solar thermal**, in the **hybrid between solar thermal and photovoltaic** and in **biofuels**. In addition, based on the last most recent data available, there are about **1,200 Italian patents filed with the European Patent Office (EPO) relating to renewable energy sources**. Among these, **solar photovoltaic** is certainly the technological field with the highest number of patents (almost a third of Italian patents), followed by solar thermal (22%) and wind (about 16%). Becoming strong innovators in certain fields could allow Italy to avoid technological dependence on other countries especially if innovation is matched by industrial development.

9
Technology advantage index > 1.

FIG 12 → **Composition of Italian patents in renewables per typology, last available year** (% values)



Source → The European House – Ambrosetti and Enel Foundation elaboration on "*Transizione energetica: la filiera delle tecnologie delle rinnovabili in Italia*[10]," Intesa SanPaolo, 2022.

In general, apart from the innovation aspect, it is worth mentioning that the transition to a clean energy system leads to **new energy trade patterns, countries and geopolitical considerations**. In particular, the diffusion of green technologies requires the redefinition of global economic arrangements and balances along value chains. In this regard, it can be seen that **Europe currently plays – although not widely along the value chain - a role in the "international scenario"** in the development of electric vehicles and the installation of solar panels and wind power plants. Within this context, **also Italy can play a crucial role**, taking advantage of the knowledge gained especially in **photovoltaic and solar thermal technologies**. As for **Spain** (together with Germany), it **represents a benchmark when it comes to wind turbines and relative components** and, thus, has a current competitive edge.

10
Solar thermal is a technology that captures solar energy and transforms it into thermal energy. Subsequently, the heat obtained is used for the production of hot water.

FIG 13 → Indicative supply chains of oil and gas and selected clean energy technologies

Oil and gas	Upstream	Refining/midstream	Consumption
Oil	US SA RU	US CN RU	US CN IN
Natural gas	US RU IR	RU BH AU	US RU CN

Clean technologies	Mining	Processing	Battery material	Battery cell/pack	EV deployment
Copper	CL PE	CN CL	CN KR JP	CN US KR	CN US EU
Lithium	AU CL	CN CL	**Polysilicon**	**Solar panel**	**PV installation**
Nickel	DK PH	CN DK	CN KR DE	CN KR CA	CN EU US
Cobalt	CD	CN	**Wind turbines and components**		**Wind installation**
Rare earths	CN	CN	CN IN US ES DE		CN EU US

AU → Australia
BH → Bahrein
CA → Canada
CD → Democratic Republic of the Congo
CL → Chile
CN → China
DE → Germany
DK → Denmark
ES → Spain
EU → European Union
IN → India
IR → Israel
JP → Japan
PE → Peru
PH → Philippines
RU → Russia
SA → Saudi Arabia
KR → South Korea
US → United States

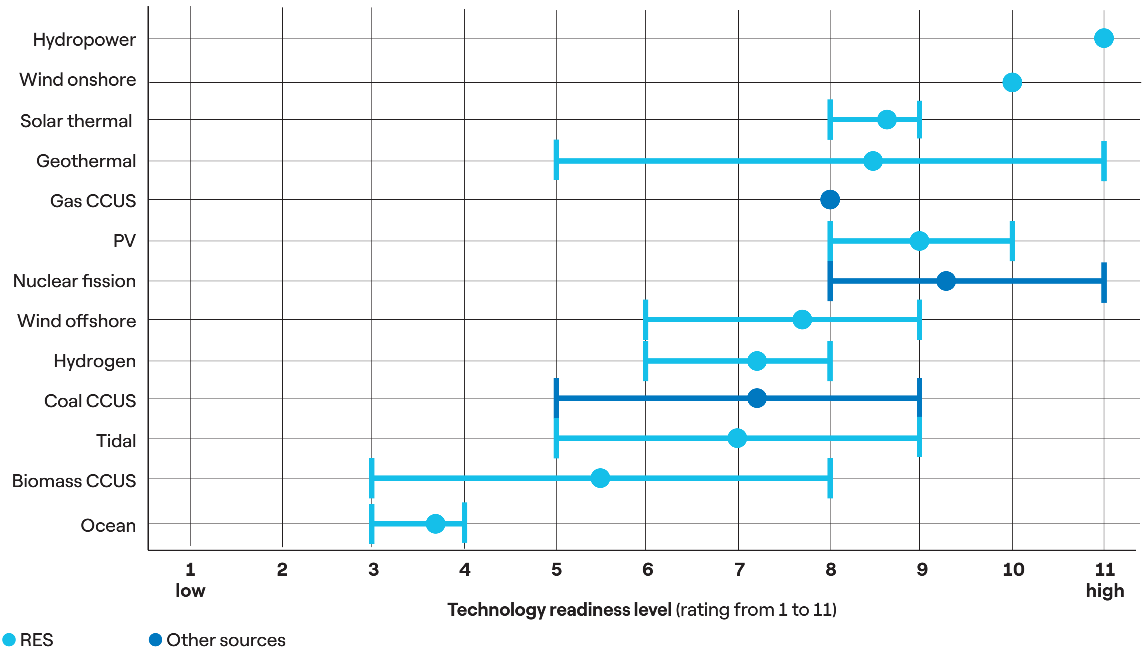
Source → The European House – Ambrosetti and Enel Foundation elaboration on IEA data, 2022.

→ **Power "pros" and "cons", challenges and future perspectives**

To evaluate the pros and cons of the clean technologies used for electricity generation, three criteria have been used, in line with the reference literature: the **Technology Readiness Level** (TRL), the **Levelized Cost Of Energy**[11] (LCOE) and **environmental and social impact**.

From the TRL dimension, it emerges that **hydropower, onshore wind, PV, geothermal, solar thermal, and nuclear** solutions are "**mature**" technologies, meaning that they have reached a sizeable deployment and only incremental innovations are expected. On the other hand, technologies such as power-to-gas appear to be in the "**early adoption**" stage, meaning that some designs have reached the markets, but policy support is required in order to scale up. Finally, solutions such as coal with CCUS, biomass with CCUS, ocean energy and tidal energy are technologies in the "**demonstration**" phase, meaning that designs have just been prototyped.

FIG 14 → **Readiness level for green technologies in the electricity and heat generation sector***



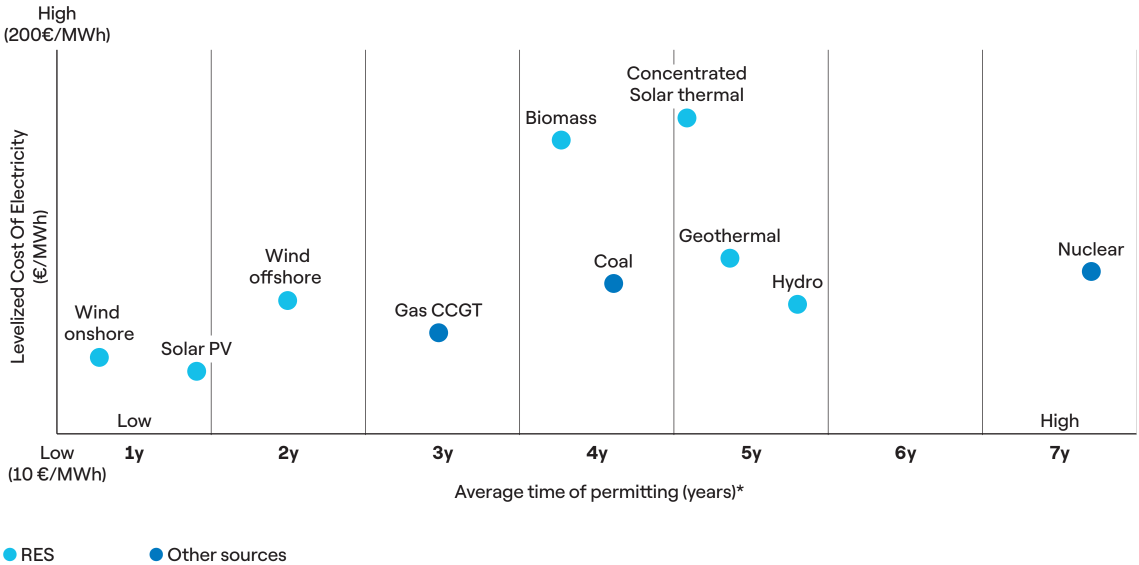
* The value displayed is the mean across the technology readiness level of the component necessary to build such technology; the metric is expressed from 1 to 11, where 1 means that a basic principle has been identified and 11 that there is proof of stability reached.
N.B. The graph displays nuclear fission only. Nuclear fusion technology is still in an early phase and assumes a TRL equal to 2. Hydrogen refers to power-to-gas-to-power technology.

Source → The European House - Ambrosetti and Enel Foundation elaboration on IEA data, 2022

11
The Levelized Cost of Energy (LCOE) is a measurement used to assess and compare alternative methods of energy production. In other terms, the LCOE is the average total cost of building and operating the asset per unit of total electricity generated over an assumed lifetime.

Overall, the **levelized costs of electricity generation** (LCOE) of renewables are falling and are **increasingly below the costs of conventional fossil fuel generation**. In fact, RES costs have kept on decreasing in recent years and they are now competitive, in terms of LCOE, with fossil fuel-based electricity generation in several parts of the world. With regard to Europe, **the great majority of renewable energy sources have become cheaper than combined cycle gas turbines (CCGT) and coal power plants**. In particular, this is true for onshore wind (60 €/MWh), offshore wind (85 €/MWh) and utility-scale solar PV (87 €/MWh). Looking back at the last 10 years, LCOE decreased by 18% for onshore wind technologies and by 77% for utility-scale solar PV, also thanks to the wider deployment of these technologies. At the same time, the LCOE for CCGT plants and coal power plants increased by 20% and 12.5%, respectively[12]. These costs vary greatly according to the geographical and energy characteristics of each European country and are therefore represented over the entire possible range in Figure 15. Moreover, these costs do not take into account the disposal costs of technologies at the end of their useful life.
Figure 15 shows the **average construction time** of each technology as wel,l an equally important variable to consider in light of the decarbonization targets to be achieved by 2030 and 2050 and the gaps described in Part 1. Looking at this variable as well, therefore, it quickly becomes clear that some technological solutions, e.g., wind (both onshore offshore) and photovoltaics, are preferable when it comes to speed of deployment while other options face greater delays in implementation (e.g., nuclear).

FIG 15 → **Median LCOE by technology in the European Union** (€/MWh)



* Permitting time does not consider the administrative time of approval.

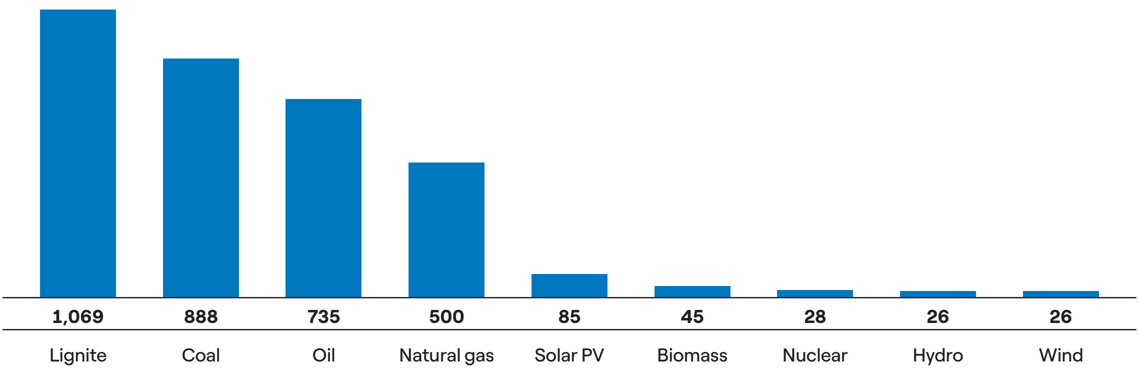
Source → The European House - Ambrosetti and Enel Foundation elaboration on European Commission data, 2022.

12
Source: European Commission, "*Cost of Energy: Energy costs, taxes and the impact of government interventions on investments*", 2020.

Apart from the dimensions previously mentioned, namely TRL and LCOE, there is another important criterion playing a key role in stating the most appropriate technology, that is the **environmental and social impact**. In order to properly evaluate this aspect, it is important to consider the **GHG emissions generated by each technology during the entire life cycle**.

According to the analysis of the Joint Research Centre of the European Commission[13], the "life cycle assessment" of GHGs produced by renewable energy sources are the lowest of all energy technologies available today. In particular, it appears that **wind and hydro are the best technologies available on the market from an environmental point of view**, registering the lowest GHG emission intensity during the life cycle of electricity production (about 26 tonnes of CO_2-eq. for every GWh of power generated). With regard to the environmental impact of nuclear power, it is important to mention that this technology creates a relevant amount of **highly radioactive waste, which poses a potential threat for both health and environment**. Public concern about environmental and safety considerations has led to plans to **phase out nuclear power** in certain Member States (such as Spain), with some others either declaring or considering moratoria on the building of new nuclear plants. In Europe[14] **there are still no permanent disposal sites for the most hazardous radioactive waste**, despite nuclear power provides about one third of electricity in Europe (under the Horizon 2020 Program, researchers were working on ways to place radioactive waste some four to eight hundred meters underground and seal it off with specialized plugs. Even if this project were eventually to succeed, the first permanent disposal sites would not be operating in Europe before 2025).

FIG 16 → **GHG emission intensity during the life cycle of electricity production by technology, 2021 or the latest available data** (tonnes of CO_2-eq. per GWh)



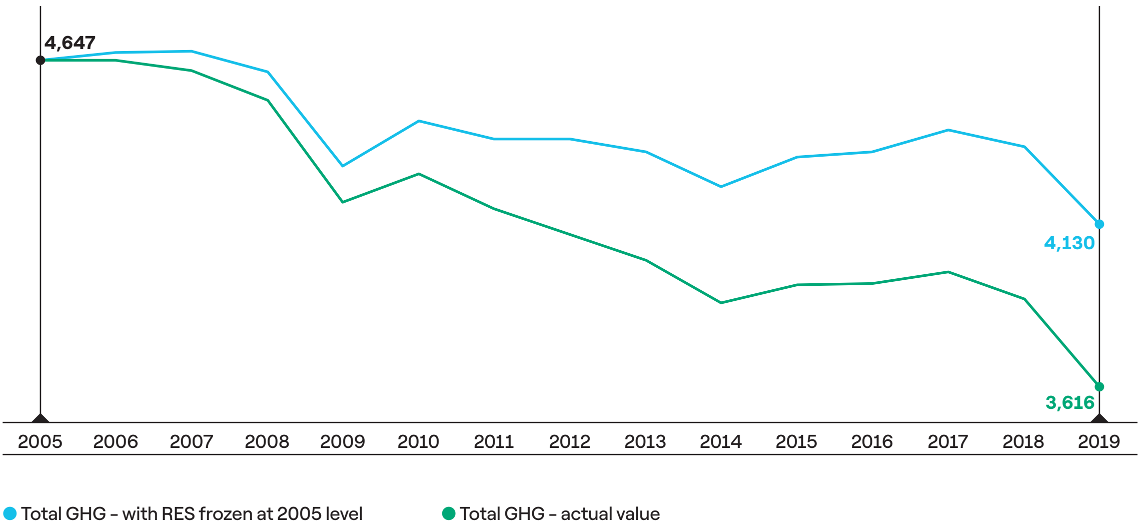
Source → The European House – Ambrosetti and Enel Foundation elaboration on JRC data, 2022.

13
Joint Research Centre, "*Technical assessment of nuclear energy with respect to the 'do no significant harm' criteria of Regulation (EU) 2020/852 ('Taxonomy Regulation')*", 2021.

14
There are no permanent disposal sites for radioactive waste at the global level. It is worth mentioning that in Finland a deep geologic nuclear waste repository for spent nuclear fuel at Onkalo it is expected to start operations in 2023.

Hence, the contribution that renewable energy sources provide in terms of **reduction of GHG emissions** is clear, as well as the benefits in terms of improving air quality and circular economy performance. In 2019, total GHG emissions (including international aviation, but excluding LULUCF[15]) in Europe amounted to around 3,616 Mt CO_2-eq.. According to the European Environment Agency (EEA), **growth in energy consumed from renewable sources** after 2005 led to an estimated **514 Mt CO_2-eq. emissions avoided at European Union level in 2019 (more than the total GHG emissions of France in 2019**, equal to 455 Mt CO_2-eq.).

FIG 17 → **Estimated gross effect on GHG emissions in the EU of renewables, 2005-2019** (Mt CO_2)



Source → The European House - Ambrosetti and Enel Foundation elaboration on EEA data, 2022.

Lastly, given the high contribution played by gas in terms of electricity generation[16] (especially in Italy), it is essential to pay close attention to **energy security**, **dependence on foreign countries** and all the related **potential vulnerabilities**. On the one hand, electrification and electricity generation with renewables allow the weight of gas in the energy mix to be reduced and thus also **increase energy independence**. On the other hand, however, if hydropower (together with nuclear) **shows no "critical"** dependence on so-called essential raw materials[17] and rare earths, the other zero emissions technologies such as solar and wind are dependent particularly on copper, rare earths, chromium and aluminum. In particular, hydropower mainly requires materials such as cement (to a greater extent than other energy sources), while the use of raw materials such as copper (1,050 kg/MW) and nickel (30 kg/MW) is the lowest among all RES[18].

15
Land Use, Land-Use Change and Forestry.
16
Further details can be found in Part 1 of this Study.
17
Essential raw materials are defined by the European Commission as those materials with a high supply risk and great economic importance, for which reliable and unhindered access is essential. The same matters have been included, by the Implementing Regulation on *Golden Power* (Prime Ministerial Decree no. 179/2020), among the assets of strategic importance for which the Italian Government may exercise special powers. Source: Copasir, "*Report on Energy Security in the Current Phase of Ecological Transition*", 2022.
18
Source: International Energy Agency (IEA), "*The role of critical minerals in clean energy transitions*", 2022.

FIG 18 → **Dependence of zero emissions technologies on minerals**

Raw material/RES	Copper	Cobalt	Nickel	Lithium	Rare earths	Platinum	Chromium	Zinc	Aluminium
Solar (photovoltaic)	High	Low	Low	Low	Low	Low	Low	Low	High
Solar (concentrated)	Medium	Low	Medium	Low	Low	Low	High	Medium	High
Wind	High	Low	Medium	Low	High	Low	Medium	High	Medium
Hydro	Medium	Low	Low	Low	Low	Low	Medium	Medium	Medium
Bioenergy	High	Low	Low	Low	Low	Low	Low	Medium	Medium
Geothermal	Low	Low	High	Low	Low	Low	High	Low	Low
Nuclear	Medium	Low	Medium	Low	Low	Low	Medium	Low	Low
Hydrogen	Low	Low	High	Low	Medium	High	Low	Low	Medium

Renewable Energy Source's dependence on the mineral ● High ● Medium ● Low

Source → The European House - Ambrosetti and Enel Foundation elaboration on IEA data, 2022.

→ **Power: penetration of technologies in the identified scenarios**

After having analyzed the state of the art and the pros and cons of the different power technologies, **two scenarios** have been defined for both Italy and Spain. The rationale is to assess the penetration of these technologies in the 2021-2050 period for both scenarios and to extrapolate the related investment costs[19].

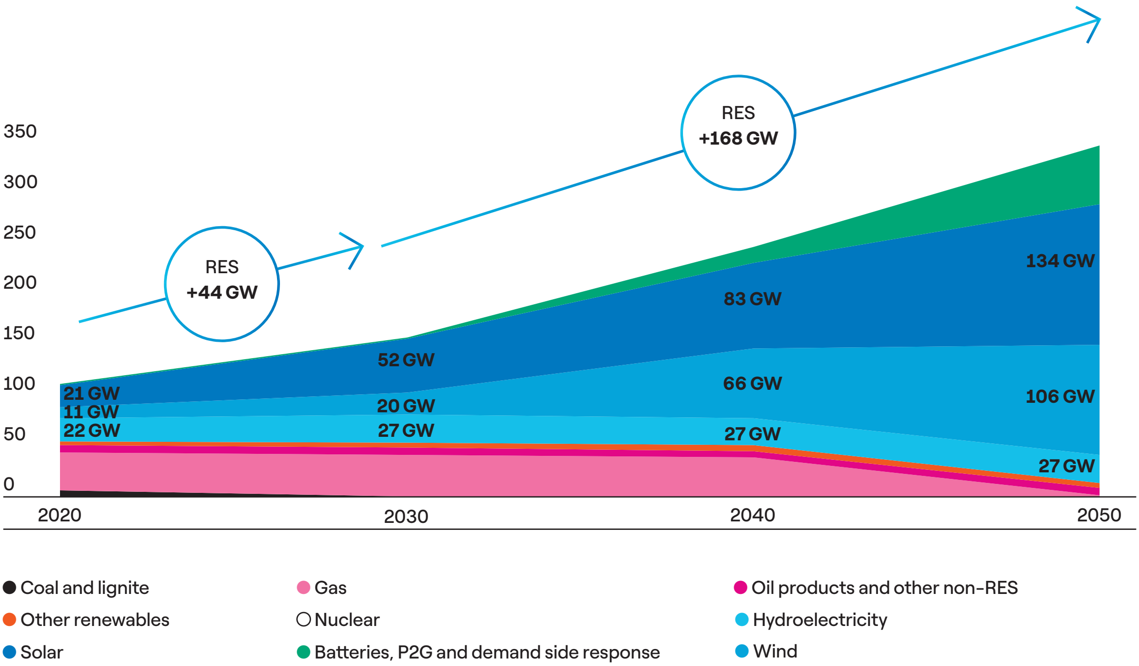
The first scenario, which is called **"Low Ambition" scenario**, is based on updated NECP data and provide, compared to the existing NECP, a more ambitious trend from 2030 to 2050, based on a recalibration of "EU Reference Scenario 2016" data. On the other hand, a more ambitious scenario, the **"Net Zero" scenario**, includes the more ambitious goals set by "Fit for 55" for 2030 and the economic and environmental impacts of COVID-19. To sum up, it expects **faster decarbonization** thanks to a greater penetration of clean technologies and flexible technologies in the next decade.

19
The investment costs needed in the two scenarios will be detailed in Part 3 of this Study.

ITALY →

In Italy, the "Low Ambition" scenario expects **+44 GW** of renewables between 2020 and 2030 and **+168 GW** between 2030 and 2050, leading to a total installed capacity of renewables equal to **272 GW in 2050** (201 GW of solar, 124 GW of wind, 27 GW of hydropower and 5 GW of other renewables). Moreover, it is expected a phase-out of coal by 2030, while **gas will maintain its relevance until 2040** (36 GW in 2020 vs. 37 GW in 2030) and eventually will reach a value of **1 GW in 2050**. Lastly, given the rise of variable RES (solar and wind), there will be a significant increase also in terms of resource capacity flexibility, with the development of batteries, power-to-gas-to-power and demand side response. Overall, **flexibility sources will increase up to 56 GW in 2050**.

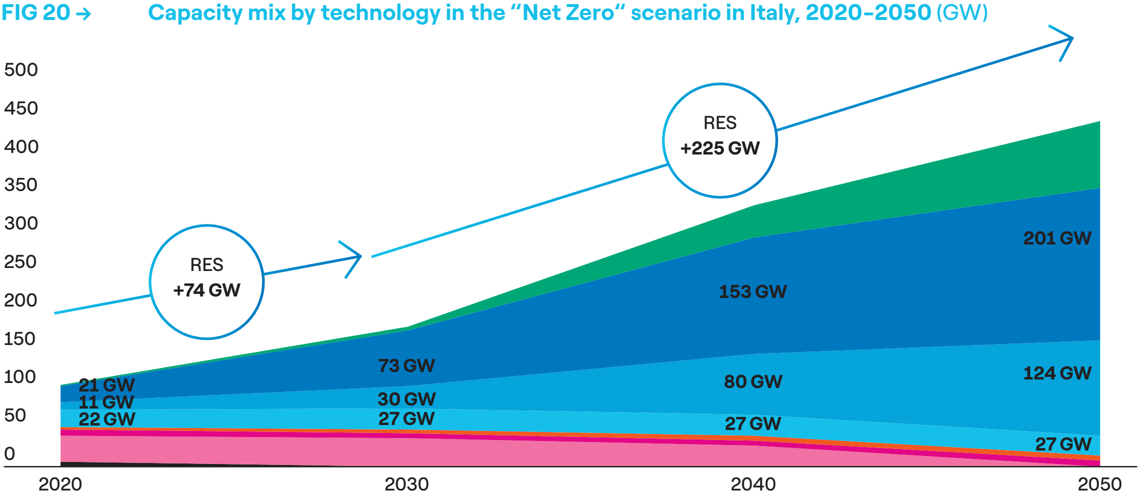
FIG 19 → **Capacity mix by technology in the " Low Ambition" scenario in Italy, 2020-2050** (GW)



Source → The European House - Ambrosetti and Enel Foundation, 2022.

The "Net Zero" scenario, compared with the "Low Ambition" one, entails a **greater penetration of renewables**. In fact, RES installed capacity is expected to increase by **+74 GW between 2020 and 2030** (+30 GW vs. "Low Ambition" scenario) and **+225 GW between 2030 and 2050** (+57 GW vs. "Low Ambition" scenario). Overall, the installed capacity of renewables is expected to be equal to **359 GW in 2050** (+87 GW vs. "Low Ambition" scenario; 201 GW solar, 124 GW wind, 27 GW hydropower and 7 GW other renewables). In parallel, given the more stringent decarbonization objectives implied by the "Fit for 55" plan, the "Net Zero" scenario expects a sharp increase in flexibility: in particular, **flexibility sources will increase to 87 GW in 2050** (+31 GW vs. "Low Ambition" scenario).

FIG 20 → **Capacity mix by technology in the "Net Zero" scenario in Italy, 2020-2050** (GW)



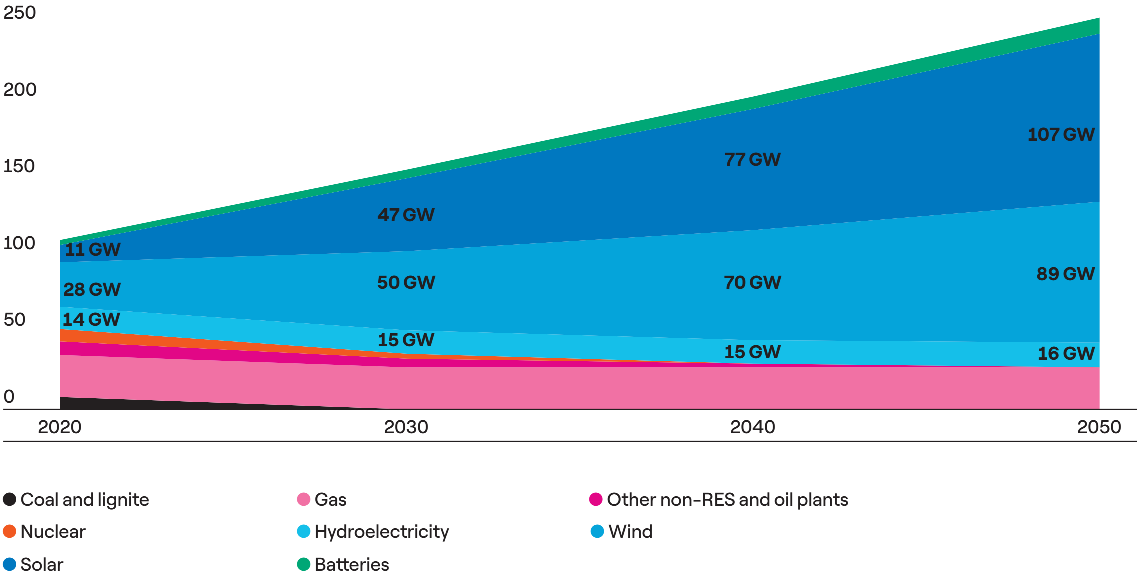
- Coal and lignite
- Gas
- Oil products and other non-RES
- Other renewables
- Hydroelectricity
- Wind
- Solar
- Batteries, P2G and demand side response

Source → The European House – Ambrosetti and Enel Foundation, 2022.

It is worth mentioning that **both in the "Low Ambition" scenario and the "Net Zero" scenario the share of renewables on electricity generation is equal to 98% in 2050**, with the power sector fully decarbonized in 2050. The most significant difference between the two, as previously mentioned, is the **faster growth of RES**.

SPAIN → In Spain, the "Low Ambition" scenario expects **+57 GW** of renewables between 2020 and 2030 and **+101 GW** between 2030 and 2050, leading to a total installed capacity for renewables equal to **212 GW in 2050** (107 GW solar, 89 GW wind, 16 GW hydropower). Moreover, as in Italy, coal is expected to be phased out by 2030, while **gas will maintain its relevance until 2050** (27 GW). Lastly, given the rise of variable RES (solar and wind), there will be a significant increase also in terms of flexibility resource capacity: overall, **flexibility sources will increase to 10 GW in 2050**.

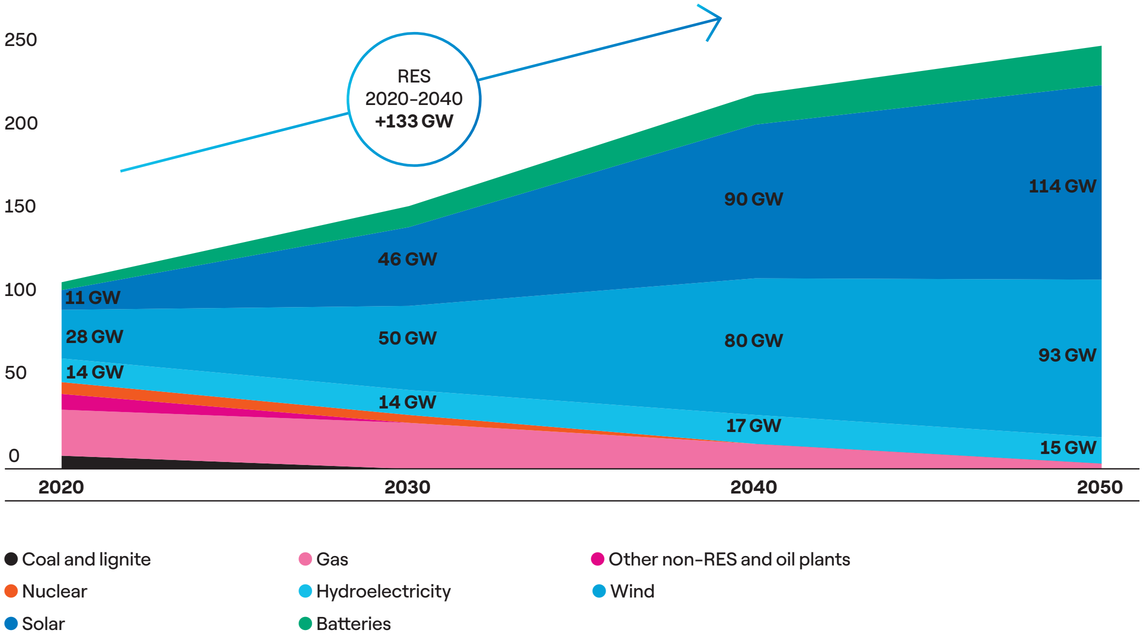
FIG 21 → **Capacity mix by technology in the "Low Ambition" scenario in Spain, 2020-2050** (GW)



Source → The European House - Ambrosetti and Enel Foundation, 2022.

The "Net Zero" scenario, compared with the "Low Ambition" one, entails a greater penetration of renewables, especially between 2020 and 2040. In fact, the RES installed capacity is expected to rise by **+133 GW** between 2020 and 2040 (+18 GW vs "Low Ambition" scenario). Overall, the installed capacity of renewables is expected to be equal to **222 GW** in 2050 (114 GW solar, 93 GW wind and 15 GW hydropower). In parallel, given the more stringent decarbonization objectives implied by the European Climate Law, the "Net Zero" scenario foresees a strong increase in flexibility: in particular, flexibility sources will increase to **23 GW** in 2050 (+13 GW vs "Low Ambition" scenario). Lastly, a final remark on phase-out of gas: in the "Net Zero" scenario there is a faster phase-out of such technologies, with the capacity declining from **27 GW** in 2020 to **15 GW** in 2040 (vs 27 in the "Low Ambition" scenario), reaching a final value of 3 GW in 2050.

FIG 22 → **Capacity mix by technology in the "Net Zero" scenario in Spain, 2020-2050** (GW)



Source → The European House - Ambrosetti and Enel Foundation, 2022.

Overall, it is important to highlight that, in contrast with Italy, the Spanish scenarios entail different shares of renewables on electricity generation in 2050. In particular, while in the "Low Ambition" scenario the share of renewables does not exceed **90%** in 2050, the "Net Zero" scenario envisions almost **100%** of RES in 2050. Finally, regarding nuclear technology, it is worth mentioning that both scenarios foresee a gradual reduction in terms of installed capacity between 2020 (7 GW) and 2040 (**0 GW**), based on the current useful life of the various nuclear power plants.

→ Electricity generation: impact of "REPowerEU"

The "REPowerEU" plan, defined by the European Commission to address dependence on Russian fossil fuel imports both in the short, medium, and long term, includes an accurate analysis of the guiding lines to follow and the paths of initiatives to be undertaken by the European Union and its Member States in order to pursue the increased ambitious target of **45% RES penetration in gross final energy consumption by 2030**, achieving **1,236 GW** of RES installed capacity (with respect to the previous 40% RES penetration target set out in the "Fit for 55" package, which envisaged 1,067 GW of RES installed capacity). There are major implications for the power sector in the coming years.

The European Commission's study on the implementation of "REPowerEU", in light of the events related to the energy crisis and the Russia-Ukraine war, estimated a **faster decrease in use of gas with respect to the implementation of the "Fit for 55" measures** (the installed capacity of gas power plants will be approximately **8 GW lower** by 2030, with lower electricity generation from gas power plants of 240 TWh than the amount generated by gas under the "Fit for 55" implementation scenario). In addition, the share of RES and coal in gross electricity generation in the "REPowerEU" modelling scenario will increase by **+3.7** and **+2.6** percentage points respectively with respect to the implementation of the proposals anticipated in the "Fit for 55", while the share of gas is expected to decrease faster (**-7** percentage points)[20].

In fact, faster electrification, increasingly powered by domestically produced RES thanks to a massive scale-up of wind and PV plants, represents the key lever to secure Europe's energy future, while pursuing its long-term decarbonization targets. Among the initiatives described in the strategy to accelerate the deployment of renewables, the introduction of a new EU legislation, aimed at **speeding up permitting procedures** for wind farms and solar panel installation and introducing specific **"go-to" areas** with low environmental risk (that is specific locations, whether on land or sea, particularly suitable for the installation of plants for the production of energy from renewable sources), while providing new regulatory incentives. The European Commission will draw up a recommendation and provide guidance on permitting procedures for RES projects, besides country-specific recommendations.

The set of initiatives in solar power capacity development aims at deploying over **320 GW of newly installed solar capacity by 2025**, and almost **600 GW by 2030**. At this rate, the expected decrease in yearly Russian gas imports will amount to 9 billion m^3. The definition of a common EU Solar Energy Strategy is expected to introduce the **European Solar Rooftops Initiative**, which will accelerate rooftop installations and add 19 TWh of electricity after the first year of its implementation (36% more than expected in the "Fit for 55" projections). By 2025, it will result in **58 TWh of additional electricity generated** (more than double the "Fit for 55" projections). Moreover, setting up an **EU Solar PV Industry Alliance** will bring together industrial actors, research institutes, consumer associations and other stakeholders with an interest in the solar PV sector, including the emerging circularity industry, in order to develop European know-how in solar PV manufacturing, reducing dependence on the monopoly of non-EU countries in the market.

Biomethane production will gain weight in the European energy mix, as the setting-up of an industrial biogas and bio-methane partnership and the co-financing of around 37 million Euros of eligible investments by the Common Agricultural Policy, Connecting Europe Facility, Cohesion Policy and Recovery and Resilience Facility are expected to **boost production by 35 billion m^3 of biomethane by 2030**.

20
Source: PRIMES model.

Finally, the European Union has set a target of **10 million tonnes of domestic renewable hydrogen production** and **10 million tonnes of renewable hydrogen imports** by 2030, in order to replace natural gas, coal and oil in hard-to-decarbonize industries and transport. Among the proposed measures, the European Commission:

- Will call on industry to accelerate the work on the lack of hydrogen standards (for hydrogen production, infrastructure and end-use appliances).
- Will regularly report, starting in 2025, on hydrogen uptake, and the use of renewable hydrogen in hard-to-abate applications in industry and transport.
- Will increase Horizon Europe investments in the Hydrogen Joint Undertaking to double the number of Hydrogen Valleys.

Overall, the "REPowerEU" plan envisages 27 billion Euros in direct investments in electrolyzers and hydrogen distribution, which translate into an **additional 20 GW of installed capacity from electrolyzers** by 2030, to be added to the expected 44 GW of installed capacity in the "Fit for 55" proposals.

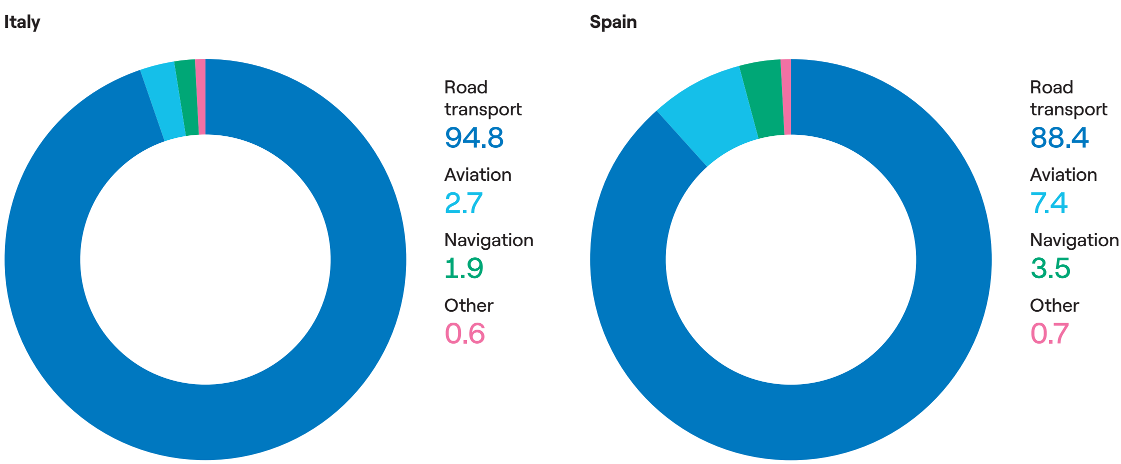
→

TRANSPORT

Transport: state of the art

According to IEA data, the transport sector accounts for **25%** of CO_2 emissions at global level. At national level, (Figure 1) transport is responsible for the largest share of CO_2 emissions, 29% in Italy and 25% in Spain. Most of the emissions in this sector are caused by **road transport** (94.8% in Italy and 88.4% in Spain, respectively), followed by air transport, with a definitely lower share. As also reflected in the "Fit for 55" package targets[21], it is evident that most of the efforts along the decarbonization path must be focused on road transport.

FIG 23 → **Transport CO_2 emissions by mode of transport, 2019** (% values)



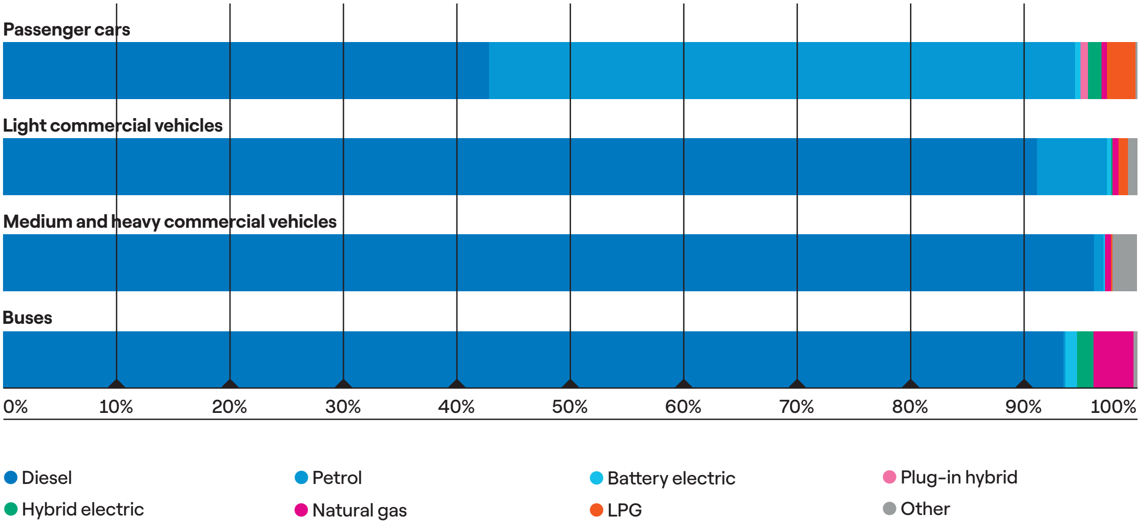
N.B. "Other" includes pipelines and rail.

Source → The European House - Ambrosetti and Enel Foundation elaboration on OECD data, 2022.

21
The "Fit for 55" package set targets to cut CO_2 emissions from new cars by 55% and from new vans by 50% by 2030.

The data reflects the current composition of the vehicle fleet in the EU, in which petrol and diesel **Internal Combustion Engines** (ICEs) are still the most common powertrains. In particular, petrol cars account for **51.7%** and diesel cars for **42.8%** of the passenger cars fleet, while larger vehicles (Light Commercial Vehicles, Buses and Trucks) are fueled mainly by diesel (more than 91% in each category). Taking into account the other solutions, **Battery Electric Vehicles** (BEVs) and **Plug-in Hybrid** (PHEVs) account for 0.5% and 0.6% in passenger cars respectively, while alternative fuels (e.g., natural gas and liquefied petroleum gas) cover between 2% and 4% of the fleets. Fuel Cell Electric Vehicles (FCEVs) are already present in the market, but with a share close to zero[22].

FIG 24 → **Road vehicles in the European Union by fuel type, 2020** (% values)

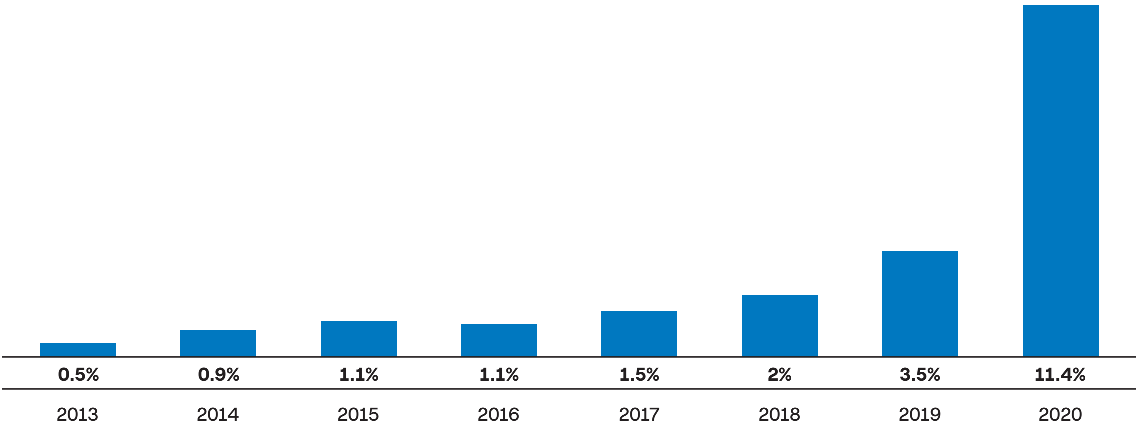


Source → The European House - Ambrosetti and Enel Foundation elaboration on ACEA data, 2022.

In this context, it is important to mention that in 2020 electric vehicles accounted for **11.4% of new registrations** in Europe (vs. 3.5% in 2019). However, Italy and Spain still lag behind, with a share of registered electric vehicles equal to 2% in both countries (vs. 33% in Sweden, best performer in Europe).

22
Hybrid cars use a conventional petrol engine and an electric motor powered by a comparatively small battery pack. Both motors can work independently or together. In PHEV the battery pack can be recharged from an external electricity source. BEVs, on the contrary, are powered by a large battery pack only and must be recharged using an external electricity source. FCEVs are fully electric too, but they generate electricity by themselves, through a fuel cell that combines oxygen from the air and hydrogen from an on-board storage tank.

FIG 25 → **Share of electric cars in new registrations in Europe, 2013-2020** (% values)



Source → The European House - Ambrosetti and Enel Foundation elaboration on European Environment Agency data, 2022.

Among other modes of transport, which at the moment play a minor contribution to CO_2 emissions, **railways** represent a benchmark in terms of electrification: the latest Eurostat data show that electricity accounts for 90% of the final energy consumption of railways in Italy and 81% in Spain, with the remaining part being mainly fueled by diesel.

With respect to **navigation**, according to the International Energy Agency[23], only 0.1% of energy consumed in shipping comes from low-carbon fuels: under their current policy framework scenarios, low and zero-carbon fuels will only account for less than 3% of the total energy consumption of shipping by 2030 and roughly 5% by 2050, significantly short of the "Net Zero" target; considering the sustainable development scenario by the IEA, low and zero-carbon fuels could account for 8% by 2030 and 27% by 2050. To date, the sector can already count on cold ironing, the process of providing shoreside electrical power to a ship at berth while its main and auxiliary engines are turned off. At the same time, most of the ongoing experiments are trying to remove key roadblocks to technologies and solutions, namely through ammonia and electrification. As regards the former, the International Maritime Organization is allowing preliminary experiments to be carried out in the next few years for ammonia-fueled container ships[24]; to date, the latter seem a viable option for short-shipping only. Given that more than 60% of the emission reductions required in 2050 will come from technologies that are not commercially available today, the shipping industry faces relevant challenges in its decarbonization pathway, which could be addressed through a rapid transformation in its whole innovation ecosystems. From this perspective, R&D of alternative powertrain and fuels is urgently needed to reduce costs and improve performance, as well as measures to be developed in the associated infrastructures[25]. Excluding freight shipping, electrification of boats is feasible mainly for recreational boats and (short-range) ferries.

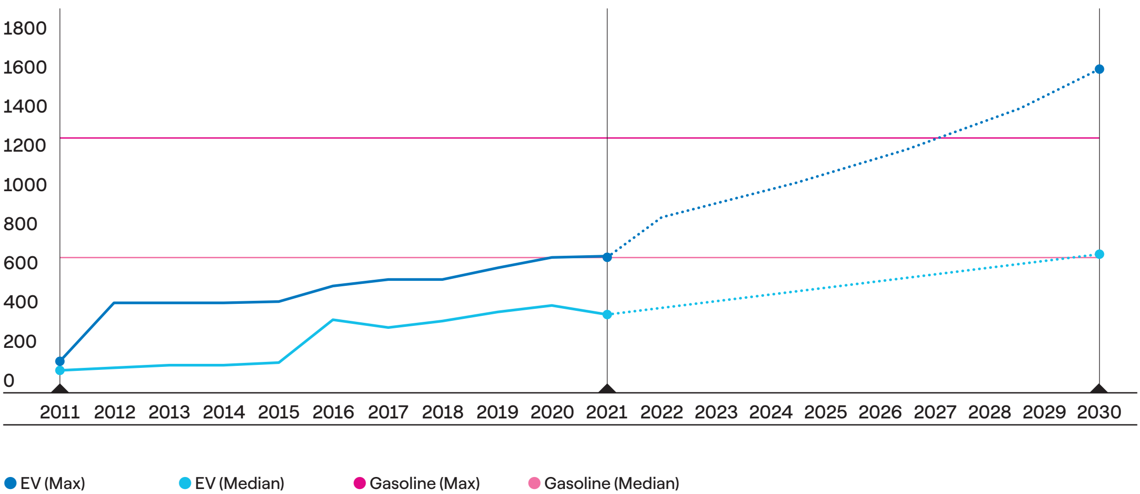
23
Source: International Energy Agency, "*International Shipping*", 2021.
24
Authorizations are needed because standards necessary for the use of ammonia as a fuel still need to be developed. Source: International Renewable Energy Agency, "*Global hydrogen trade to meet the 1.5°C climate goal*: Part II – Technology review of hydrogen carriers", 2022.
25
Source: Internal Chamber of Shipping in collaboration with Ricardo, "*A zero emission blueprint for shipping*", 2021.

With respect to **aviation**, the use of electricity as the main fuel source seems to be possible only in the long term. Nevertheless, other options are being explored to support decarbonization in the sector. Among the solutions currently under development, supported by overall structural optimization (e.g., lighter materials, improved dynamics, etc.), there are hydrogen[26] and low-carbon fuels (biofuels and synthetic fuels). At the same time, opportunities could arise in the medium-term thanks to the deployment of electric drones. Finally, it is worth mentioning that some countries (e.g. Sweden, Denmark and Norway) are already testing small electric planes for domestic routes, and have set the date for all internal routes to be electric by 2030 in the case of Sweden and Denmark, and 2040 in Norway.

→ Transport: "pros" and "cons" of technologies, challenges, and future perspectives

The electric solutions for road transport are already present in the mass market with performances close to or better than those of ICEs (e.g., in terms of costs and autonomy). Nevertheless, major improvements can still be expected by BEVs in the coming years, first and foremost in terms of efficiency and autonomy range. For example, looking back at the last decade, **median autonomy** of Electric Vehicles grew an average annual rate of **+16%** reaching **376.6 km** in 2021, while maximum autonomy grew by **+13%** a year reaching **651.8 km** in 2021; as a comparison, gasoline engines in 2021 registered a median of 648.6 km and a maximum of 1,231.1. Assuming an average annual growth rate half of that registered between 2011 and 2021 for the autonomy of Electric Vehicles, and constant autonomy for gasoline vehicles, the autonomy of EVs is expected to equal the maximum range of ICEs by 2030. Considering that in 2022 a car with an autonomy of 837 km was launched, it is clear that the estimated improvements are probably quite conservative.

FIG 26 → **Forecast of median and maximum range autonomy of Electric Vehicles, 2011-2030E (km)**

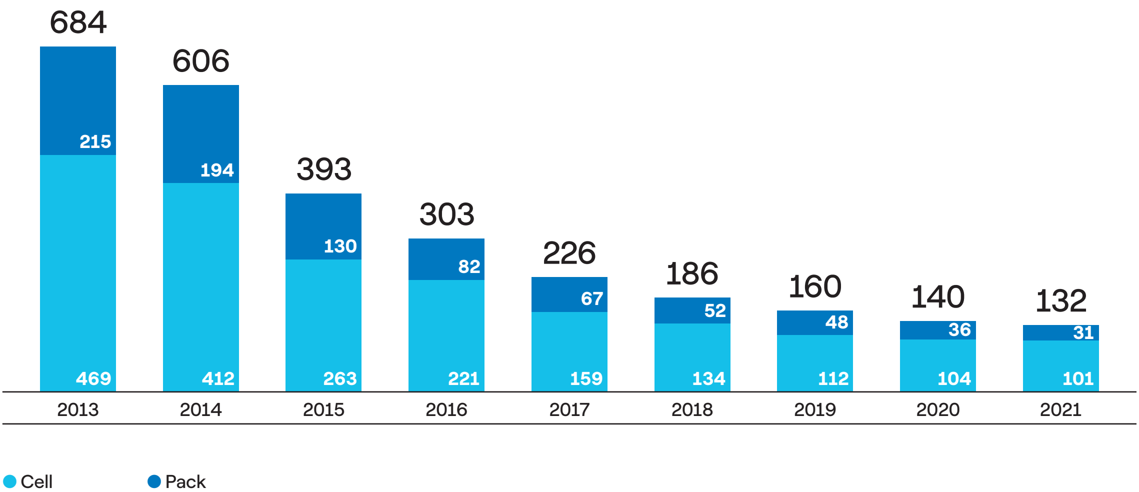


Source → The European House - Ambrosetti and Enel Foundation elaboration on US Department of Energy data, 2022.

26
In September 2020, Airbus presented three concepts of zero-emission commercial aircraft, all relying on hydrogen on primary source, which could enter service by 2035.

In addition to lighter car bodies, a key driver for enhancing the efficiency of Electric Vehicles is the **decrease in battery prices**. Lithium-ion battery pack prices, which were close to USD 700 per kWh in 2013, have fallen by 80.7% in real terms to USD 132 per kWh in 2021. Based on historical trends, Bloomberg estimates that by **2024** average pack prices should be **below USD 100 per kWh**: at this price, automakers should be able to produce and sell mass-market EVs at the same price as Internal Combustion Vehicles. In addition, by 2024 and 2026 respectively, the total cost of ownership of small and large BEVs will be **cheaper than ICEs** (medium BEVs are already cheaper).

FIG 27 → **Average lithium-ion cell and pack price, 2013-2021** (USD/kWh, 2021 constant prices)



Source → The European House - Ambrosetti and Enel Foundation elaboration on Bloomberg data, 2022.

Taking into consideration the **bus segment**, according to Enel Foundation and Università Bocconi, full-electric buses are already competitive with diesel buses (in terms of Total Costs of Ownership, TCO) both in Italy and Spain thanks to the reduction of initial costs of buses and batteries made possible by economies of scale[27]. From 2023 onwards, the TCOs of battery-electric buses will continue to decrease, making them the most convenient solution.

Similar considerations to passenger cars and buses can be made for **Light Commercial Vehicles**. While in several European Union countries eLCVs are already cost competitive, because of fiscal support, some remaining **market barriers** need to be overcome to pave the way to mass market deployment of eLCVs. High penetration of eLCVs alone can lead to a reduction of total transport CO_2 emissions by more than 3% by 2030. For pollutant emissions, such as nitrogen oxide (NO_x) and particulate matter (PM), the reduction would be equal or even higher[28].

27
Source: Università Bocconi with the scientific contribution of Enel Foundation, *"A TCRo (Total Costs and Revenues of ownership) Benchmark analysis in the BUS SECTOR. Market scenario for 2025 and 2030 (Spain case)"*, 2021; Università Bocconi with the scientific contribution of Enel Foundation, *"Scenari e prospettive dell'elettrificazione del trasporto pubblico su strada. Un'innovativa analisi di benchmark: Il TCRO - Total Cost and Revenues of Ownership (Metodologia e risultati per l'Italia)"*, 2021.

28
Tsakalidis A., Krause J., Julea A., Peduzzi E., Pisoni E., Thiel C., *"Electric light commercial vehicles: Are they the sleeping giant of electromobility?"*, 2020.

A slightly different consideration has to be made for **heavy-duty or long-distance vehicles**: despite some Battery Electric trucks have already been launched on the market, at present there are some gaps if compared to ICE trucks, notably in terms of autonomy (up to around 800 km, vs. more than 3,000 km of diesel-fueled trucks) and recharging time (around 1 hour with an ultra-fast charger)[29]. At the same time, *ad-hoc* recharging stations (different from the ones for passenger cars) will have to be deployed on a large-scale. Fuel Cell Electric trucks are instead close to the performance of ICE trucks, although vehicle cost, availability of cost competitive green hydrogen and development of the refueling infrastructure are issues yet to be solved. Nevertheless, in the next 10 to 20 years technological advances could make these solutions entirely competitive with diesel trucks, also in terms of costs.

With regard to the environmental impact, on the other hand, electric vehicles naturally enable a definite cut in direct emissions. In fact, not only BEVs eliminate all toxic tailpipe pollution such as nitrogen oxides (NO_X), carbon monoxide (CO) and hydrocarbons (HC), but they also have definitely lower **PM emissions**, which are particularly harmful for health[30]. In fact, both lighter weight and heavier weight BEVs emit less PM_{10} and $PM_{2.5}$ than their ICE counterparts: depending on the size of the cars, BEVs emit between -17.8% and -19.3% PM_{10} compared to gasoline ICEs and between -11.2% and -13.3% $PM_{2.5}$[31]. Last but not least, EVs also produce far less noise, which can strongly **reduce sound pollution**, mostly in urban areas.

Considering **Well-to-Wheel** emissions, although they depend on the GHG intensity of the electricity used for charging and the GHG emissions associated with battery production, the inherent high efficiency of the electric powertrain is alone capable of delivering a huge reduction in emissions: the life cycle emissions of lower-medium segment BEVs registered in Europe today are already **66%/69% lower** than for comparable new gasoline cars; for this segment, the life cycle emissions gap between BEVs and gasoline vehicles is expected to increase to around **74%/77%** thanks to the increased penetration of RES in the electricity mix. With fully renewable powered BEVs the life cycle reduction can reach values as high as 81%[32]. The impact of FCEVs is highly dependent on the type of hydrogen used: the reduction of GHG emissions can reach 76% when utilizing "green hydrogen".

Considering other solutions, **HEVs** are estimated to reduce life cycle GHG emissions to up to 20% of the emissions from conventional gasoline cars and **PHEVs** by 25%/27%, while those of CNG-fueled cars can even exceed the emissions of gasoline and diesel cars. With regard to alternative biofuels, they do not significantly improve the life cycle GHG emissions of average gasoline, diesel and Compressed Natural Gas (CNG) vehicles, even considering a phase-out of palm oil and increased shares of waste – and residues – based feedstocks. Combined with the high production costs, these aspects substantiate the view that e-fuels will not contribute substantially to decarbonization of the fuel mix, at least in the coming decades.

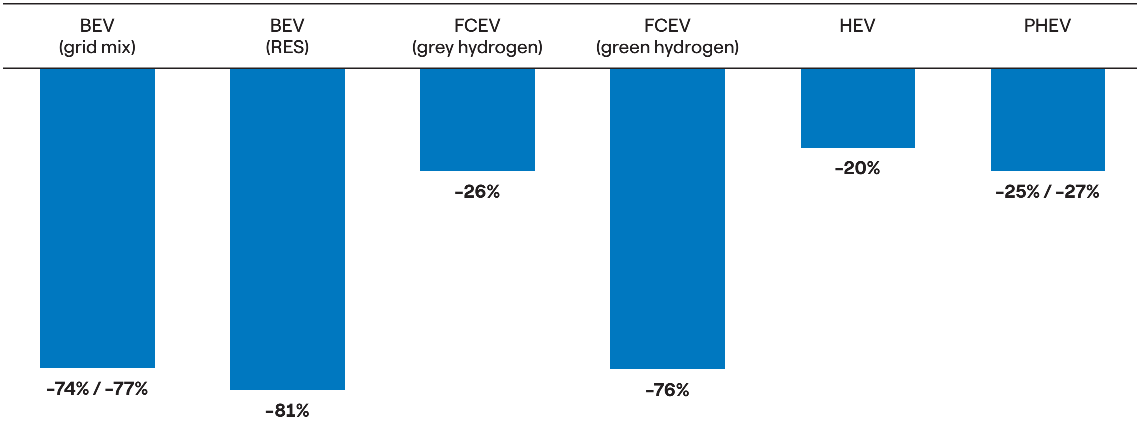
29
Cunanan C., Tran M., Lee Y., Kwok S., Leung V., and Fowler M., "*A Review of Heavy-Duty Vehicle Powertrain Technologies: Diesel Engine Vehicles, Battery Electric Vehicles, and Hydrogen Fuel Cell Electric Vehicles*", 2021.

30
Non-exhaust particle emissions from road traffic consist of airborne particulate matter (PM) generated by the wearing down of brakes, clutches, tyres and road surfaces, as well as by the suspension of road dust. Epidemiological studies have established that exposure to non-exhaust PM emissions, and to $PM_{2.5}$ in particular, is associated with a variety of adverse health outcomes in the short and long term, such as increased risks of cardiovascular, respiratory, and developmental conditions, as well as an increased risk of overall mortality.

31
OECD, "*Non-exhaust Particulate Emissions from Road Transport: An Ignored Environmental Policy Challenge*", 2020.

32
The International Council on Clean Transportation, "*European Union CO_2 standards for new passenger cars and vans*", factsheet 06, July 2021.

FIG 28 → **Life cycle greenhouse gas (GHG) emissions of selected vehicles**
(% reduction compared to Internal Combustion Engines)



Source → The European House - Ambrosetti and Enel Foundation elaboration on The International Council on Clean Transportation data, 2022.

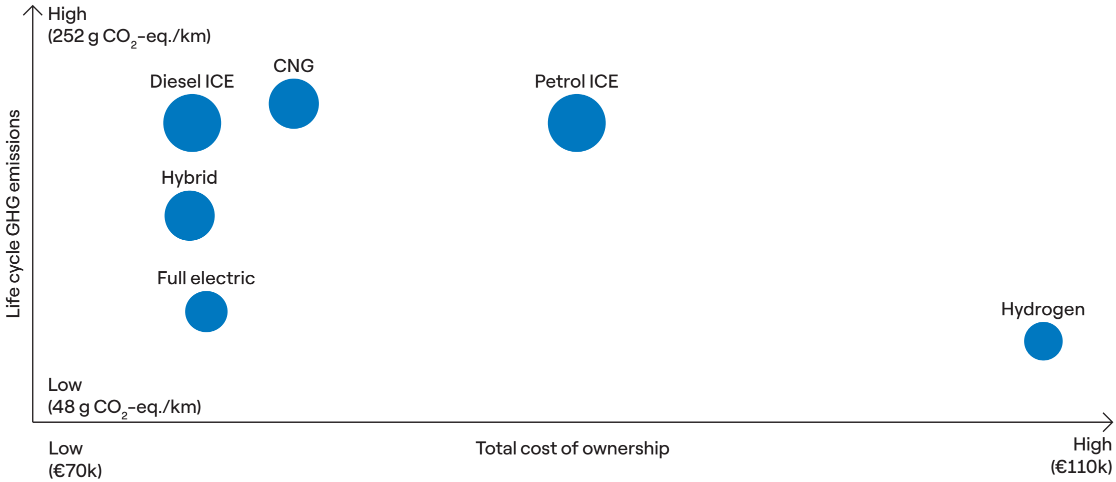
With regard to **aviation**, despite ongoing research and experiments, the commercial viability of full-electric aircrafts for long haul is expected no earlier than in the second half of the 21st century[33]. Similar considerations can be made for **navigation**: the large-scale deployment of batteries to power large full-electric freight ships – especially for heavy-duty and large-scale commercial operations – does not seem feasible with the currently available technologies and technological advancements and could start having visible effects only in the coming decades[34].

Overall, it emerges that the transport sector will benefit from the development of electric and hydrogen technologies, emitting **1/3 of GHG** compared to traditional ones. Lastly, it is important to mention that full electric vehicles appear to be already **cost competitive** compared to traditional ones, such as diesel ICE and hybrid.

33
Source: National Renewable Energy Laboratory (NREL), "*Electrification of Aircraft: Challenges, Barriers, and Potential Impacts*", 2021; International Transport Forum (ITF), "*Decarbonising Air Transport Acting Now for the Future*", 2021.

34
Source: Enel Foundation, Politecnico di Torino and MIT, "*Electrify Italy*", 2020.

FIG 29 → **Assessment of green technologies in the transport sector by total cost of ownership** (X axis: Euros) **and life cycle GHG emissions at European level** (Y axis: g CO_2-eq./km)**, medium passenger car registered in 2021**



N.B. The dimension of the technology refers to their technology readiness level (TRL). The higher the TRL, the higher the dimension. ICE: internal combustion engines. CNG: compressed natural gas. "Hybrid" includes plug-in vehicles.
The data are focused on the 'as is' picture and already shows the current affordability of the electric vehicle, which is set to improve significantly in the next decade, thanks to economies of scale and reduced technology costs (e.g., batteries)

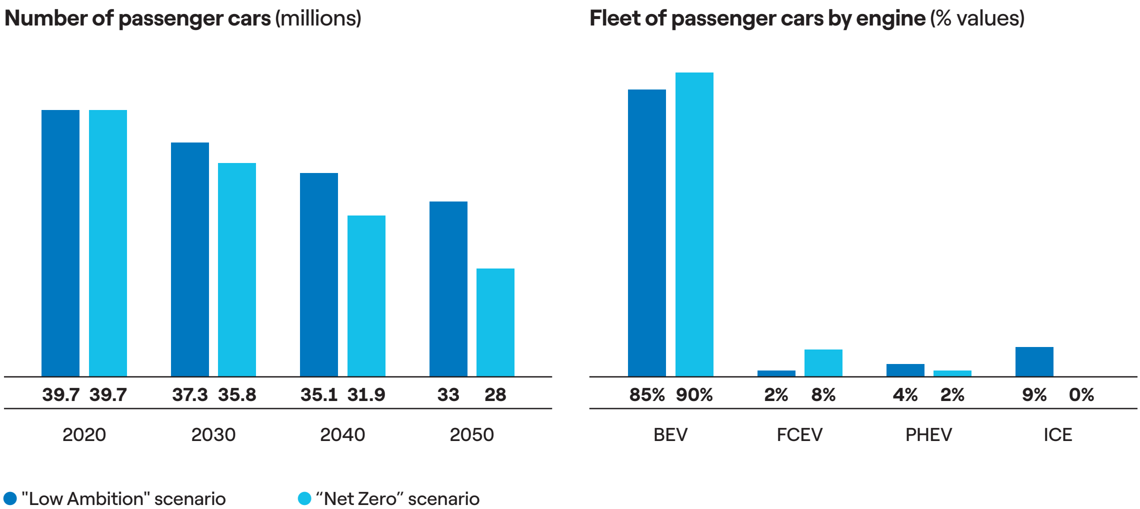
Source → The European House - Ambrosetti and Enel Foundation elaboration on ICCT and BEUC, 2022.

→ **Transport: penetration of the technologies in the identified scenarios**

As for the power sector, the "Low Ambition" and "Net Zero" scenarios for transports are outlined, highlighting the key drivers for decarbonization in Italy and Spain: on the one hand, the high penetration of **Electric Vehicles** will reduce energy demand and enable direct renewable-powered electrification; on the other hand, **shared mobility and autonomous vehicles** should allow a reduction in the number of circulating cars.

ITALY → In the "Net Zero" scenario, by 2050 passenger cars should decrease to 28 million, 5 million less than the "Low Ambition" scenario, a **29%** reduction compared to the 2021 value (39.7 million). Regarding fleet composition, **9 out of every 10** passenger cars will be BEVs by 2050, with the remaining shares represented by FCEVs (8%) and PHEV (2%). In the "Low Ambition" scenario, the penetration of electric vehicles may be lower (85% of BEVs, 2% of FCEVs, 4% of PHEVs), and ICEs will still be present, with a share of **9%**.

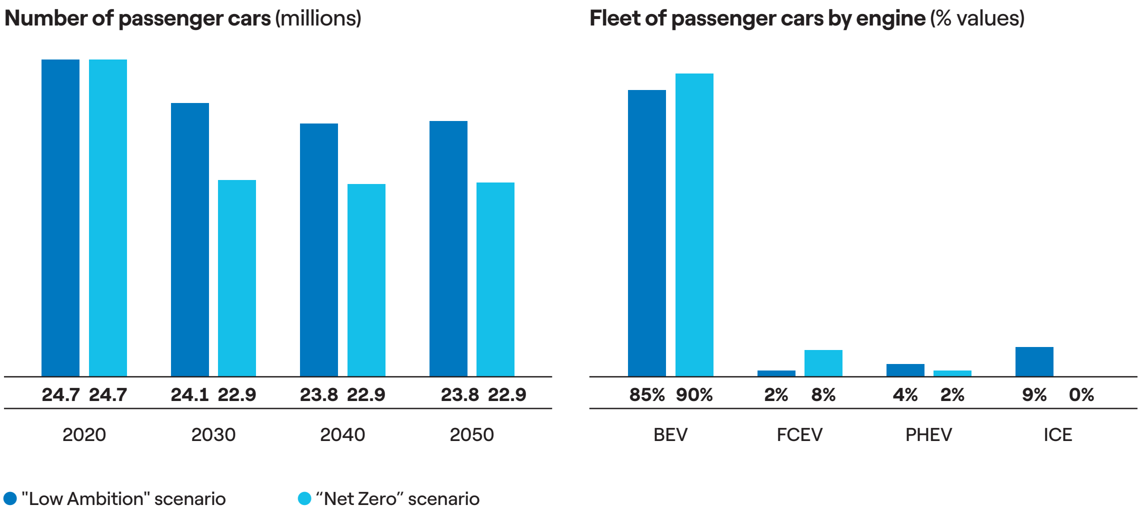
FIG 30 → **Number of passenger cars, 2020-2050 and fleet by engine in Italy, 2050**



Source → The European House - Ambrosetti and Enel Foundation, 2022.

SPAIN → In Spain too, shared mobility is expected to lead to an overall reduction in the number of passenger cars, from 24.7 million in 2020 to **22.9 million** in 2050 in the "Net Zero" scenario and 23.8 million in the "Low Ambition" scenario. As for Italy, the two scenarios diverge also in terms of electrification of the fleet by 2050, with **90% BEVs** in the "Net Zero" scenario and 85% in the "Low Ambition" scenario, with ICEs accounting for 9% of the fleet.

FIG 31 → **Number of passenger cars, 2020-2050 and fleet by engine in Spain, 2050**



Source → The European House - Ambrosetti and Enel Foundation, 2022.

→ Transport: the impact of "REPowerEU"

The "REPowerEU" plan provides for the combination of electrification and fossil-free hydrogen as the key drivers to accelerate decarbonization in the transport sector and to reduce reliance on fossil fuels. In this context, the European Commission has pledged to adopt a set of new regulatory initiatives, among which legislation to increase the share of zero emission vehicles in public and corporate car fleets above a certain size; calls on the co-legislators to adopt the pending proposals on alternative fuels to support green mobility; the adoption of a legislative package on greening freight transport, expected in 2023. As a result, final energy consumption in the transport sector is expected to decrease to **221 million tonnes of oil equivalent** in 2030 (compared to 229 million of tonnes of oil equivalent expected under "Fit for 55").

Given the higher RES penetration target adopted in the "REPowerEU" plan, there are many implications for the transition in the transport sector: the **share of RES in final consumption in the transport sector in 2030** is expected to reach **32%** (against 28% estimated under "Fit for 55" proposals), while the **GHG intensity in the transport sector is expected to decrease by 16%** (compared with -13% expected by the "Fit for 55" measures); the **share of advanced biofuels will increase to 2.2%** in 2030, while the **share of hydrogen and derived fuels** (renewable fuels of non-biological origin) in the transport sector would also **increase to above 5%**[35]. Moreover, the sub-targets in the transport sector for renewable fuels of non-biological origin included in the Renewable Energy Directive will be aligned with "REPowerEU" (5% for the transport sector).

Considering the new Hydrogen Accelerator, starting from 2025, the European Commission and Member States will regularly report on hydrogen uptake, and the use of renewable hydrogen in hard-to-abate modes in the transport sector (for instance, air transport, or long-haul road transport).

Besides the initiatives proposed in the plan, in its analysis on the implementation of the "REPowerEU" and expected investment needs and impacts, the European Commission also considered useful **good practices and behavioral measures** defined by the International Energy Agency to increase oil savings and reduce fossil imports in the very short term: among others, making the use of public transport cheaper and incentivize micro-mobility would save 5.4 million of tonnes of oil equivalent (Mtoe) per year; promoting efficient driving for freight trucks and delivery of goods would save 5.6 Mtoe; reinforcing the adoption of electric and more efficient vehicles could save 1.8 Mtoe, while reducing speed limits on highways by at least 10 km/h, working from home up to 3 days where possible and the diffusion of car-free Sundays in cities would save 8.3 Mtoe, 5.9 Mtoe and 4.1 Mtoe per year, respectively. Including other measures, such as the use of alternate private car access to roads in large cities, increasing car sharing and adopting practices to reduce fuel use, the total oil savings deriving from all these practices could amount to **43.4 Mtoe** per year (around 17% of the final energy consumption of transport in the EU, based on 2020 level).

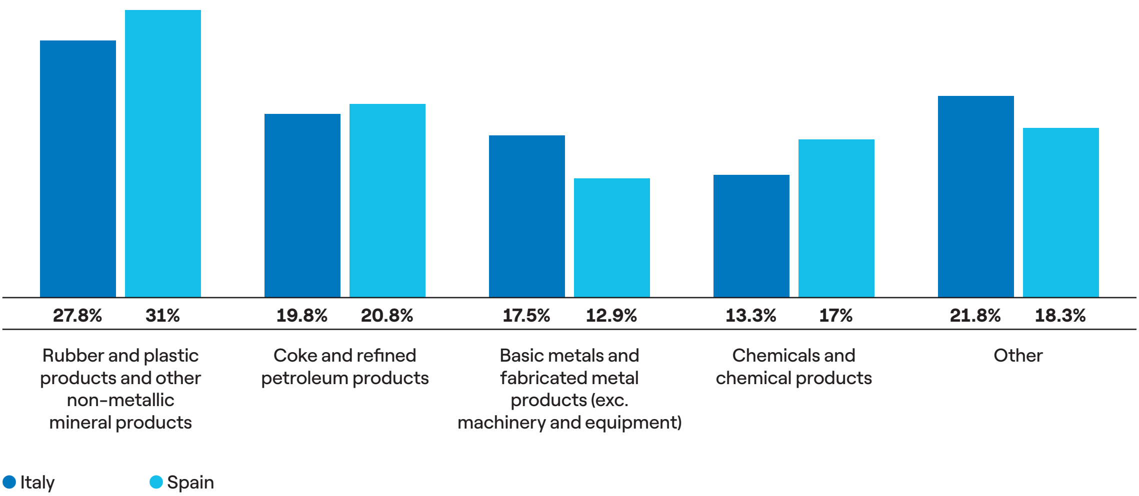
35
Source: PRIMES model.

→ **INDUSTRY**

Industry: state of the art

According to IEA data, the industrial sector accounts for **20%** of global CO_2 emissions, the highest share among the sectors considered, with a share of 23% in Italy and 20% in Spain, and an average of 21% in the EU27. From a within-industry perspective[36], this impact can be traced to some specific sectors, the so-called **"hard-to-abate" sectors**, i.e., rubber and plastic products, coke and refined petroleum products, basic metals and fabricated metal products, and chemicals and chemical products. These four sectors alone contribute to **78%** of the CO_2 emissions of the manufacturing sector in Italy and **82%** in Spain, with particularly high levels for rubber and plastic products (28% and 31%, respectively). These are relevant industrial sectors also from an economic perspective, accounting for **1/3 of the manufacturing added value** in Italy and Spain in 2019[37].

FIG 32 → CO_2 emissions of manufacturing sectors in Italy and Spain, 2019
(% of total manufacturing emissions)



Source → The European House - Ambrosetti and Enel Foundation elaboration on OECD data, 2022.

Therefore, the two main sources of industrial emissions (mainly CO_2 and methane) are the fuel consumption used to supply **process heat** for manufacturing and **chemical reactions** and processing feedstocks (e.g., natural gas processing for ammonia production or processing of iron ore to make steel). As a consequence, according to the existing literature, key pathways for the decarbonization of industry include the **electrification of processes and heat generation**, the fuel switch from fossil fuels (e.g., through bioenergy and hydrogen), and, where no other alternative is available, Carbon Capture solutions[38], which might be useful in sectors where emissions are mainly caused by **processes** (e.g., emissions from chemical transformation of raw materials and fugitive emissions): one clear example is the **cement industry**, where the chemical reactions of the process are responsible for up to 60% of emissions (40% of the weight of limestone is CO_2, which is released during this process)[39].

36
Utilities and construction are excluded.
37
Source: Eurostat data, 2022.
38
For more details, refer to paragraph "Cross-Sectoral Solutions".
39
See also: Fennell P.S., Davis S.J., Mohammed A., "*Decarbonizing cement production*", Joule, Volume 5, Issue 6, 2021.

In addition to these cross-industry solutions, there are also sector-specific ones that are capable of enhancing decarbonization in industry, such as **Direct Reduced Iron**. In this process, **hydrogen** is exploited, instead of coal, to reduce iron ore.

→ Industry: "pros" and "cons" of technologies, challenges, and future perspectives

As previously highlighted, decarbonization strategies for industry focus on the "**hard-to-abate**" sectors, namely those connected to the production of non-metallic mineral products, metals, and chemicals[40]. According to different estimates, around **40% to 50%** of industry's final energy could be electrified[41], and this can be achieved through some technological solutions that are already mature and present in the market, though not in all sectors (i.e., cement) and at all temperature levels (i.e., higher temperatures).

As shown in Figure 33, **low temperature** heat pumps (<100°C), thanks to the high conversion efficiency (COP[42] range of 3.5/5.5 for low temperature heat pumps vs. 0.75/0.8 of a gas boiler), are already cost-competitive with gas appliances. By 2030, also **low-to-medium temperature** (between 100°C and 200°C) heat pumps will be cost-competitive thanks to high conversion efficiency (COP range of 2/3, vs. 0.7/0.8 of a gas boiler) and to the decrease in the electricity-to-gas price gap to below 3.5.

For **medium temperatures** (between 200°C and 1000°C), high electricity-to-gas price ratios will represent the real obstacle to compete with gas boilers, more than counterbalancing the (slightly) higher efficiency. Unless substantial improvements in the price gap, this segment is set to be less competitive than fossil alternatives, at least in the coming decades; nevertheless, higher but stable costs could represent a valid option if compared to lower but volatile prices (i.e., natural gas). That said, other paths will have to be pursued to reach decarbonization targets, including **indirect electrification** (fuel switching). A similar consideration can be made for **high and ultra-high temperature** appliances (>1000°C), which would need green hydrogen for indirect electrification. Besides capital cost, the competitiveness of these solutions strongly depends on the availability of cost-effective green hydrogen. Before "REPowerEU" and the increase in gas prices, hydrogen solutions were expected to be viable in the medium to long term, but the new scenario could potentially accelerate technological developments[43]. Nevertheless, adjustments in systems will still represent an open issue, given the differences in the combustion of hydrogen and methane.

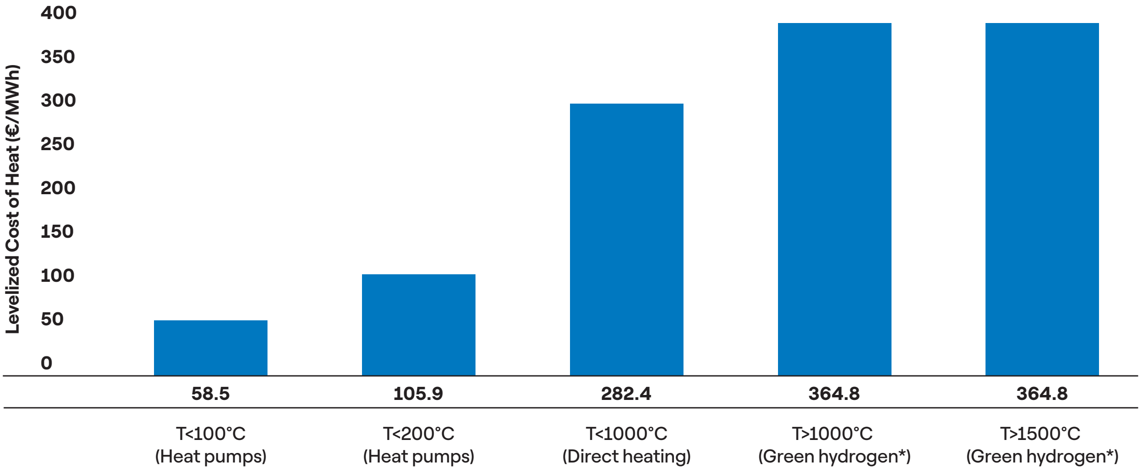
40
The decarbonization of the manufacturing of coke and petroleum products is not presented.

41
Source: EPRI, "U.S. *National Electrification Assessment*", 2018 and National Renewable Energy Laboratory (NREL), "*Electrification Futures Study: Scenarios of Electric Technology Adoption and Power Consumption for the United States*", 2018.

42
Coefficient of Performance.

43
See also: IRENA, "*Green hydrogen cost reduction*", 2020; RMI, "*Strategic Advantages of Green Hydrogen Imports for the EU*", 2022.

FIG 33 → **Estimated Levelized Cost of Heat for electric appliances compared to fossil fuel technologies, 2030** (€/MWh)



* Produced by RES-powered electrolysis. Note: High Electrification Scenario.

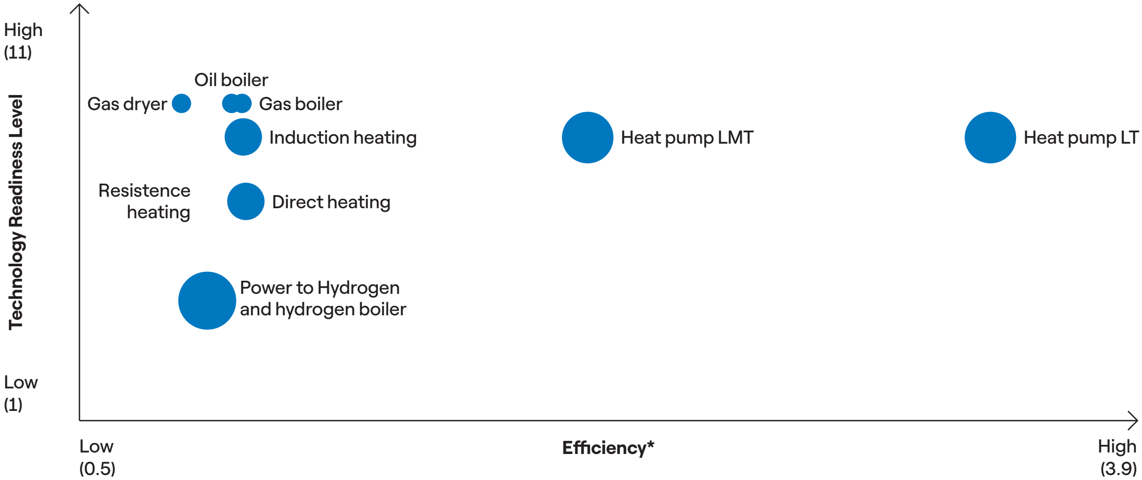
Source → The European House - Ambrosetti and Enel Foundation elaboration on Enel Foundation, Politecnico di Torino and MIT data, 2022.

In addition to these cross-sectoral solutions, there are other technologies already in the market and potentially competitive with fossil fuel alternatives. One of these is Hydrogen-based **Direct Reduced Iron** (DRI) in the iron and steel sector, at the moment at a TRL 6/8 and at TRL 9 by 2030-2040, it is capable of reducing CO_2 emissions by up to **95%** compared to Blast Furnace-Basic Oxygen Furnace (BF-BOF)[44]. Nevertheless, this solution requires substantial **changes in plant equipment and processes**, and not only a mere substitution of coal with hydrogen[45].

44
Green Steel for Europe, "*Technology Assessment and Roadmapping (Deliverable 1.2)*", 2021.

45
See also: European Union, "*Carbon-free steel production: Cost reduction options and usage of existing gas infrastructure*", 2021; IEA, "*Iron and Steel Technology Roadmap. Towards more sustainable steelmaking*", 2021.

FIG 34 → **Assessment of technologies in industrial sector by efficiency** (X axis: energy input/energy output) **and TRL at European level** (Y axis: values from 1 to 11), **2021**



* Efficiency is expressed as the coefficient of performance, calculated as the ratio between energy input and energy output.

N.B. The dimension of the technology refers to its cost. The higher the cost, the higher the dimension.

LT= low temperature (<100°C). LMT= low-medium temperature (100°C – 200°C).

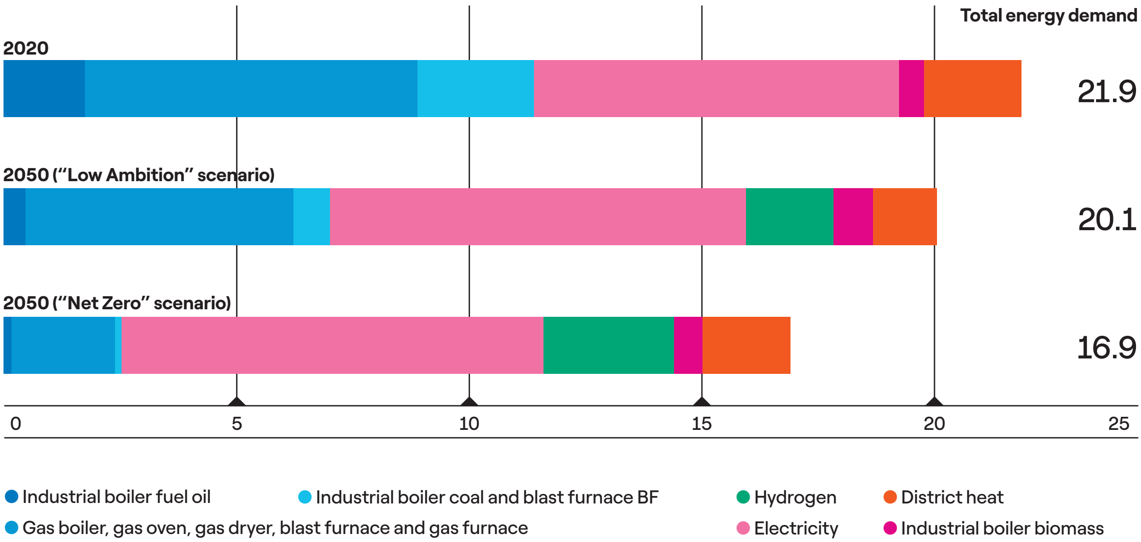
Source → The European House - Ambrosetti and Enel Foundation elaboration on Enel Foundation, Politecnico di Torino and MIT data, 2022.

Industry: penetration of technologies in the identified scenarios

ITALY → In Italy, the industrial sector sees a **significant reduction in energy demand** in both "Low Ambition" and "Net Zero" scenarios. In particular, in the "Low Ambition" scenario, by 2050 final energy demand will decrease by 1.8 Mtoe compared to 2020 (-9%), while in the "Net Zero" scenario the drop is expected to be equal to 5 Mtoe (-30%).

This improvement is mainly related to the **substitution of gas, oil and coal technologies with electrified ones** (plus hydrogen), which allow an increase in **efficiency** and thus, assuming constant output, a decrease in consumption. In particular, in the "Net Zero" scenario, **72% of industrial energy demand will come from electricity in 2050** (+16 percentage points compared with the "Low Ambition" scenario), including direct use of electricity (59%) and indirect use thanks to hydrogen (13%).

FIG 35 → **Energy demand in industry by technology in Italy, 2020-2050** (Mtoe)



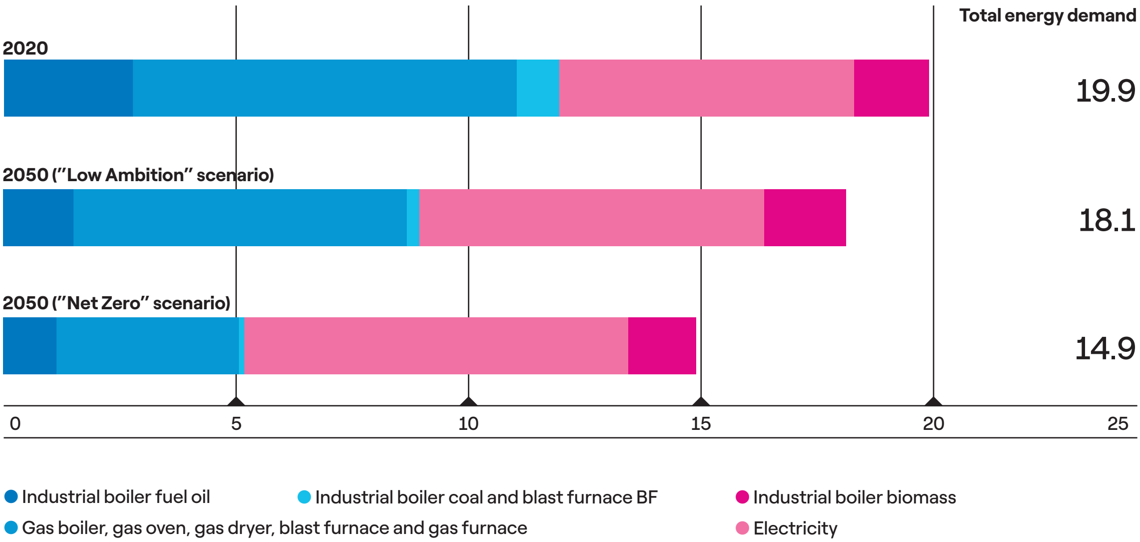
Source → The European House - Ambrosetti and Enel Foundation, 2022.

Looking at industry sub-sectors, **the greatest penetration in terms of electrification – both direct and indirect - is recorded in the steel and iron sector** (87%), followed by the chemical sector (67%) and non-metallic minerals (54%), where technologies to reduce process emissions are not yet mature.

SPAIN → As for Spain, the result is quite similar to Italy. Spanish industry will see a **25% reduction in energy demand** in the "Net Zero" scenario by 2050, with a final value of 14.9 Mtoe (vs. 18.1 Mtoe in the "Low Ambition" scenario, -9%).

Overall, this result is linked to the strong penetration of **electrification technologies**. In particular, in the "Net Zero" scenario electrification is expected to dramatically increase, especially in the chemical sector (from 22% in 2020 to 42% in 2050), in the non-metallic mineral sector (from 14% in 2020 to 38% in 2050) and in the iron and steel sector (from 47% in 2020 to 80% in 2050).

FIG 36 → **Energy demand in industry by technology in Spain, 2020-2050** (Mtoe)



Source → The European House - Ambrosetti and Enel Foundation, 2022.

→ Industry: the impact of "REPowerEU"

Taking into consideration the "REPowerEU" plan in the industrial sector, its implementation is expected to increase the RES share growth rate up to 2030 at EU level, **from 1.1%** under the "Fit for 55" scenario **to 1.9%**, considering the faster and more ambitious targets. Furthermore, "REPowerEU" will lead to a switch from natural gas to hydrogen and coal, and to a lesser extent oil. In particular, compared with the "Fit for 55" package scenario, in the "REPowerEU" analysis, **natural gas consumption in industry is 35% lower** (i.e., -35 billion m^3), mainly due to a huge decrease in gas consumption in chemicals and non-metallic minerals (the increase in fossil fuel prices is expected to explain the 10% reduction in gas consumption). The main drivers are more energy-efficient processes, the speeding-up of direct renewables, electrification and renewable hydrogen integration in industrial processes, digitalization and industrial symbiosis (useful to apply the more energy efficient processes in more industries and manufacturing chains). Compared with the "Fit for 55" scenario, the "REPowerEU" modelling scenario expects **higher oil and coal consumption in industrial sectors** in 2030 (additional 4 million tonnes of oil equivalent in oil use and 1.9 million tonnes of oil equivalent in coal consumption)[46]. Although this represents a step back towards carbon neutrality, "REPowerEU" is designed to include **all the available options** that may be useful **to address the energy emergency and gas shortage in the short run**, many of which do not require investments as they are just a temporary, partial bouncing back to plants exploiting traditional fossil fuels. For instance, some countries have considered delaying the pledged coal phase-out in order to offset a potential energy supply shortage (Italian Prime Minister, in February 2022, announced the possible re-opening of 7 coal plants, in theory capable of supplying 15% of national energy demand in the very short term)[47].

46 Source: PRIMES model.

47 Italian Prime Minister Mario Draghi's speech in Parliament, 25 February 2022.

Considering the boost to domestically produced renewable hydrogen envisioned in the "REPowerEU" plan, industry will be hugely impacted by the initiative, especially those industrial sectors and processes which are not suitable for direct electrification, and where the development of hydrogen as an energy carrier represents the key lever for their decarbonization. In particular, the European Parliament and the Council are expected to align the sub-targets for industry for renewable fuels of non-biological origin under the Renewable Energy Directive (75% of penetration) and to quickly conclude the revision of the **Hydrogen and Gas Market Package**. Moreover, the Commission will call on industry to accelerate the definition of currently lacking hydrogen standards, concerning production, infrastructure and end-use appliances. Finally, starting from 2025, the European Commission and Member States will regularly report on hydrogen uptake, and on the use of renewable hydrogen in hard-to-abate applications in industry. As a result, under "REPowerEU" implementation scenario, **78% of the hydrogen consumed in the industry will be renewable in 2030** (+28% with respect to the percentage expected under the "Fit for 55" scenario).

Beyond this, in order to support hydrogen uptake and electrification in industrial sectors, the Commission pledges to roll out carbon contracts for dedicated "Fit for 55" windows under the Innovation Fund[48] to support a full switch of existing hydrogen production in industrial processes from natural gas to renewables, while new industrial sectors will be characterized by hydrogen-based production processes. Moreover, the Commission will double the funding available for the 2022 Large Scale Call of the Innovation Fund (during which large-scale innovative projects will be awarded) in autumn 2022 to around 3 billion Euros, that will be useful to support innovative electrification and hydrogen applications in industry and mid-sized pilot projects for testing and optimizing highly innovative solutions. To mention a specific industrial sector, under the"REPowerEU" plan the Commission expects 30% of EU primary steel production to be decarbonized thanks to renewable hydrogen by 2030. As a result, **green hydrogen use in the industrial sector in 2030 in the "REPowerEU" analysis will amount to 16.2 million tonnes (roughly 2.5 times the amount consumed in the "Fit for 55" scenario).**

FIG 37 → **Natural gas, oil and coal consumption in industrial sectors in the "REPowerEU" scenario, the "Fit for 55" scenario and the differences, 2030** (absolute values)

	"REPowerEu"	"Fit for 55"	Difference
Natural gas use in 2030 (billion of m³)	57	91.9	-34.9
Oil use in 2030 (Mtoe)	97.8	94.8	+4
Coal use in 2030 (Mtoe)	24.6	22.7	+1.9

Source → The European House - Ambrosetti and Enel Foundation elaboration on European Commission, 2022.

48 The EU program aimed at reducing GHG emissions through the award of innovative low-carbon technologies and processes in energy-intensive industries, CCS technologies, innovative renewable energy generation and energy storage projects.

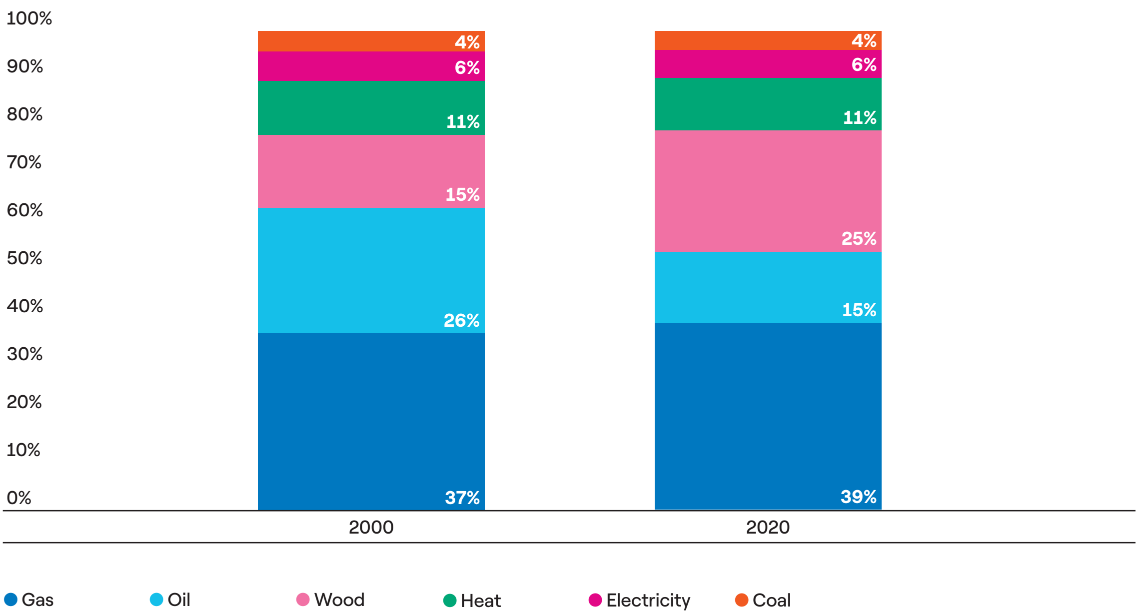
→ **BUILDINGS**

Buildings: state of the art

Buildings account for **9%** of global CO_2 emissions, with a share of 13% in the EU27+UK. At global level[49] electricity accounts for 51% of the final energy demand in non-residential buildings, while the same value for residential sector is currently lower than **18%**. This highlights where the highest potential for electrification – and thus decarbonization – lies.

With regard to the **heating sector**, in Europe the share of coal, oil and natural gas on overall **household energy consumption** is still relevant. In particular, in 2020 the contributions of these sources accounted for **almost 60%**, with gas being the leading energy source for household heating in Europe (**39%** of the total in 2020). However, some variations occurred in the last 20 years: mainly because of a growth of wood (+10 p.p.), the share of coal, oil and natural gas decreased by almost 11 percentage points.

FIG 38 → **Household energy consumption for heating by source in Europe, 2000 and 2020** (% values)

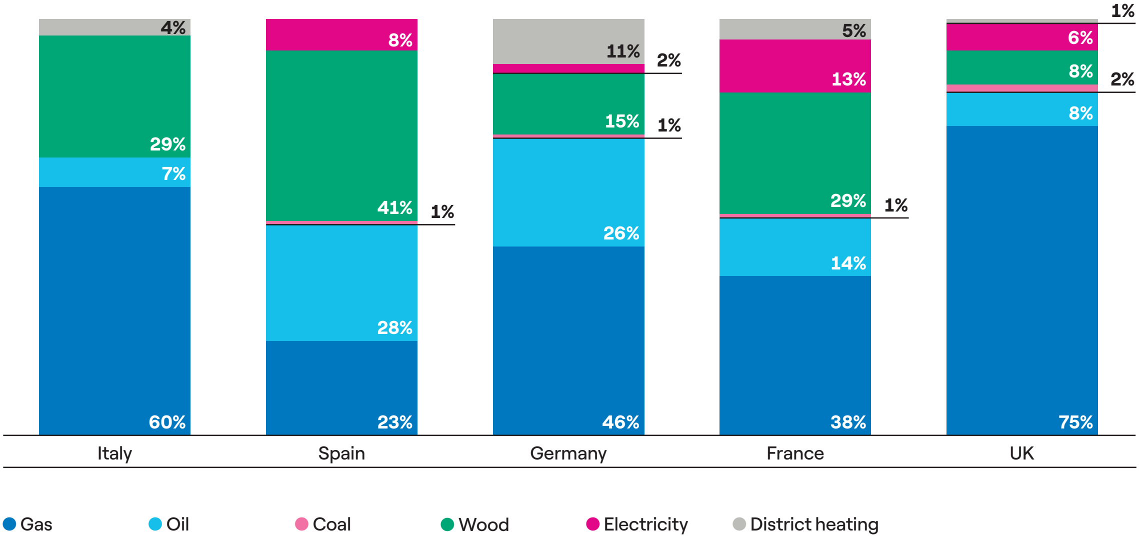


Source → The European House - Ambrosetti and Enel Foundation elaboration on ODYSSEE-MURE data, 2022.

49
Enel Foundation, Politecnico di Torino and MIT, "*Electrify Italy*", 2020.

In countries like the **Netherlands**, **UK** and **Italy**, the use of gas raises a concern, because of its key role in residential heating, accounting for **85.4%**, **74.5%** and **59.8%**, respectively, of the overall energy used for residential heating. In Spain, on the other hand, gas accounts for 23% only.

FIG 39 → **Household energy consumption for heating by source in selected European countries and UK, 2020** (% values)

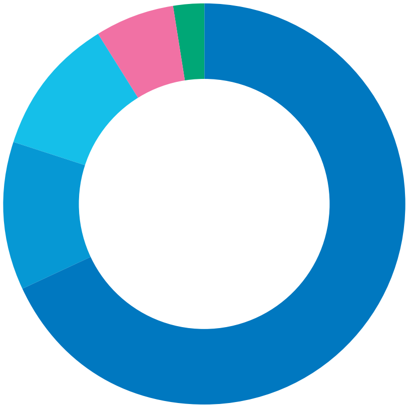


Source → The European House - Ambrosetti and Enel Foundation elaboration on ODYSSEE-MURE data, 2022.

In Italy, 68.3% of the energy is used for **space heating**, followed by water heating (11.8%) and electrical appliances and lighting (11.2%). Space heating and water heating are also low-electrified uses: in fact, respectively 59% and 65% of their energy depends on gas; on the contrary, space cooling, appliances, and lighting are 100% electrified[50]. From a technological perspective, the most common solutions for space and water heating in residential buildings are gas boilers and oil boilers, while electric heat pumps and electric boilers represent the emerging sustainable alternatives.

50
Ibidem.

FIG 40 → **Energy share of final uses in Italy in the residential sector** (% values)



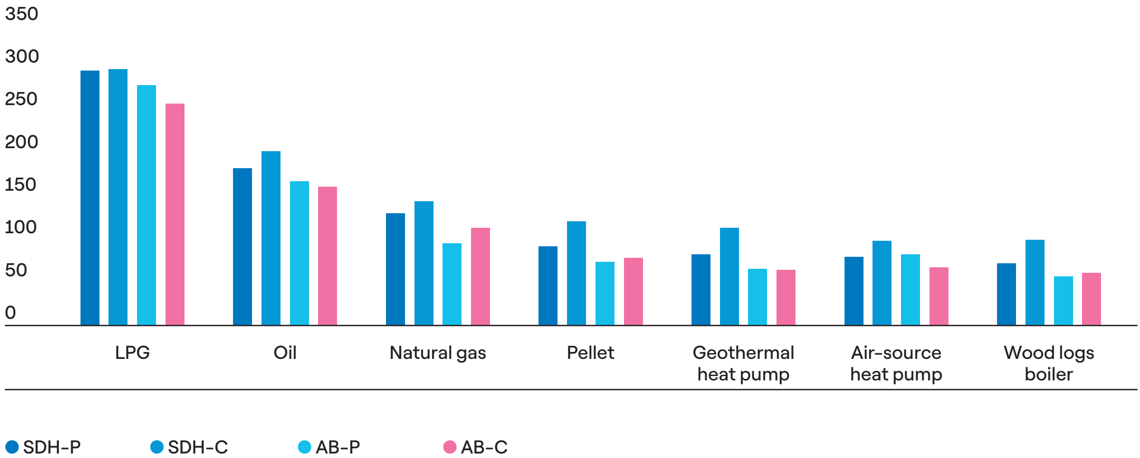
Source → The European House - Ambrosetti and Enel Foundation elaboration on Enel Foundation, Politecnico di Torino and MIT data, 2022.

→ **Buildings: "pros" and "cons" of technologies, challenges and future perspectives**

Most of the solutions for the decarbonization of buildings are mature and already present in the market: the key to their large-scale deployment is strictly dependent on **financial convenience** trade-off between investment cost and energy saving, but also on the **overall interventions** on heating systems of existing buildings (in most cases, heat pumps cannot easily replace boilers without an overall adjustment to spaces and heating systems). Given the current energy demand of the building sector, another key action to carry out is the **renovation of buildings**: thermal insulation reduces energy demand, and building refurbishment allows for more radical modification and adaptation of HVAC (heating, ventilating and air conditioning) systems, favoring the installation of heat-pump-based systems. With regard to **heating technologies**, at present, there is already a clear gap in Levelized Cost of Heat (LCOH) values between renewable and fossil fuel solutions: for example, the most expensive renewable heating technology is always cheaper than a natural gas boiler (up to 34%), and even more convenient if compared to LPG (60-70%) and heating oil (40-50%) solutions[51]. With regard to biomass solutions, they emit high levels of particulate and they can be considered as a sustainable option only when the biomass derives from short and sustainable supply chains (e.g., without deforestation).

51
Source: Ruffino E., Piga B., Casasso A., Sethi R., "*Heat Pumps, Wood Biomass and Fossil Fuel Solutions in the Renovation of Buildings: A Techno-Economic Analysis Applied to Piedmont Region (NW Italy)*", 2022.

FIG 41 → **Levelized Cost of Heat for domestic heating according to different scenarios, 2022** (€/MWh)



N.B. SDH=Single detached house; AB=Apartment block; P=Partial renovation; C=Complete renovation.

Source → The European House - Ambrosetti and Enel Foundation elaboration on Ruffino E., Piga B., Casasso A., Sethi R. data, 2022

Taking into account green solutions only, electric heat pumps are in most cases the **cheapest heating options** available to consumers. Other estimates that include comparisons with biomass technologies highlight that, by 2050, heat pumps will be more convenient than biomass boilers (in terms of global costs) thanks to the projections of energy commodity prices[52].

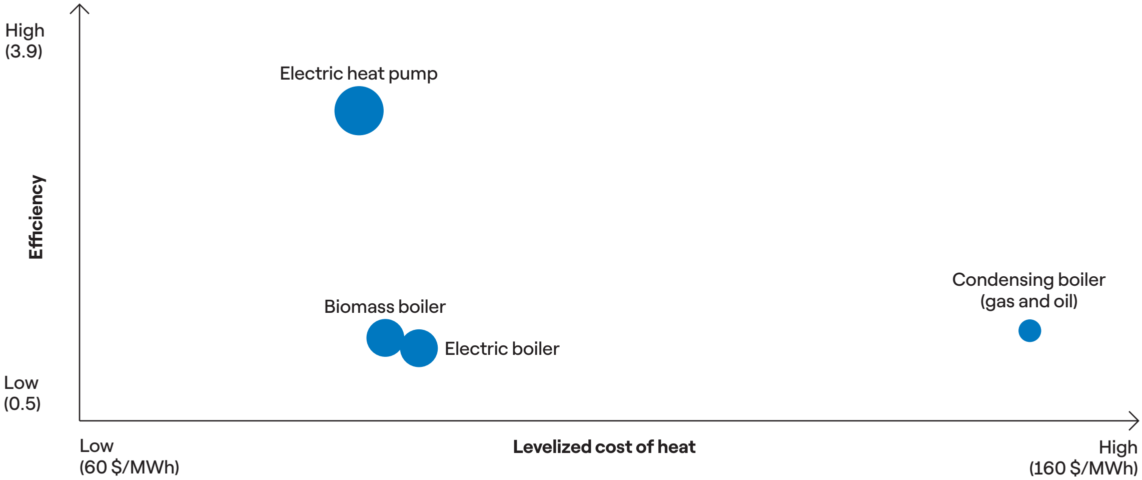
Moreover, unlike hydrogen boilers, electric heat pumps can deliver **cooling** during the summer, thus offering a relevant two-in-one solution for consumers looking for a versatile all-year solution. This opportunity can be advantageous in particular in places with consistent levels of both heating and cooling (otherwise, cost savings may be less substantial).

Electric technologies are also the most **environmentally sound**: thanks to their efficiency they can drastically reduce energy demand, as well as CO_2, NOx and PM_{10} emissions. When powered with renewable electricity the emissions are reduced to zero. On the contrary, biomass boilers are the highest particulate emitters, while gas boilers produce the highest CO_2-eq. emissions over their entire lifetime[53].

52
Source: Enel Foundation, Politecnico di Torino and MIT, "*Electrify Italy*", 2020.

53
Enel Foundation, Politecnico di Torino and MIT, "*Electrify Italy*", 2020.

FIG 42 → **Assessment of residential sector technologies by cost of heat** (X axis: $/MWh) **and efficiency at European level** (Y axis: energy input/energy output)**, 2021**



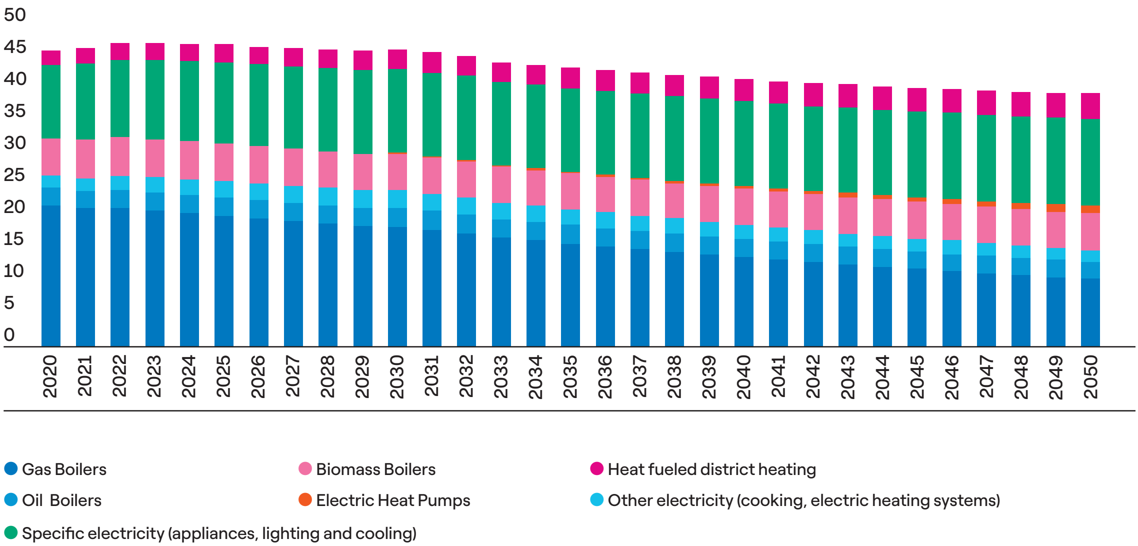
N.B. The dimension of the technology refers to their investment costs. The higher the cost, the higher the dimension. For condensing boiler, the average between gas boilers and oil boilers has been taken into account. Heat pumps can provide both heating and cooling, but the additional investment needed to provide cooling where other heating technologies (biomass or fossil fuel boiler) are used is not considered in this comparison.

Source → The European House - Ambrosetti and Enel Foundation elaboration on various sources, 2022.

ITALY → **Buildings: penetration of technologies in the identified scenarios**

In the "Low Ambition" scenario, gas boilers will still account for **27%** of the final energy demand (equal to 10.3 Mtoe). The slower deployment of electric heat pumps – around **21.7 million** by 2050 – will also prevent substantial reductions in the final energy demand and hinder the overall decarbonization of buildings.

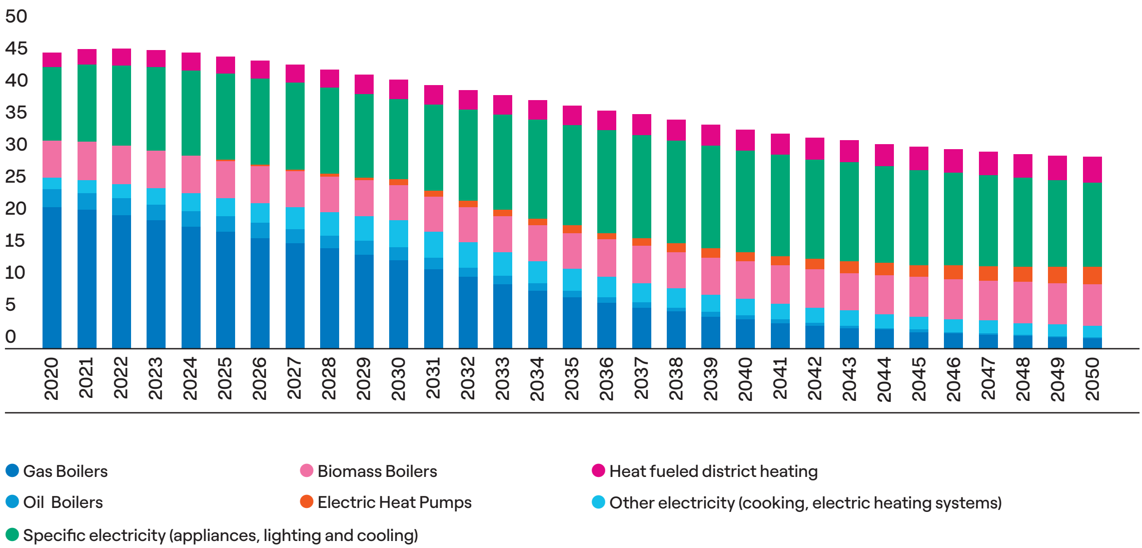
FIG 43 → **Energy demand of buildings in the "Low Ambition" scenario in Italy, 2020-2050** (Mtoe)



Source → The European House – Ambrosetti and Enel Foundation, 2022.

In Italy, the "Net Zero" scenario will require a strong reduction in the number of gas boilers, which by 2050 should account for no more than **5.5%** of the final energy demand of buildings (vs. 47.9% in 2020). The overall final energy demand will decrease by **-1.4%** CAGR, from 45 Mtoe in 2020 to 29 in 2050, enabled by the large deployment of electric heat pumps (around 50 million electric heat pumps installed by 2050).

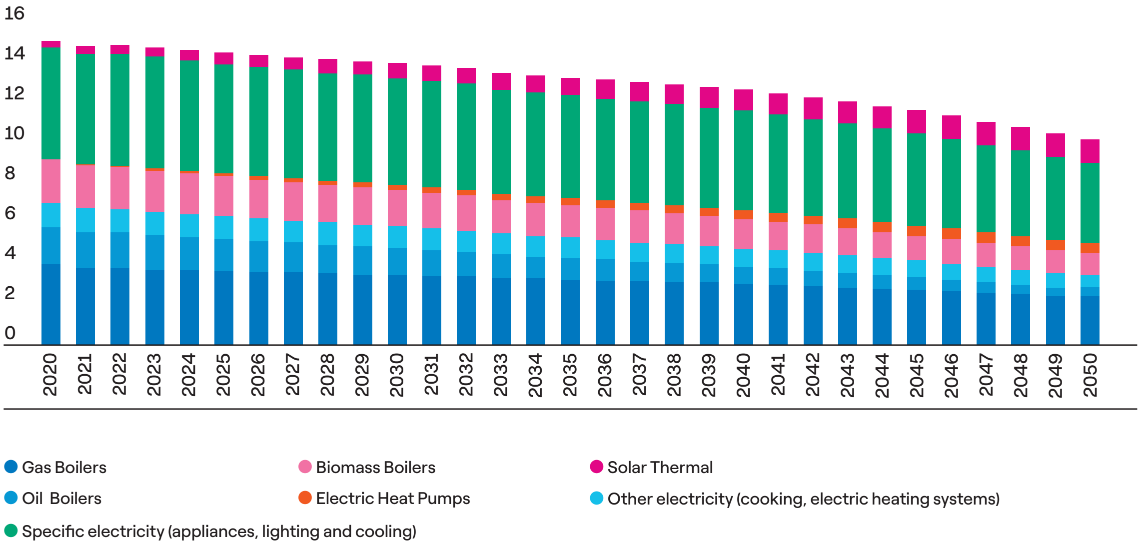
FIG 44 → **Energy demand of buildings in the "Net Zero" scenario in Italy, 2020-2050** (Mtoe)



Source → The European House - Ambrosetti and Enel Foundation, 2022.

SPAIN → As for Italy, in Spain the "Low Ambition" scenario is linked to a less intense reduction in final energy demand: with a CAGR of **-1.3%** in the 2020-2050 period (vs. -2.2% in the "Net Zero" scenario), final energy demand should reach **10 Mtoe** by 2050. This is a consequence of lower deployment of electric heat pumps (9.6 million by 2050) and, at the same time, a still significant role of gas boilers, covering **24%** of final energy demand.

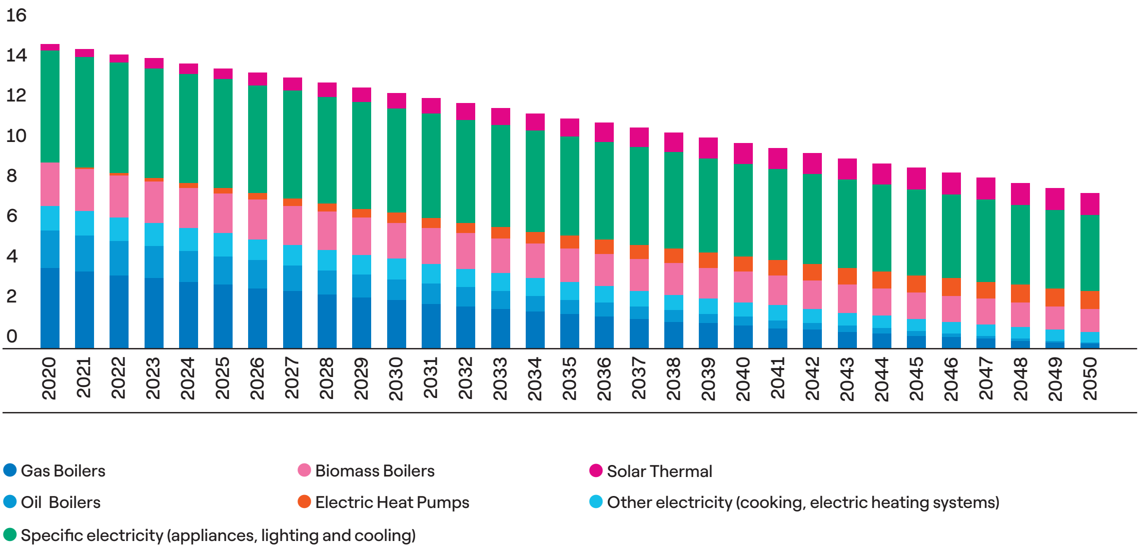
FIG 45 → **Energy demand of buildings in the "Low Ambition" scenario in Spain, 2020-2050** (Mtoe)



Source → The European House - Ambrosetti and Enel Foundation, 2022.

Also in Spain a key driver of the decarbonization of buildings will be the large-scale deployment of electric heat pumps, estimated to amount to around **16.4** million by 2050 in the "Net Zero" scenario. Thanks to these solutions, final energy demand could therefore be reduced from 14.7 Mtoe in 2020 to 7.5 Mtoe in 2050. At the same time, the share of gas boilers will diminish from **27%** of final energy demand in 2020 to **4%** in 2050.

FIG 46 → **Energy demand of buildings in the "Net Zero" scenario in Spain, 2020-2050** (Mtoe)



Source → The European House - Ambrosetti and Enel Foundation, 2022.

→ **Building: the impact of "REPowerEU"**

If the "REPowerEU" proposals will be approved, the buildings sector will be massively impacted. Given the increased ambition in the 2030 RES penetration target (45% RES share in final energy consumption), the **RES share in the final energy consumption of the buildings sector will achieve 60%** (+11% compared with the "Fit for 55" scenario), with a **2.3% yearly average increase in the RES share in heating&cooling and district heating&cooling** (+0.8% and +0.2%, respectively, if compared to the "Fit for 55" scenario). Gas use in buildings is expected to decrease by roughly 27 million tonnes of oil equivalent (**32 billion m³** by 2030, around 38% of total gas consumption in the residential sector in 2019) by 2030[54].

The new **Solar Rooftop Initiative** included in the Plan will make the installation of rooftop solar energy compulsory for all new public and commercial buildings with useful floor area larger than 250 m² by 2026; all existing public and commercial buildings with useful floor area larger than 250 m² by 2027, and all new residential buildings by 2029, which have to be "solar ready" (designed to optimize the generation potential based on a site's solar irradiance, enabling the fruitful installation of solar technologies without costly structural interventions). According to estimates, rooftop PV could cover almost 25% of the EU's electricity consumption.

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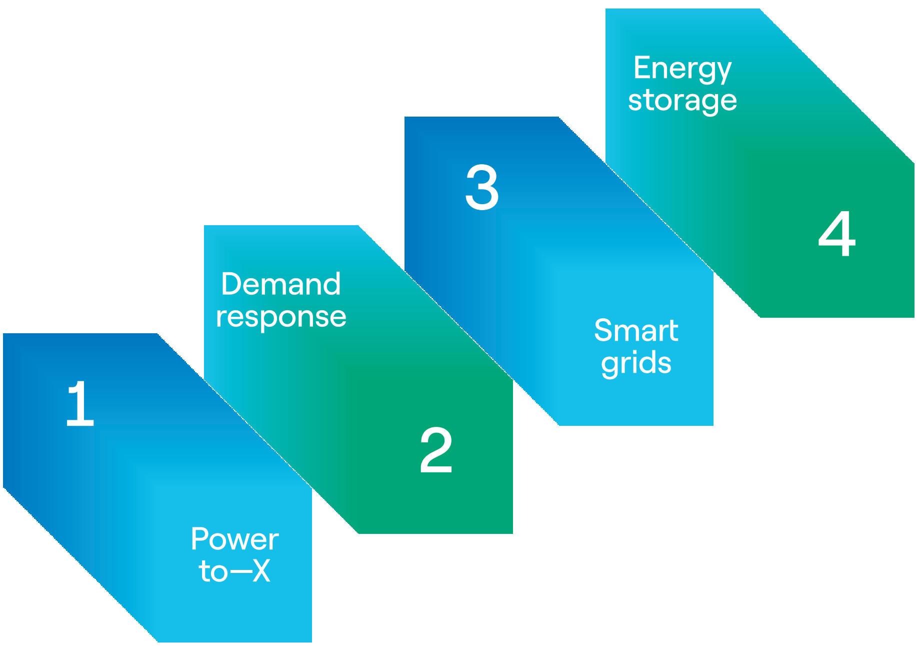
Source: PRIMES model.

Within the scope of energy efficiency and energy savings initiatives, the "REPowerEU" plan defines a more ambitious European Energy Efficiency Target in 2030, **from 9% to 13%**. Considering the building sector, the measures envisaged are to **extend the Minimum Energy Performance Standards for buildings**, in addition to the already stated goal of improving the energy performance of existing buildings (15% of European buildings stock belongs to the lower energy efficiency category), also **boosting the renovation rate** (for instance, by reducing VAT for renovation projects and works in Member States), which is expected to **increase to 2.25%** from the 2% estimated under the "Fit for 55" proposals. National energy requirements for new buildings are to be consolidated; national heating system requirements for existing buildings are expected to be tightened, while national bans for boilers based on fossil fuels in existing and new buildings will be introduced (the Plan includes an anticipated end of Member States' subsidies for fossil fuel-based boilers from 2027 to 2025). As a result, in case of adoption and implementation, additional energy efficiency measures included in the "REPowerEU" would reduce **energy consumption in the residential sector by more than 6% compared to the "Fit for 55" package** in 2030 (174 million tonnes of oil equivalent versus the 186 million of the "Fit for 55" scenario).

→ CROSS-SECTORAL SOLUTIONS

On top of sector-specific technologies, there are other technologies that must be considered in the Study to achieve the "Net Zero" target by **2050** and that **transversely** impact multiple markets and sectors. In particular, **4 possible cross-sectoral solutions** that might help to achieve the "Net Zero" target by 2030, 2040 and 2050 have been identified: Power-to-X, smart grids, energy storage and demand response.

FIG 47 → Cross-sectoral technologies to achieve "Net Zero" target by 2030, 2040 and 2050



Source → The European House - Ambrosetti and Enel Foundation elaboration on different sources, 2022.

A first technology to take into account for decarbonization in the long run is the one that has to do with the transformation of electrical energy into other energy carriers (**Power-to-X**). Although every transformation results in a loss of energy, these new energy carriers will be able to contribute significantly to the **decarbonization of hard-to-abate sectors**. The following transformations head in the direction just described:

- **Power-to-Heat** (conversion of electricity into heat). The primary purpose of these technologies is to make the system flexible. In the case of **daily storage**, the heat produced can be accumulated and subsequently used to cover the loading points of district heating networks (typically in the morning and evening during the thermal season). In the case of **seasonal storage**, the heat accumulated during the summer can be distributed during the winter months, contributing to the decarbonization of electrical district heating networks by absorbing the overgeneration related to renewable sources and transforming it into heat.
- **Power-to-Hydrogen** (conversion of electricity into hydrogen). These technologies allow **breaking down water molecules into hydrogen and oxygen** through the passage of electric current. With electrolysis, it is possible to obtain an energy carrier that can be sent: *(i)* to the final sectors (e.g., hydrogen heavy vehicles); *(ii)* industries using hydrogen as a feedstock in specific production processes; *(iii)* the production of synthetic fuels; *(iv)* gas blending to be fed into the methane gas network. With regard to this last point, it is worth mentioning that **gas blending** entails **significant disadvantages**. The Fraunhofer Institute for Energy Economics and Energy System Technology highlights the limitations and cost of hydrogen blending in the European gas grid at the transport and distribution level. In particular, according to their study, adding up to 20% green hydrogen to gas grids would be expensive, wasteful, technically complex to achieve and would reduce carbon emissions by a far lower amount than other uses of that H_2.
- **Hydrogen-to-Gas** (conversion of hydrogen into methane gas). Through hydrogen and carbon dioxide it is possible to synthetically produce **methane**, useful for decarbonizing final sectors that are hard to abate. In the face of an inevitable loss of energy due to the conversion of hydrogen into methane, the opportunity offered by methanation is the production of an **energy carrier easier to manage than hydrogen**, in fact: *(i)* there are already infrastructures for the transport, distribution, storage of methane on a large scale (unlike hydrogen, synthetic methane can be directly stored in traditional geological storage sites of natural gas and represents, therefore, an interesting possibility of seasonal storage of overgeneration from renewable sources); *(ii)* it is not necessary to convert the technologies that currently use gas, in particular in the final sectors (such as domestic boilers), to hydrogen. However, the solution presents several disadvantages: (i) it is needed to spend more energy for the convertion step, both to capture CO_2 and to synthesize the methane; (ii) in order to obtain environmental benefits, a non-fossil source of CO_2 is needed.
- **Hydrogen-to-Liquid**[55] (conversion of hydrogen into liquid fuels). Liquid fuels can be produced synthetically according to appropriate chemical reactions that combine hydrogen and CO_2. This way, **strategic energy carriers can be obtained for the decarbonization of transport**, in particular for sectors that are difficult to electrify (aircraft, ships and heavy road transport). In the face of an inevitable loss of energy due to the conversion of hydrogen into hydrocarbons (as well as the supply of CO_2), it is possible to maintain the internal

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It should be noted that hydrogen fuels are being considered for the decarbonization of isolated systems.

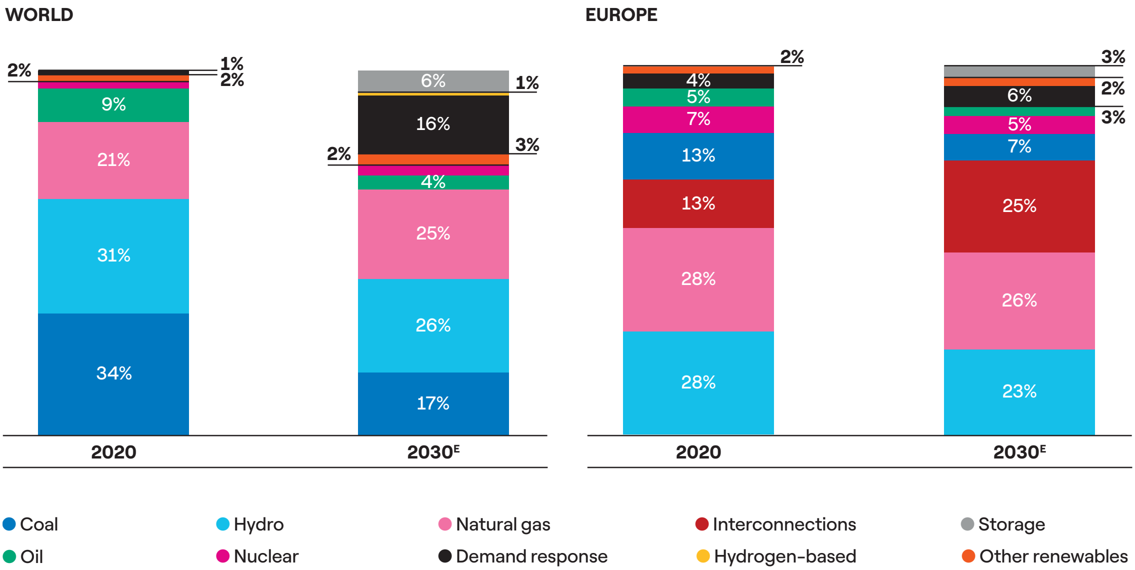
combustion engines currently in use in transport and exploit the current distribution and storage infrastructure of liquid fuels. On the other hand, it is important to highlight a great limitation of these technologies: in fact, the production of these energy carriers is a critical issue since it will involve **additional electricity consumption**. Overall, the Power-to-Gas and Power-to-Liquids processes to create synthetic fuels using hydrogen all have a rather **low efficiency**, and therefore **make sense only when it is not possible to decarbonize otherwise**. To decide what to develop first it is essential to follow the criterion of maximum efficiency: therefore, in the first instance, it is crucial to use all possible renewables to electrify everything that is directly electrified with green technologies.

With regard to Power-to-Gas-to-Power technologies, they might be able to play a significant role with the increase in the installed capacity of **non-programmable renewables** (especially wind and photovoltaic), characterized by production fluctuations: this will mean that, many times of the year, **electricity production will exceed consumption**. After meeting the daily balance of final electricity consumption (via pumped hydro storage and batteries), the additional overgeneration could be transformed into **heat or hydrogen** and, subsequently, into other energy forms or carriers.

It is important to mention some other technologies which head towards a more **flexible energy system**. In particular, this category includes **energy storage**, **demand response** and **smart grid**, which sum up to dispatchable power generation. In fact, rapidly scaling up these technologies will be critical to address the hour-to-hour variability of wind and solar PV, especially as their share of generation will rapidly increase. Spain has attached particular attention to this topic, defining its "Estrategia de Almacenamiento Energético". After defining the various available storage technologies, the strategy explains their potential contribution, in a combined manner, to provide the flexibility required for the system's gradual decarbonization, towards climate neutrality. In fact, synchronous storage can reduce dependence on fossil fuels by restoring certain characteristics of thermal power plants, such as synchronous inertia, synchronous voltage control and instantaneous reactive current supply, all to ensure a renewable and gas-free energy system.

To date, conventional thermal and **hydropower plants are the primary sources of system flexibility**, helping to accompany the increasing share of renewable energy sources. However, looking forward, in 2030 there will be other technologies that will provide further flexibility to the energy system, such as – in particular – **batteries** (that will account for 6% of the system flexibility) and **demand response** (that, at a global level, will account for 16% of system flexibility, recording an increase of 15 percentage points compared to 2020). At present, Europe benefits from a range of different flexibility sources: 28% from hydropower and natural gas, 13% from interconnections and coal, 7% from nuclear, 5% from oil, 4% from demand response and 2% from other renewables. However, the phase-out of coal, nuclear plant retirements and impacts of climate change on hydro availability will lead to a reduction in traditional flexibility sources (–5 percentage points coal, -2 percentage points nuclear, -5 percentage points hydro). On the other hand, there will be an increase in new flexibility sources, such as interconnection (+12 percentage points), demand response (+2 percentage points) and storage (+3 percentage points).

FIG 48 → **Electricity system flexibility by source at global and European level, 2020 and 2030E** (% values)

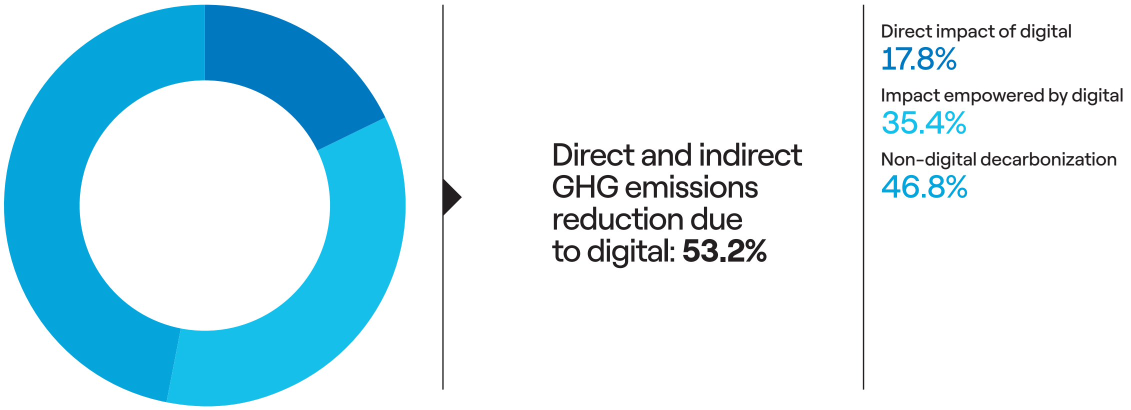


Source → The European House - Ambrosetti and Enel Foundation elaboration on IEA, 2022.

Moreover, it is worth mentioning that the energy transition goes hand in hand with the **digital transition**, which represents an enabling factor for the full deployment of the benefits deriving from decarbonization. In this sense, a key lever among the cross-sectoral solutions has to deal with **digitalization** in the management of transmission and distribution networks and in the production part of the energy chain.

As a matter of fact, **digital technology – directly or indirectly – will contribute to reducing Italy's emissions by 53.2% by 2050**. Of these, **17.8%** will be reduced thanks to a **direct contribution** (logistics and production optimization, smart cities, autonomous driving, mobility as a service, smart grids, digital platforms for the circular economy, etc.), while **35.4%** will be enabled **indirectly** (energy communities, hydrogen integration to the grid, etc.) thanks to the impulse that digital technology can provide to further technologies, processes and infrastructures.

FIG 49 → **Contribution of digital technology to decarbonization** (% values on total emissions to be reduced by 2050)



Source → The European House - Ambrosetti and Enel Foundation elaboration on "*Verso una "Net Zero" society: tecnologie e strategie digitali per un mondo a emissioni zero*" by The European House – Ambrosetti and Atos, 2022.

Overall, the combination of the technologies available in the energy sector and the innovation provided by digitalization and ICT technologies could represent the **winning option** to effectively and positively face the challenges of the energy transition through electrification.

→ Cross-sectoral technologies: the impact of "REPowerEU"

The aforementioned cross-sectoral technologies will be significantly impacted by "REPowerEU". In particular, the strategy pays great attention to the acceleration on the development and application of hydrogen: the overall quantitative goal set by the new Hydrogen Accelerator is the development of **10 million tonnes of domestic renewable hydrogen production** and **10 million tonnes of renewable hydrogen imports by 2030**, to be achieved through new financing of hydrogen-related projects under Horizon Europe, a regulatory framework development that should boost the production, consumption and market developments of renewable and low-carbon hydrogen, and the establishment of a Global European Hydrogen Facility and of a Green Hydrogen Partnerships to incentivize renewable hydrogen production and global trade. According to PRIMES modelling, upscaling the use of renewable hydrogen would accelerate decarbonization and greatly reduce the EU's dependence on Russian natural gas by approximately 27 billion m^3 in 2030.

In "REPowerEU", the potential of hydrogen consumption is higher in all sectors if compared to the "Fit for 55" scenario. The difference between the two scenarios, computed with the PRIMES model, amounts to almost 10 million tonnes of hydrogen consumed in 2030. For this reason, cross-sectoral technologies based on hydrogen will benefit from additional measures introduced by the "REPowerEU" plan.

FIG 50 → **Hydrogen use by sector in the "REPowerEU" scenario, 2030** (kt)

	"REPowerEU"	"Fit for 55"	Difference
Refineries	2,273	613	+1,660
Industrial Heat	3,629	756	+2,873
Transport	2,319	882	+1,437
Petrochemicals	3,232	1,306	+1,925
Blast furnaces	1,520	1,152	+368
Synthetic fuels	1,788	1,870	-82
Power Generation	105	0	+105
Blending	1,335	0	+1,335
Total	**16,200**	**6,579**	**+9,621**

Source → The European House - Ambrosetti and Enel Foundation elaboration on European Commission, 2022.

Besides hydrogen technologies and infrastructure development, "REPowerEU" includes **further investments in the grid**: in fact, to increase and strengthen the flexibility of the grid, the Plan envisages **39 billion Euros of additional investments in the power grid and storage** in the 2022-2030 period. The electricity transmission and storage projects to be implemented to make the grid fit for the increased use and production of electricity are included in the list of PCIs (Projects of Common Interest). "REPowerEU" plan aims at accelerating their implementation. The Plan aims at promoting a partnership for **sustainable production and use of biogas and biomethane** at EU, national and regional level, and its injection in the gas pipelines. The Plan will promote the adaptation and adjustment of existing and the deployment of new infrastructure for the transport of increased shares of biomethane through EU gas pipelines.

2.4

A promising energy mix to increase energy efficiency and reduce GHG emissions in Italy and Spain

From the previous analysis and considerations, **electricity** emerges as the critical energy vector to achieve "Net Zero" targets in 2050. In addition, the inclusion of green hydrogen (see Power-to-Hydrogen, previously mentioned) as a new innovative energy vector, together with bio-energies, will lead to massive increase in the share of renewables in 2050. Hence, direct electrification will be complemented by indirect electrification, thanks to hydrogen and Power-to-X technologies, in order to decarbonize hard-to-abate sectors.

This situation is particularly evident in Italy, where **electricity will contribute to more than half of final energy consumption** in the Decarbonization scenario in 2050 (55%), according to the Italian long-term strategy. Within this scenario, **gas** – either renewable or non-renewable – will play a residual role, although it will be a useful way to progressively shift from fossil fuel technologies to clean ones. As a matter of fact, according to the Italian long-term strategy energy scenario, in the long term gas will contribute only to 4% of the final energy consumption (vs. a more significant role in the 2050 Reference scenario, where natural gas still contributes to 24% of the total final energy consumption).

Although Italy's long-term strategy is already in line with the technology analysis described above, it is possible to imagine an **even more ambitious scenario at 2050 for the country's decarbonization**. Therefore, a "Net Zero" scenario has been elaborated by integrating the greater ambitions set out by the "Fit for 55" package and including the economic and environmental impacts of COVID-19. This scenario has been compared to a "Low Ambition" scenario, which has been elaborated starting from the reference scenario of the Italian Long-Term Strategy to which a more ambitious decarbonization trend from 2030 to 2050 was added.

FIG 51 → **The scenario from the Italian long-term strategy** (left column) **and the update scenarios integrating greater ambitions set out by the "Fit for 55" package** (right column)

Scenarios from Italian LTS	Updated scenarios
Reference scenario: Designed to reach the **PNIEC** target up to 2030 It follows an **inertial trend** from 2030 to 2050	**"Low Ambition" scenario:** Like the Reference scenario, but including: **a more ambitious trend** from 2030 to 2050, based on a recalibration of "EU Reference Scenario 2016" data.
Decarbonization scenario: Designed to reach a **"Net Zero"** economy by 2050 Does not consider the increased ambition of the **"Fit for 55"** targets by 2030	**"Net Zero" scenario:** Like the Decarbonization scenario, but including: ● The higher ambitions set by **"Fit for 55"** for 2030. ● The economic and environmental impacts of **COVID-19** on the scenario.

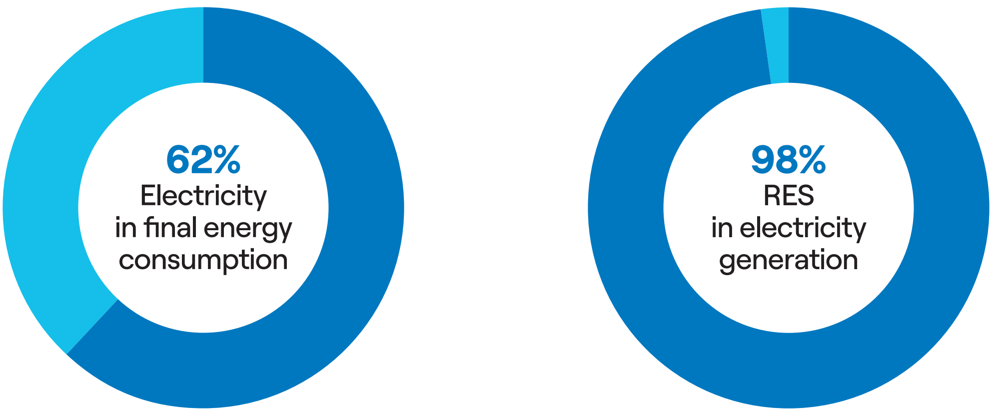
Source → The European House – Ambrosetti and Enel Foundation elaboration on Enel internal data, 2022.

The "Net Zero" scenario foresees a **62%** penetration of the electric vector in final energy consumption by 2050 and a **98%** penetration of renewables for electricity generation by 2050. Looking at the targets in 2030, in Italy a 32% penetration of the electric vector is expected in final energy consumption in the "Net Zero" scenario (vs. 28% in the "Low Ambition" scenario). At the same time, the share of RES in electricity generation will be equal to about 64% in 2030 in the "Net Zero" scenario (vs. 55% in the "Low Ambition" scenario).

FIG 52 → **Key figures of the Italian "Low Ambition" scenario and "Net Zero" scenario, 2050**

"Low Ambition" scenario

"Net Zero" scenario



Source → The European House – Ambrosetti elaboration on Enel internal data, 2022.

The importance of electrification is pointed out in the Spanish long-term strategy as well. The Spanish NECP – which represents the basis of the Spanish long-term strategy - was evaluated by the European Commission as very ambitious in terms of GHG emissions, renewable sources and energy security targets. In order to achieve carbon neutrality by 2050, Spain also defined its previously mentioned "Estrategia de Almacenamiento Energético", which highlights the importance of the development of energy storage technologies to ensure the required flexibility of the power grid to manage the higher electricity stream, and the "Hydrogen Roadmap: A Commitment to Renewable Hydrogen" plan, to which the business community is responding: Enagás, the Spanish energy company and transmission system operator that owns and operates the country's gas grid, is planning the largest hydrogen plant in Spain. This installation would involve an investment of 309 million Dollars. The project consists of a 32-MW electrolyzer, powered by a 150-MW photovoltaic plant. There will also be a warehouse for daily production of 12 tonnes of green hydrogen and other associated infrastructure.

FIG 53 → **The scenario from the Spanish long-term strategy** (left column)

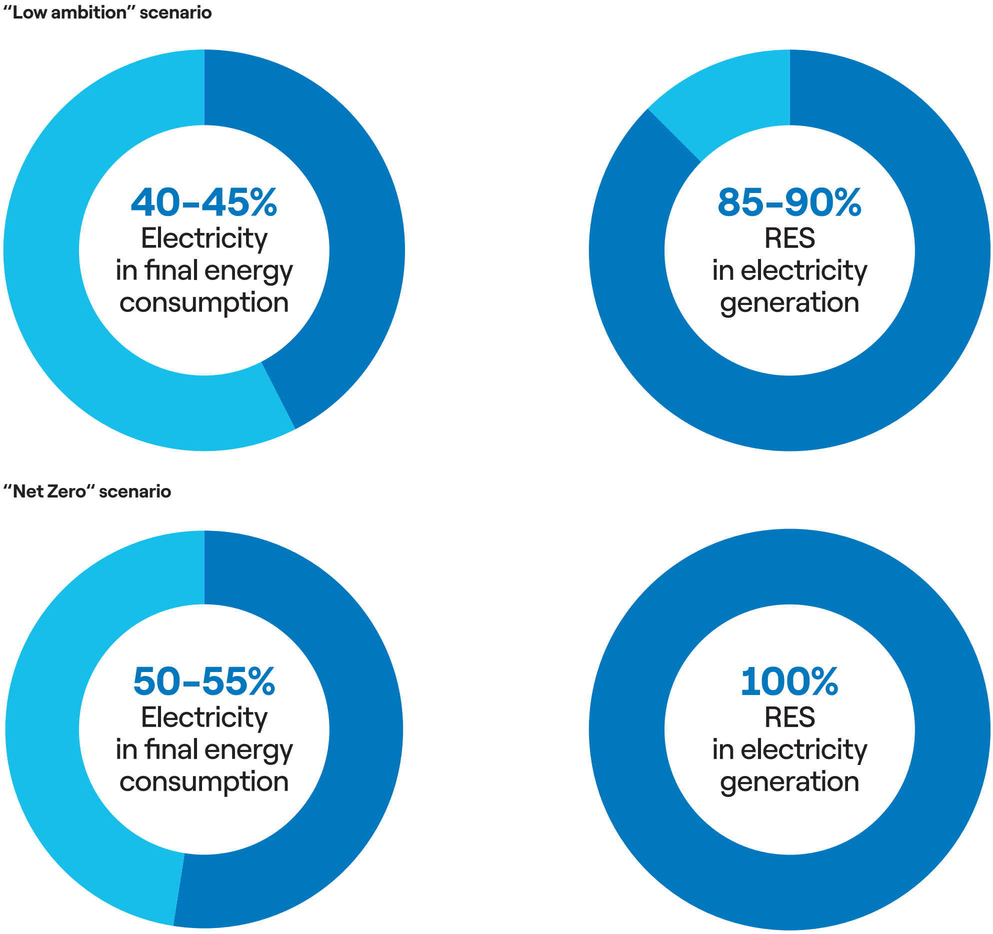
Scenarios from Spanish LTS	
"Low Ambition" scenario: It is based on NECP targets for 2030 (elaborated in 2020), which are projected to 2050	**According to the assessment made by the European Commission in October 2020 (months before the "Fit for 55"), the targets of the Spanish NECP were significantly more ambitious than EU requirements.**
"Net Zero" scenario: It is designed to reach a "Net Zero" economy by 2050	**Therefore, the scenarios from the LTS have been confirmed as starting point for the impacts' analysis.**

Source → The European House – Ambrosetti and Enel Foundation elaboration on Enel internal data, 2022.

Overall, according to the Spanish long-term strategy, the amount of electricity in final energy consumption is expected to increase from nearly 20 Mtoe to almost 25 Mtoe, recording the most significant increase (second only to renewable energy sources, which are assumed to shift from nearly 5 Mtoe to almost 25 Mtoe). On the contrary, the contribution of no-renewables sources is expected to dramatically decline, from about 55 Mtoe to less than 5 Mtoe. Overall, in the "Net Zero" scenario, the share of electricity in final energy consumption is expected to reach **50-55%**, with an intermediate share of **30% by 2030**.

In all, **97%** of final energy consumption will be covered by RES in the Decarbonization scenario (vs. 31% in 2020 and 64% in the Reference scenario), with an intermediate share of **70-75% by 2030**. Achieving this ambitious goal will be possible thanks to the deployment of renewable energy sources in the electricity generation sector, where they are expected to reach a value equal to **100%**.

FIG 54 → **Key figures of the Spanish "Low Ambition" scenario and "Net Zero" scenario, 2050**



Source → The European House – Ambrosetti elaboration on Spanish long-term strategy, 2022.

Part

The economic, social, environmental and energy benefits in Italy and Spain deriving from “Net Zero” and “Low Ambition” scenarios

t 3

Key Messages

1 → The previous Part illustrates the **two scenarios** identified for Italy and Spain: “Net Zero” and “Low Ambition”, with the former envisaging a more determined decarbonization path than the latter. The scenarios are articulated over four sectors - power generation, transport, buildings, and industry - and define the energy and technology mixes needed to reach the scenarios’ targets (in Spain these are based on the Long-Term Strategies, whilst in Italy the targets set in the Long-Term strategy incorporate higher ambition). The impact assessment model requires an **estimation of the investments needed** for the deployment of specific technologies in each scenario. To achieve this, for both Italy and Spain from 2021 to 2050, an estimation of the investments for each of the sectors reported in Part 2 was carried out.

2 → Overall, considering power (including power networks), transport, buildings and industry, the “Net Zero” scenario **requires less resources** compared to the “Low Ambition” scenario. In Italy, while the “**Low Ambition**” scenario needs around 3,899 billion Euros of investments, the “Net Zero” scenario requires **3,351** billion of investments, **548** billion less than the “Low Ambition”, with a major role played by **trans-**

port and a relevant share of investments to be carried out in the **2031-2040 period**. In Spain, the "Low Ambition" scenario will need **2,761 billion Euros** of investments, while the "Net Zero" scenario will encompass **2,215 billion Euros** of investments, around **546 billion** Euros less than the "Low Ambition" one.

3 → The different assumptions underlying the scenarios explain the differences in terms of investments. For **transport**, in particular, in both countries the "Net Zero" scenario envisages fewer passenger cars up to 2050 thanks to **shared mobility** and more sustainable behaviors, quicker deployment of sustainable vehicles, lower cost of sustainable vehicles, and lower charging point per vehicle ratios. The sum of these considerations translates into lower investment costs in the "Net Zero" scenario both in Italy and Spain.

4 → The impact of the investments in the two scenarios is calculated on four dimensions: 1) **economic and social impacts**; 2) **reduction of pollution**; 3) **savings in fossil fuel expenditures**; 4) **energy security and independence**.

1. With regards to **economic benefits**, in both Italy and Spain investing in **the "Net Zero" scenario produces a better** and more efficient **impact on the economy**. In fact, the **GDP/investment ratio is better** than in the "Low Ambition" scenario (1.64 vs 1.59 in Italy and 1.28 vs 1.23 in Spain). This means that **the "Net Zero"**

scenario not only **requires fewer resources** than the "Low Ambition"one but, for each Euro invested, also **generates a better** (€0.05 more) **economic effect** than the "Low Ambition" scenario. As for **social benefits**, the "Net Zero" scenario creates more jobs than the "Low Ambition" scenario (**2.6 million jobs** vs 2.1 in the "Low Ambition" one in Italy and **1.8** vs 1.7 jobs in the "Low Ambition" one in Spain).

2. The reduction of pollution generates a positive effect on public health. The savings connected with the reduction of diseases, improved productivity and the avoidance of premature deaths made possible by the reduction of pollution in the "Net Zero" scenario amount to around **614 billion Euros** in Italy and **317 billion Euros** in Spain.

3. Regarding savings in fossil fuel expenditures, for Italy the benefit would be equal to **1,914 billion Euros in the "Net Zero" scenario compared to a Counterfactual scenario** in the 2021-2050 period (851 billion Euros in the "Low Ambition" scenario). With regards to Spain, fossil fuel savings would be equal to **1,279 billion Euros in the "Net Zero" scenario compared to a Counterfactual scenario** in the 2021-2050 period (702 billion Euros in the "Low Ambition" scenario).

4. Lastly, in terms of **energy security and independence**, the "Net Zero" scenario would permit a **significant reduction in both gas intensity of GDP and energy dependence.**

- In Italy, in the **"Net Zero"** scenario the **gas intensity of GDP index in 2050 will be 94% lower than today** (1.9 toe per million Euros of GDP vs. 34.9 in 2020), while **in Spain it will be 92% lower** (1.9 toe per million GDP in 2050 vs. 23.3 in 2020).
- The "Net Zero" scenario would also allow a **strong reduction in the energy dependence index. In Italy** energy dependence decreases to **56.7% in 2030** and **0% in 2050**, vs. today's 73.5%. In Spain it could reach **61% in 2030** and **13% in 2050** vs. today's 67.9%.

3.1

Estimation of the investments at the basis of the impact assessment model

The previous Part illustrates the **two scenarios** identified for Italy and Spain: "Net Zero" and "Low Ambition", with the former envisaging a more determined decarbonization path than the latter. The scenarios are articulated over four sectors - power generation, transport, buildings and industry - and define the energy and technology mixes needed to reach the scenarios' targets (in Spain these are based on the Long-Term Strategies, whilst in Italy the targets set in the Long-Term strategy incorporate higher ambition). The impact assessment model requires an **estimation of the investments needed** for the deployment of specific technologies in each scenario. To achieve this, for both Italy and Spain from 2021 to 2050, an estimation of the investments for each of the sectors reported in Part 2 was carried out.

In particular, The European House – Ambrosetti and Enel Foundation developed a methodological approach to **break down the investments**, starting with the "Net Zero" and the "Low Ambition" scenarios depicted for Italy and Spain and the corresponding **energy and technology mixes**. The latter are the result of projections by the research team based on the Long-Term Strategies data.

→ POWER

For the power sector, the starting point was an estimation of the **expected capacity installed** from 2021 to 2050. Then, for all the technologies taken into consideration in the power sector (ranging from fossil fuel technologies to renewables, as shown in Figure 1), the **differential capacity** in terms of GW from 2021 to 2050 was calculated.

Subsequently, the **investments needed**, expressed in Euros per GW, were estimated **for each technology** in the power sector, using the technology assumptions reported in the PRIMES model as a reference[1].

Finally, combining the additional capacity (GW) found in the first step with the required investment cost (Euros/GW), it was possible to estimate **the overall investment required for each power generation technology from 2021 to 2050**.

1
Techno-economic assumptions of the PRIMES model, E3 modelling, October 2019.

FIG 1 → **The methodological approach to break down the investments by technology in the power sector in Italy and Spain**

Power sector

Sources for Italian data	Analysis at the Italian and Spanish level	Sources for Spanish data
PRIMES	**Capacity by solutions (kW)** Coal, gas, oil, nuclear, hydro, wind, solar, batteries, Power-to-X, demand response	**LTS and NECP**
PRIMES	**Cost by solutions (Euros/kW)** Cost (2021-2050) for each power solution	**PRIMES**
PRIMES and IEA	**Investment cost by solutions (Euros)** Absolute capital expenditure (2021-2050) for each power solution	**LTS, NECP and PRIMES**

Source → The European House - Ambrosetti and Enel Foundation elaboration of PRIMES, IEA, Long-Term strategies and NECP data, 2022.

→ TRANSPORT

For the transport sector, the starting point was the **cost** (in Euros) of each vehicle in the 2021-2050 period. To this end, the PRIMES model[2] provides estimates for each type of **vehicle** (passenger cars, light commercial vehicles, buses, heavy goods vehicles and motorbikes) **according to powertrain** (Internal Combustion Engine, Plug-in Hybrid, Electric Battery, Fuel Cell, LPG and CNG) but also in terms of Charging Points (CPs). In particular, given that the model provides for different cost options, the weighted average was adopted.

After that, the **evolution of the number of vehicles** in each fleet and specifically the composition of the fleet in terms of powertrain was estimated, starting with the 2020 historical data of Italy and Spain[3]. Given these estimates, the **number of charging points** required was estimated on the basis of various sources[4]. In particular, up to 2030, the following was estimated: 1 public CP for 6 electric vehicles and 1 private CP for 3 EVs for the "Net Zero" scenario; between 2031 and 2050, 1 public CP for 4 EVs and 1 private for 2 EVs was assumed. Regarding the "Low Ambition" scenario, fewer CPs per vehicle were hypothesized: in particular, up to 2030, 1 public CP for 15 EVs and 1 private CP for 8 EVs; in the 2031-2050 period, 1 public CP for 8 EVs and 1 private CP for 4 EVs.

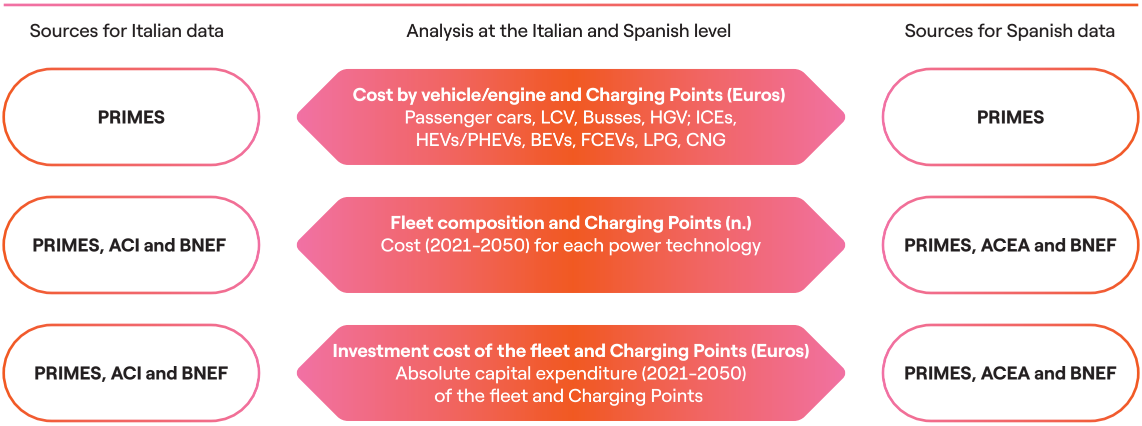
Finally, combining the investment cost with the number of vehicles and infrastructures, **the overall investment required for each vehicle (and infrastructure) from 2021 to 2050** was estimated.

2
Techno-economic assumptions of the PRIMES model, E3 modelling, October 2019.

3
Source: ACI and ACEA.
4
Source: AFIR, ACEA, IEA, EPBD, and BNEF.

FIG 2 → **The methodological approach to break down the investments by technology in the transport sector in Italy and Spain**

Transport sector



Source → The European House – Ambrosetti and Enel Foundation elaboration of PRIMES, ACI, BNEF and ACEA data, 2022.

→ BUILDINGS

As a starting point, the European House – Ambrosetti and Enel Foundation estimated the **final energy demand of buildings** in the 2021-2050 period, taking into account the different evolution over time of the "Net Zero" and "Low Ambition" scenarios.

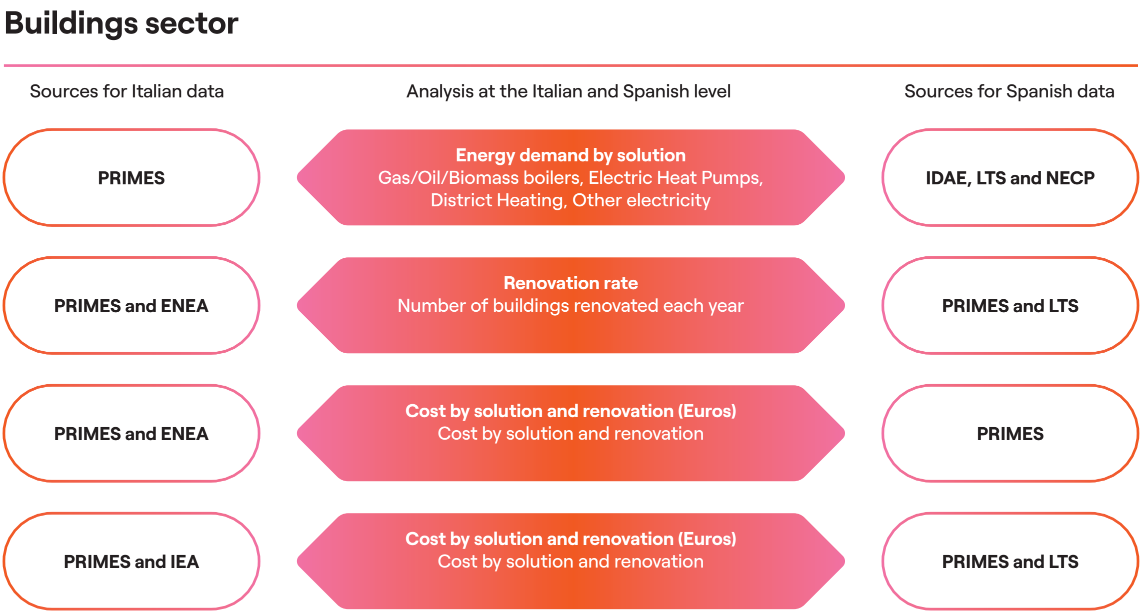
Subsequently, the **share of energy carriers from 2021 to 2050 and the corresponding technologies** (gas, oil and biomass boilers, electric heat pumps, district heating and other electricity applications, such as cooking, appliances, lighting and cooling) were identified for both scenarios. From this basis, it was possible to obtain the energy demand by technology, multiplying the share of energy carriers for the expected final energy demand. The final goal of this step was to obtain the **differential energy demand by technology from 2021 to 2050**.

Considering that the drivers for the decarbonization of the buildings sector are both technological solutions and more efficient buildings, an additional step involved the estimation of the number of **buildings renovated** each year. Starting from an estimate of the number of buildings in the 2021-2050 period and employing data from the Long-Term Strategies, different **renovation rates** were assumed both in Italy and Spain for both scenarios, thus making it possible to calculate the number of renovated buildings.

The next step was the **economic quantification of the differential demand** and of the renovation of buildings. To obtain this, the investment cost for each technology and for building renovation work was considered.

Finally, the investment costs for each technology and for the renovation of buildings were summed to obtain the **overall investment required** in both scenarios.

FIG 3 → **The methodological approach to break down the investments by technology in the buildings sector in Italy and Spain**



Source → The European House - Ambrosetti and Enel Foundation elaboration of PRIMES, ENEA, IEA, IDEA, Long-Term strategies and NECP data, 2022.

→ INDUSTRY

For the industry sector, the starting point was the breakdown of the industry sector into the main sub-sectors, namely: **chemicals, iron and steel, non-metallic minerals and other**.

On the basis of the disaggregation performed in the previous step, The European House – Ambrosetti and Enel Foundation divided the **overall final energy demand in the industry sector into the sub-sectors considered**, taking into account its evolution over time.

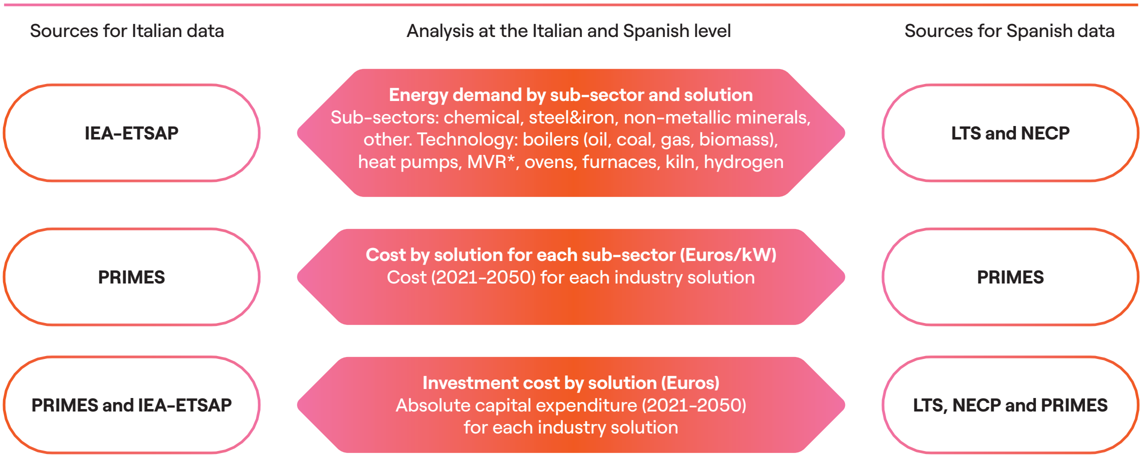
Subsequently, the **share of energy carriers from 2021 to 2050** and the **corresponding technologies** were identified for both scenarios. On this basis it was possible to determine the energy demand by technology, multiplying the share of energy carriers by the final energy demand expected in the sub-sectors. The final goal of this step was to obtain the **differential energy demand by technology from 2021 to 2050**.

The next step was the **economic quantification of the differential demand** calculated in the previous step. To determine this, the investment costs for each technology was considered.

Finally, the investment costs for each technology across all the sub-sectors considered were summed to calculate the **overall investment required** in both scenarios.

FIG 4 → **The methodological approach to break down the investments by technology in the industry sector in Italy and Spain**

Industry sector



* Mechanical Vapor Recompression.

Source → The European House - Ambrosetti and Enel Foundation elaboration of PRIMES, IEA, Long-Term strategies and NECP data, 2022.

On top of the estimated investments detailed above, The European House – Ambrosetti and Enel Foundation developed a methodological framework to calculate the **investments required in the power networks**.

Indeed, the **significant estimated penetration of new renewable energy sources** will be accompanied by investments in the power networks, which will play a crucial role in enabling the deployment of renewables and electrification. In particular, the investments considered in the power networks are those aimed at the **integration of renewable energy sources**[5].

The calculation of capital expenditure was carried out including **both transmission and distribution costs**[6]. Moreover, the analysis was based on the latest Italian and Spanish data (2021-2030)[7] for the two scenarios. The investments were calculated based on literature-sourced[8] **average investments in power networks per GW of renewable energy sources installed**.

As a result of these assumptions, power network investments in Italy are equal to about **214 billion Euros in the "Net Zero" scenario and 190 billion Euros in the "Low Ambition" scenario**, due to the higher penetration of renewable energy sources installed.

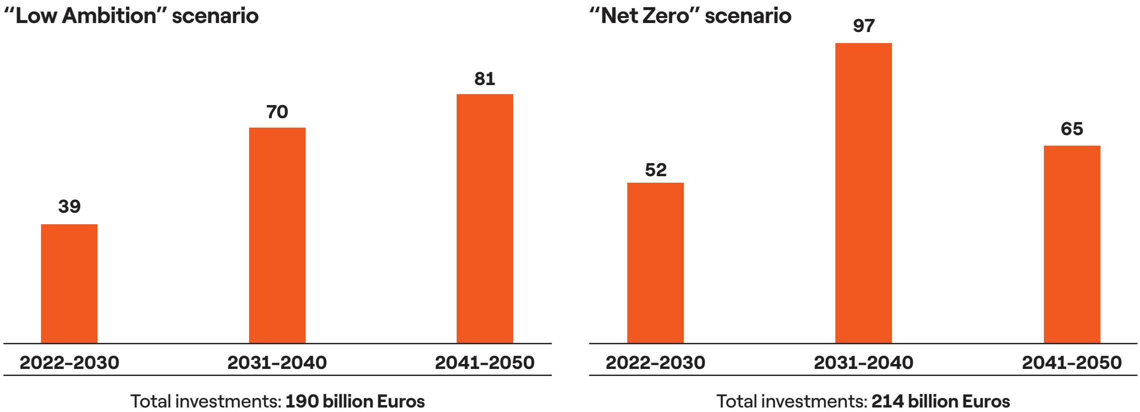
5
Tying costs to the installed power of renewable energy sources is a methodological simplification. Indeed, investments in networks also depend on sectorial (residential, industrial and transport) electrification.

6
This assessment does not include the lower investments that might be needed if flexibility services were actually enacted on a large scale.

7
The estimation of investments in power networks is based on Enel internal data, Terna, Red Eléctrica de España (REE) and Asociación de Empresas de Energía Eléctrica – AELEC data.

8
Ibidem.

FIG 5 → **Power network investments in the "Low Ambition" scenario** (left chart) **and "Net Zero" scenario** (right chart) **in Italy** (absolute values in billion Euros)

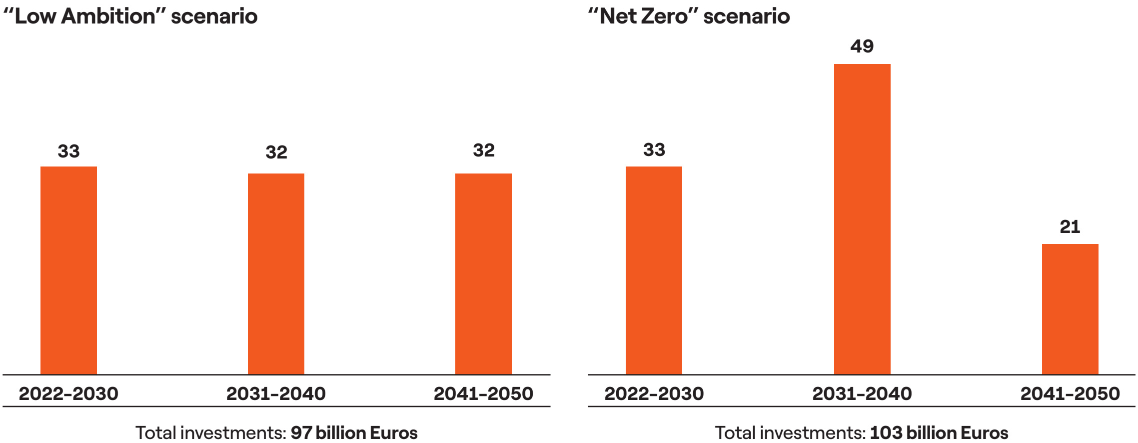


N.B. The estimated investments in power networks are based on Enel internal data and Terna data. Power network investments include both distribution and transmission investments, in particular: electrification of final uses, emission-free generation, modernization, digitalization, resilience, smart meters and storage.

Source → The European House - Ambrosetti and Enel Foundation elaboration, 2022.

With regards to Spain, like for Italy, the "Net Zero" scenario compared with the "Low Ambition" scenario entails a **greater penetration of renewables**, especially between 2020 and 2040. Overall, the investments in power networks are lower compared to those in Italy: **103 billion Euros** in the "Net Zero" scenario and **97 billion Euros** in the "Low Ambition" scenario.

FIG 6 → **Power network investments in the "Low Ambition" scenario** (left chart) **and "Net Zero" scenario** (right chart) **in Spain** (absolute values in billion Euros)



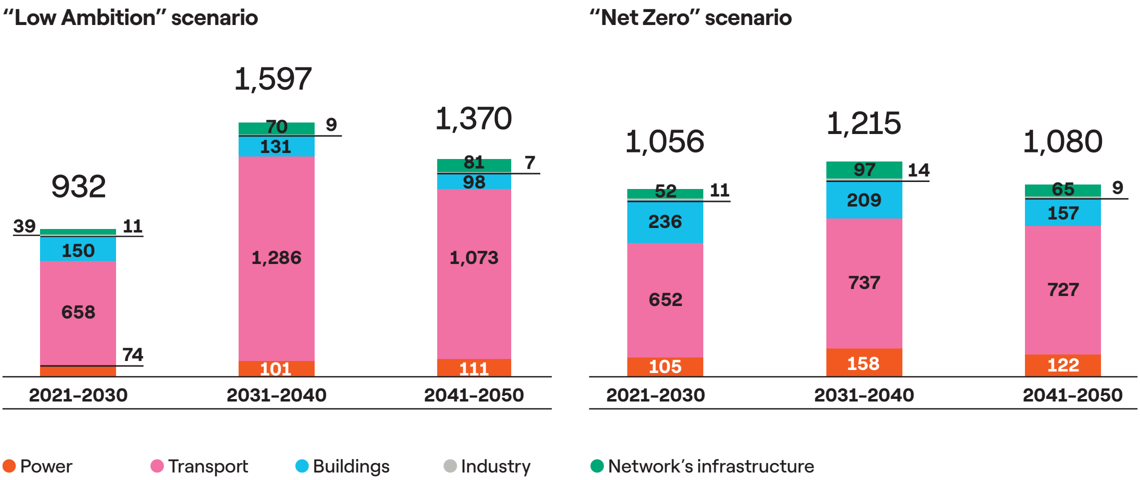
N.B. The estimated investments in power networks are based on Enel internal data and REE data. Power network investments include both distribution and transmission investments, in particular: electrification of final uses, emission-free generation, modernization, digitalization, resilience, smart meters and storage.

Source → The European House - Ambrosetti and Enel Foundation elaboration, 2022.

→ OVERALL ESTIMATES OF INVESTMENT COSTS

Overall and sectoral estimates are shown in the Figure below. The "Net Zero" scenario **requires fewer resources** compared to the "Low Ambition" one. In Italy, while the "**Low Ambition**" scenario needs around **3,899 billion Euros** of investments, the "Net Zero" scenario requires **3,351** billion, **548** billion less than the "Low Ambition", with a major role played by **transport** and a relevant share of investments to be carried out in the **2031-2040 period**.

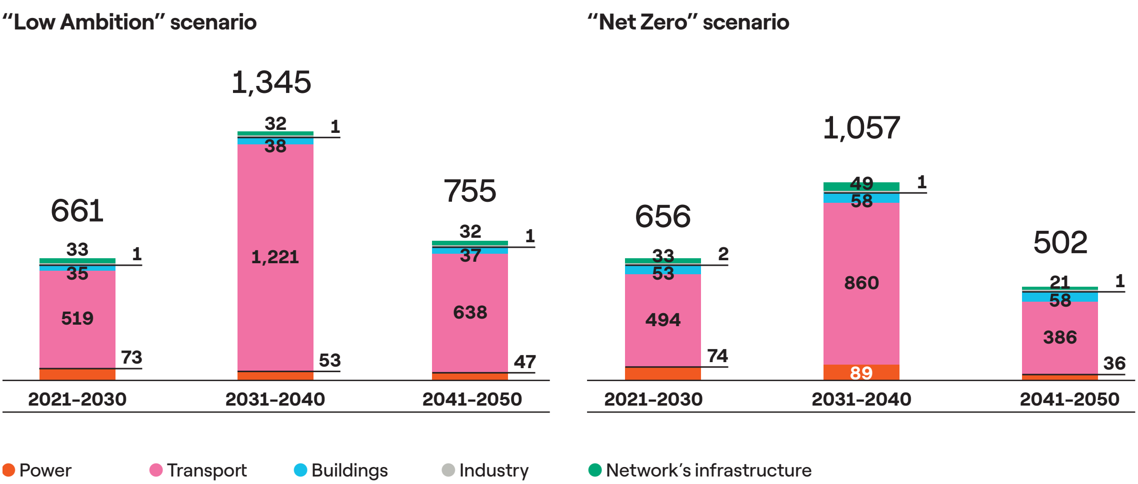
FIG 7 → **Investments per sector in the "Low Ambition" scenario** (left chart) **and "Net Zero" scenario** (right chart) **in Italy, 2021-2030, 2031-2040 and 2041-2050** (absolute values in billion Euros)



Source → The European House - Ambrosetti and Enel Foundation elaboration, 2022.

In Spain, the "Low Ambition" scenario will need **2,761 billion Euros** of investments while the "Net Zero" scenario will encompass **2,215 billion Euros** of investments, around **546 billion** Euros less than the "Low Ambition" scenario.

FIG 8 → **Investments per sector in the "Low Ambition" scenario** (left chart) **and "Net Zero" scenario** (right chart) **in Spain, 2021-2030, 2031-2040 and 2041-2050** (absolute values in billion Euros)



Source → The European House - Ambrosetti and Enel Foundation elaboration, 2022.

The different assumptions underlying the scenarios explain the differences in terms of investments. In both countries, for the **power** sector, the "Net Zero" scenario assumes a larger penetration of renewable energy sources, meaning a higher differential capacity installed and a greater use of flexible technologies (storage systems and demand side response), thus determining **higher investments needed**.

For **transport**, in both countries the "Net Zero" scenario envisages fewer passenger cars up to 2050. Indeed, in the "Net Zero" scenario electric vehicle penetration is comparatively cheaper and more convenient due to **falling battery costs, technological improvements** and **cheaper renewable power generation**, leading to a **lower total cost of ownership**. At the same time, **new business models** will develop, involving the **shared mobility paradigm**, **car-pooling** and **multi-modal transport**, encouraging a shift toward public transportation, the higher utilization rate of vehicles and an acceleration in more **sustainable behaviors** among citizens. The sum of these considerations translates into **lower investment costs** in the "Net Zero" scenario both in Italy and Spain.

As for the **buildings** sector, in both countries the "Net Zero" scenario estimates lower energy demand in the 2021-2050 period thanks to the improved efficiency of building stock, higher penetration of Electric Heat Pumps and the higher renovation rate of buildings. In terms of costs, the mix of higher penetration of Electric Heat Pumps and higher renovation rates determines **higher investment costs** in the "Net Zero" scenario.

Regarding the **industry** sector, in both countries the "Net Zero" scenario is associated with the greater electrification of consumption in all the sub-sectors considered, less use of fossil sources and wider presence of (green) hydrogen carriers. Like with the power and buildings sectors, the higher penetration of sustainable solutions determines **higher investment costs** in the aforementioned scenario.

3.2

Assessment of overall impacts

To estimate the overall impacts of the different scenarios, a **multi-factorial analysis** has been employed. In particular, the estimates regard:

- **Economic and social impacts**, through an econometric matrix (SAM) to analyze economic intersectoral interconnections and assess the impacts on **GDP** and **employment**.
- The **reduction of pollution**, through a marginal damage cost model to estimate the costs on health caused by PM and NO_x emissions and to assess the negative externalities connected to emissions.
- **Savings in fossil fuel expenditures**, through a quantitative model to estimate the savings in fossil fuel expenditures (coal, oil, gas) thanks to the higher penetration of RES and electrification of transport, buildings, and industry.
- **Energy security and independence**, through the analysis of the evolution of the **gas intensity of GDP and energy dependence indices** deriving from the two scenarios analyzed.

It is also worth mentioning that the results in terms of impacts are always represented as the difference between the **"Net Zero" scenario** and the **"Low Ambition" scenario** and between the two scenarios and a **Counterfactual scenario**, that represents the current business as usual projections[9].

3.2.1 SOCIAL ACCOUNTING MATRIX (SAM)

The **Social Accounting Matrix** (SAM) is a quantitative model which synthetically represents the entire economic system. More specifically, it is a **comprehensive and economy-wide database** that records data on transactions between economic agents in a certain economy during a certain period. Thanks to this analytical tool, it is possible to analyze intersectoral transactions, exchanges with and among actors (households, businesses, government, capital formation), with factors of production (labor and capital), and with the rest of the world.

9
For economic and social impacts the Counterfactual scenario indicates a scenario in which the same level of investment considered in the scenarios ("Net Zero" and "Low Ambition") was used for another project or for other production purposes, allocating the investments on the basis of the **historical trend over the past 10 years**. Instead, for the reduction of pollution and savings the Counterfactual scenario corresponds to the 2035 values of the "Low Ambition" scenario.

A SAM is a **square matrix** in which each account (representative of an activity, commodity, factor or institutional sector) is represented by a row and a column. Each cell shows the payment by column account to the account in the row. Therefore, the "receipts" or incomes of an account are shown along the row and "expenditures/payments" by the column. Because of this double entry accounting system, for each SAM account total revenues correspond exactly to the total payments and, as a result, the total of each row corresponds to the corresponding column total[10].

Moreover, the SAM represents an **extension of the Symmetric Input-Output Table** (SIOT). The traditional Input-Output framework is a key tool in the economic analysis as it provides a useful description of inter-sectorial relations. Nevertheless, the usefulness of these analyses is limited as they **cannot model the complete behavior of the economic system** and do not incorporate all economic transactions of the system. A SAM overcomes some SIOT limitations[11].

The first step of the analysis using the SAM model was the **breakdown of investments by technology and scenario** in 2021-2050, as illustrated in the first section of this Part. As a methodological note, additional annual investments for those technologies that see a reduction in their use (e.g. coal-fired power plants, ICE vehicles, etc.) are assumed to be zero, meaning that these industries will not encompass additional investments.

Secondly, the investment vector was reconstructed by dividing the investment value of each technology **between 65 sectors of the economy** (according to the ATECO code classification) over the period 2021-2050. The investment vector also considers the **relative share of imports**, by technology, netting out the multiplying effects that will not be retained in the country[12].

The reconstructed investment vectors and the Social Accounting Matrix have been multiplied to calculate the **net additional impacts on GDP and employment** of the "Net Zero" scenario compared with the "Low Ambition" one. In this part, the estimated GDP trends for Italy and Spain over the period 2021-2050 were incorporated in the analysis in order to update the Social Accounting Matrix.

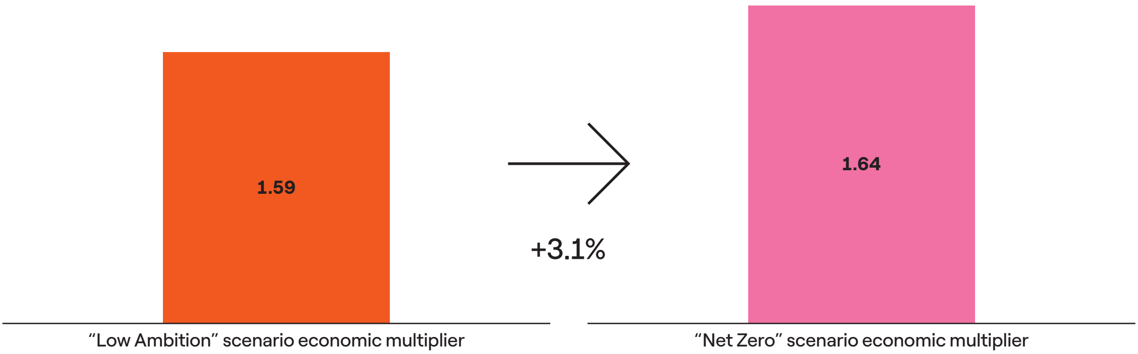
Finally, in order to evaluate the **net impacts** of the investments and compare the results against a 'historical' resource allocation scenario, a **Counterfactual scenario** was calculated where the same level of investment under consideration in the two scenarios was used for another project or for other production purposes, in line with the investments made over the last 10 years.

10
Source: Mainar-Causapé A.J., Ferrari E., and McDonald S. (2018) "*Social Accounting Matrices: basic aspects and main steps for estimation*", JRC Technical Note.
11
Ibidem.

12
Adjustments were included within the model to take into account the level of technology imports along the production value chain. For each technology subject to an investment estimation, a percentage of the value added generated by imports was applied. This percentage was estimated through the Comext and ProdCom databases, which return import and domestic production values for each technology in all European Union countries, and was assumed constant until 2050.

ITALY → According to the SAM, the investments of the "Net Zero" scenario have a **better and more efficient impact on the economy**. In fact, the **GDP/investment ratio** is better than in the "Low Ambition" one (1.64 vs 1.59). The economic multiplier indicates the direct, indirect and induced economic effect of the investment at stake. This means that the "Net Zero" scenario not only **requires fewer resources** than the "Low Ambition" one but, for each Euro invested, also generates a **better** (€0.05 more) **economic effect** than the "Low Ambition" scenario.

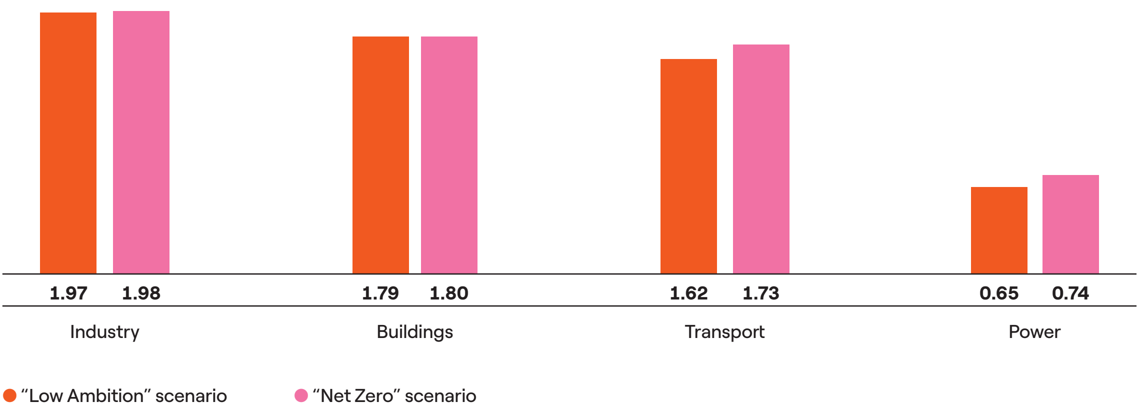
FIG 9 → **Economic multiplier in the "Low Ambition" scenario** (left chart) **and in "Net Zero" scenario** (right chart) **in Italy, including the import assumption, 2021-2050** (absolute values)



Source → The European House - Ambrosetti and Enel Foundation elaboration, 2022.

Among the sectors considered in the analysis, the highest **value-added effect** in the "Net Zero" scenario is obtained in the **industry sector**, with a 1.98 multiplier. In terms of the difference with the "Low Ambition" scenario, the widest gap is registered in the **power sector** (+14%) and transport (+7%).

FIG 10 → **Economic multiplier in the "Low Ambition" scenario and in "Net Zero" scenario in Italy by sector, 2021-2050** (absolute values)



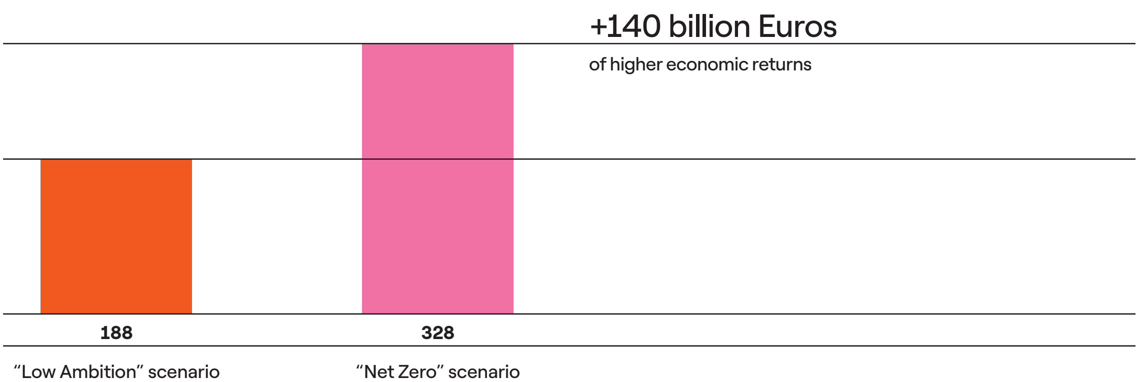
N.B. Investments in networks are included in the power sector.

Source → The European House - Ambrosetti and Enel Foundation elaboration, 2022.

As such, the "Net Zero" scenario is **more economically efficient** than the "Low Ambition" one for the decarbonization pathway. In fact, the estimated investments in the "Net Zero" scenario are **548 billion Euros lower** than in the "Low Ambition" scenario over the 2021-2050 period.

To analyze the **real net effect** of the investments in the "Low Ambition" and "Net Zero" scenarios, as described in the methodology, the impacts were compared with a **Counterfactual scenario**. This scenario indicates a scenario in which the same level of investment under consideration was used for **another project** or for other **production purposes**, allocating the investments on the basis of the **historical trend over the past 10 years**. From this analysis, it emerges that the "Low Ambition" scenario is able to generate **188 billion Euros** more than the Counterfactual scenario and that the "Net Zero" scenario has an additional impact of **328 billion Euros**, 140 billion Euros more than the less ambitious scenario.

FIG 11 → **Net economic returns from investments in the "Low Ambition" scenario** (left chart) **and in the "Net Zero" scenario** (right chart) **in Italy, compared to the Counterfactual scenario, 2021-2050** (value added, billion Euros)



Source → The European House - Ambrosetti and Enel Foundation elaboration, 2022.

Moreover, when it comes to social impacts, the "Net Zero" scenario generates **0.76 jobs (full time equivalent) for each million Euro invested**, compared to **0.52** jobs in the "Low Ambition" scenario. It is worth mentioning that the results in terms of jobs are reported as **net**. Indeed, the results include the jobs lost and gained and are calculated with respect to the **Counterfactual scenario**[13]. Therefore, the **difference** between the supported jobs in the "Net Zero" scenario and the "Low Ambition" scenario compared to the relative Counterfactual scenario, indicates the **net supported jobs** in both scenarios. Overall, the "Net Zero" scenario envisages **2.6 million additional jobs**, and the "Low Ambition" one 2.1 million additional jobs compared to the Counterfactual scenario.

13
To estimate the labor units generated, an average unit labor cost was assumed for each sector and each category of worker (source ISTAT) on which the shares of impact allocated to the creation of labor income, and thus labor units, were calculated.

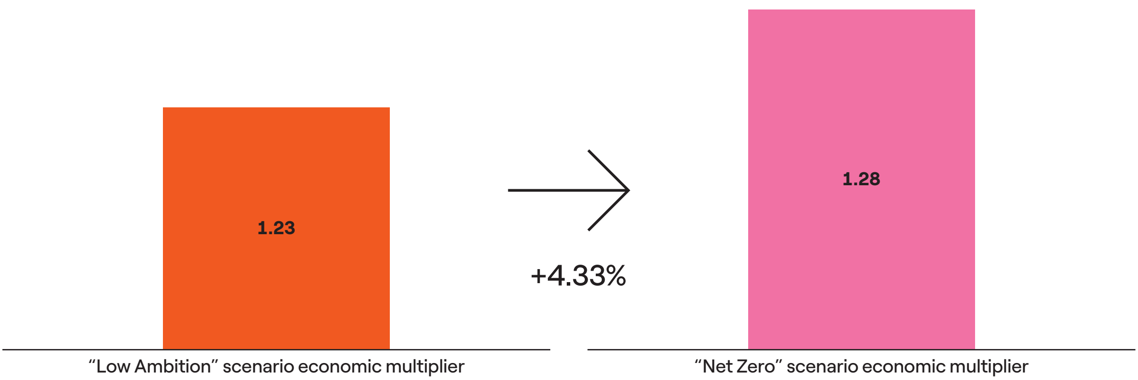
FIG 12 → **Additional jobs (FTE) per estimated investments in Italy in "Low Ambition" scenario and "Net Zero" scenario** (additional jobs in Full Time Equivalent per million Euro invested)

* The Figure includes jobs lost and gained and is calculated with respect to the Counterfactual scenario. To estimate the labor units generated, an average unit labor cost was assumed for each sector and each category of worker (source ISTAT) on which the shares of impact allocated to the creation of labor income, and thus labor units, were calculated.

Source → The European House - Ambrosetti and Enel Foundation elaboration, 2022.

SPAIN → The "Net Zero" scenario has a **better and more efficient impact on the economy** also in Spain. In fact, the **GDP/investment ratio** is better than in the "Low Ambition" scenario (1.28 vs 1.23). The economic multiplier indicates the direct, indirect and induced economic effect of the investment at stake. This means that the "Net Zero" scenario not only **requires fewer resources** than the "Low Ambition" one but for each Euro invested it also generates a **better economic effect** (€0.05 more) than the "Low Ambition" scenario.

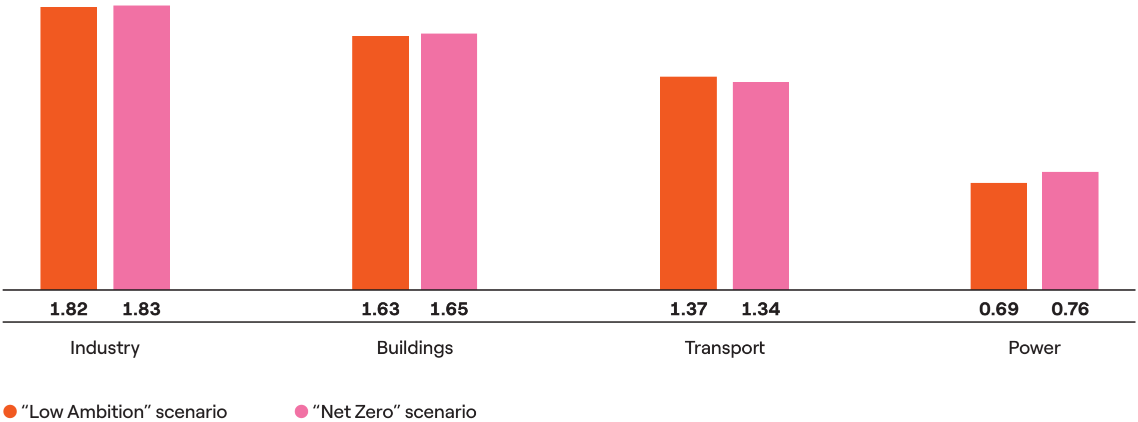
FIG 13 → **Economic multiplier in the "Low Ambition" scenario** (left chart) **and in "Net Zero" scenario** (right chart) **in Spain including the import assumption, 2021-2050** (absolute values)



Source → The European House - Ambrosetti and Enel Foundation elaboration, 2022.

From a sectoral perspective, also in Spain the highest **value-added effect** in the "Net Zero" scenario is obtained in the **industry sector**, with a multiplier of 1.83. In terms of difference with the "Low Ambition" scenario, the widest gap is registered in the **power sector** (+10% higher multiplier).

FIG 14 → **Economic multiplier in the "Low Ambition" scenario and in "Net Zero" scenario in Spain by sector, 2021-2050** (absolute values)



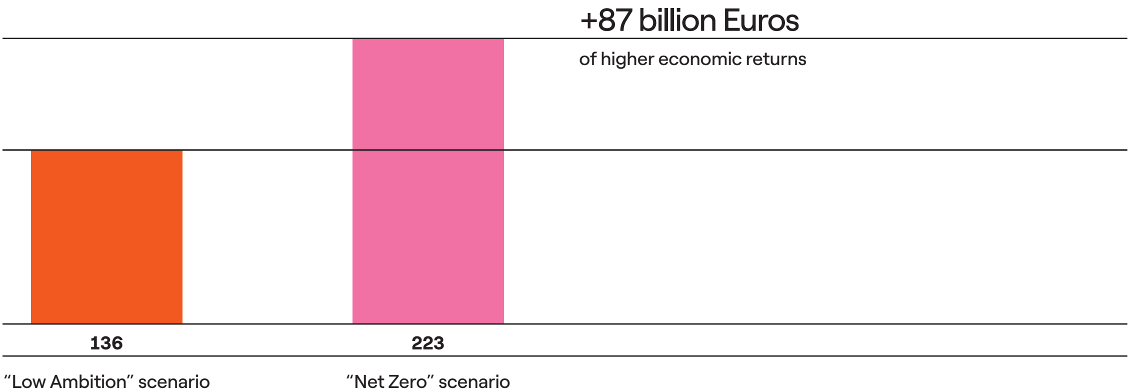
N.B. Investments in networks are included in the power sector.

Source → The European House - Ambrosetti and Enel Foundation elaboration, 2022.

The "Net Zero" scenario is **more economically efficient** for the decarbonization pathway also in Spain. Indeed, the investments needed in the "Net Zero" scenario amount to **546 billion Euros less** than in the "Low Ambition" one over the 2021-2050 period.

Also for Spain, to analyze the **real net effect** of the investments in the "Low Ambition" and "Net Zero" scenarios, the impacts were compared with a **Counterfactual scenario**. From this analysis, it emerges that the "Low Ambition" scenario is able to generate **136 billion Euros** more than the Counterfactual scenario and that the "Net Zero" scenario has an additional impact of **223 billion Euros**, 87 billion Euros more than the less ambitious scenario.

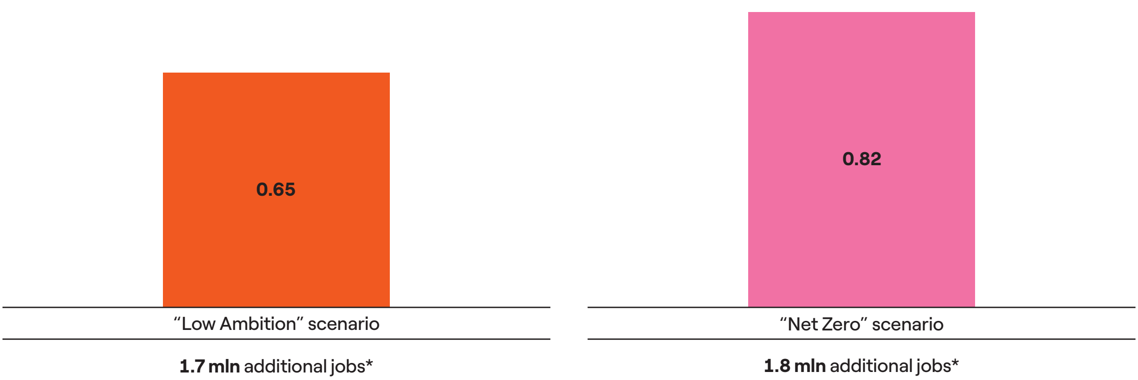
FIG 15 → **Net economic returns from investments in the "Low Ambition" scenario** (left chart) **and in "Net Zero" scenario** (right chart) **in Spain, compared to the Counterfactual scenario, 2021-2050** (value added, billion Euros)



Source → The European House – Ambrosetti and Enel Foundation elaboration, 2022.

In Spain, the "Net Zero" scenario supports more jobs (full time equivalent) per million Euros invested. In particular, a million Euro invested in the "Net Zero" scenario generates **0.82 jobs**, whilst a million Euro invested in the "Low Ambition" one generates **0.65 jobs**. As in Italy, in Spain net job impacts are computed with respect to a **Counterfactual scenario**, in which the same level of investment under consideration was used for **another project** or for other **production purposes**, allocating the investments on the basis of the **historical trend over the past 10 years**. Overall, the "Net Zero" scenario envisages **1.8 million additional jobs**, compared to **1.7 million** in the "Low Ambition" scenario.

FIG 16 → **Additional jobs (FTE) per estimated investments in Spain in the "Low Ambition" scenario and "Net Zero" scenario** (additional Full Time Equivalent jobs per million Euro invested)



* The figure includes jobs lost and gained and is calculated with respect to the Counterfactual scenario. To estimate the labor units generated, an average unit labor cost was assumed for each sector and each category of worker (source ISTAT) on which the shares of impact allocated to the creation of labor income, and thus labor units, were calculated.

Source → The European House – Ambrosetti and Enel Foundation elaboration, 2022.

3.2.2 REDUCTION OF POLLUTION

One of the key aspects behind the push for decarbonization is the **impact** that a fossil fuel-based economy has on the **environment and humans. Particulate Matter** (PM) and Nitrogen Oxides (NO_X) are particularly harmful pollutants[14]. In fact, NO_X emissions commonly lead to increased rates of diseases such as asthma and, in some cases, bronchitis or even pulmonary oedema. Nitrogen Monoxide (NO) is a cause of pulmonary oedema and harms the blood due to the formation of methemoglobin. In addition, Nitrogen Dioxide (NO_2) irritates the eyes, the mucus membranes and lungs and exacerbates respiratory diseases such as asthma, allergies, irritations, and bronchitis. It also forms fine particulate matter ($PM_{2.5}$) as it reacts with the atmosphere.

For these reasons, it has been assessed how pursuing a decarbonization and electrification path can **avoid the negative impacts of pollutants on public health**. In particular, impacts are classified in terms of the **reduction of diseases, the improvement in productivity and the avoidance of premature deaths** made possible by the reduction of pollution.

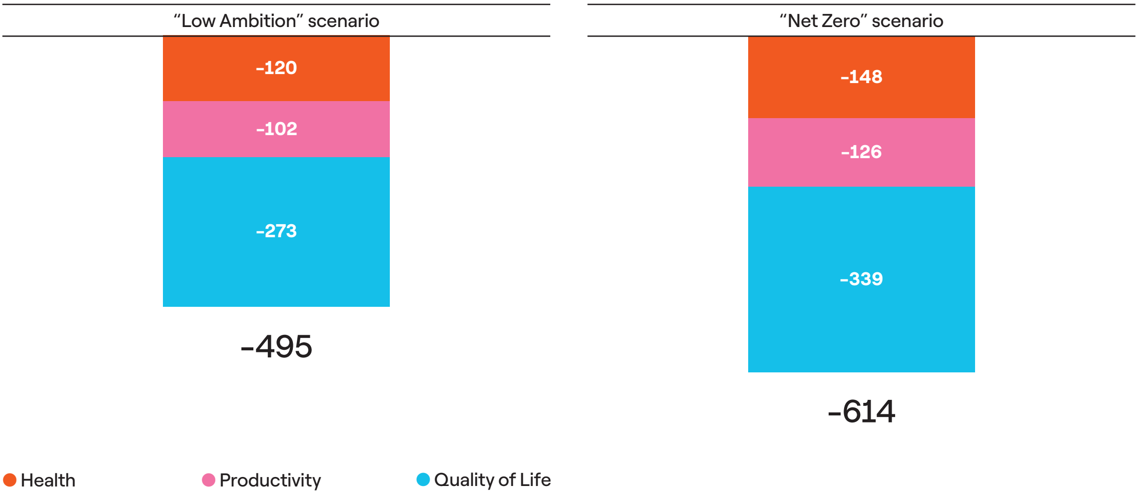
As a starting point, the PM and NO_X emission trends attributable to the transport, buildings and industry sectors were estimated for the "Low Ambition" and "Net Zero" scenarios, and an additional **Counterfactual scenario**, which corresponds to an even slower decarbonization path[15]. Secondly, emissions were associated with **negative externalities** (in terms of cases occurring per emission), in particular health (mortality), productivity (minor restricted activity days, work loss days, restricted activity days) and life (lung cancer, bronchitis, lower respiratory symptoms, etc.). Lastly, these cases were converted into **monetary terms** (based on WHO, ISTAT, ISPRA and EEA data), making it possible to calculate the **savings enabled by the "Net Zero" scenario**, in terms of health, productivity and life, compared to both the Counterfactual and "Low Ambition" scenarios.

As a result, we can estimate that in the 2021-2050 period the "Net Zero" scenario would enable **614 billion Euros of health, productivity and life savings** compared to the Counterfactual scenario and **119 billion Euros** compared to the "Low Ambition" scenario. The majority of these savings (around 55%) would be attributable to the **life** area, with savings ranging from **66 billion Euros** (compared to the "Low Ambition" scenario) to **339 billion Euros** (compared to the Counterfactual one).

14
Source: European Climate Foundation, "*Fuelling Italy's Future: How the transition to low-carbon mobility strengthens the economy*", 2018.

15
The 2050 values of the Counterfactual scenario – in terms of e.g., electric vehicles and heat pumps – corresponds to the 2035 values of the "Low Ambition" scenario. Therefore, the Counterfactual scenario is designed as a slower scenario in terms of the decarbonization path.

FIG 17 → **Cumulated health, productivity and life savings of the "Low Ambition" and "Net Zero" scenarios* in Italy, 2021-2050** (billion Euros)

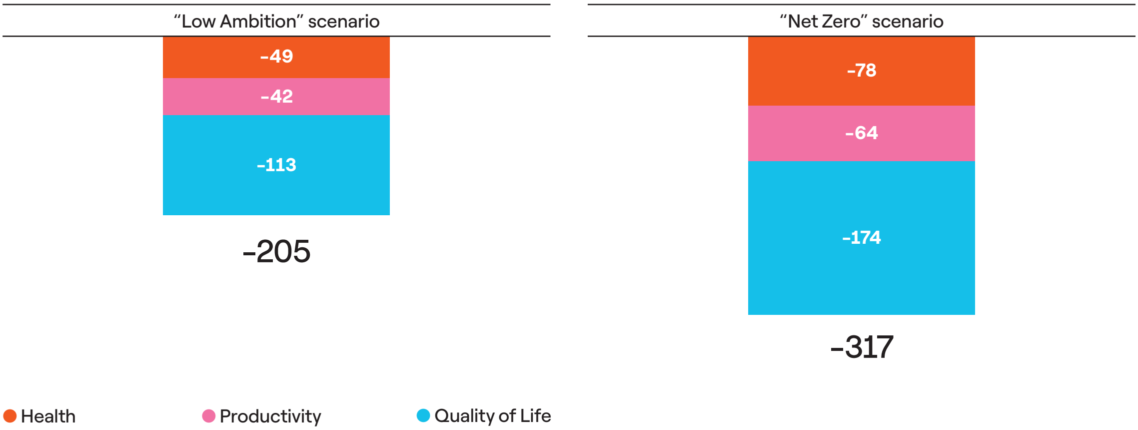


* Compared to the Counterfactual scenario.

Source → The European House - Ambrosetti and Enel Foundation elaboration, 2022.

Similarly, in Spain the decarbonization pathways will generate relevant positive impacts on public health. The quantitative model estimates that in the 2021-2050 period the negative externalities avoided by the "Net Zero" scenario will amount to **317 billion Euros** compared to the Counterfactual scenario and 112 billion Euros compared to the "Low Ambition" one, with key positive impacts on the **life** area (61 billion Euros compared to the "Low Ambition" scenario and 174 billion Euros compared to the Counterfactual one).

FIG 18 → **Cumulated health, productivity and life savings of the "Low Ambition" and "Net Zero" scenarios* in Spain, 2021-2050** (billion Euros)



* Compared to the Counterfactual scenario.

Source → The European House - Ambrosetti and Enel Foundation elaboration, 2022.

3.2.3 FOSSIL FUEL EXPENDITURES SAVINGS

Beyond the benefits already mentioned, the decarbonization pathway entails advantages in terms of **fossil fuel savings**. In fact, renewable technologies do not necessitate the burning of fossil fuels. In this sense, The European House – Ambrosetti and Enel Foundation developed an analytical model to calculate savings in terms of fossil fuel expenditures. To do this, the following steps were taken:

- **Identification of fossil fuel prices** (coal, oil and gas) for both Italy and Spain in power, transport, buildings and industry and their **projection to 2050**, taking into account the most recent geopolitical situation[16].
- **Calculation of fossil fuel expenditures** expected in the "Net Zero", "Low Ambition" and Counterfactual[17] scenarios from 2021 to 2050[18] for power, transport, buildings and industry by combining the fossil fuel expenditures in each sector with generation (power) and consumption (transport, buildings, industry).
- **Calculation of the overall fossil fuel expenditures** in Italy and Spain from 2021 to 2050 and estimation of the cumulated fossil fuel expenditure differential **by comparing the "Net Zero" and "Low Ambition" scenario with the Counterfactual scenario**.

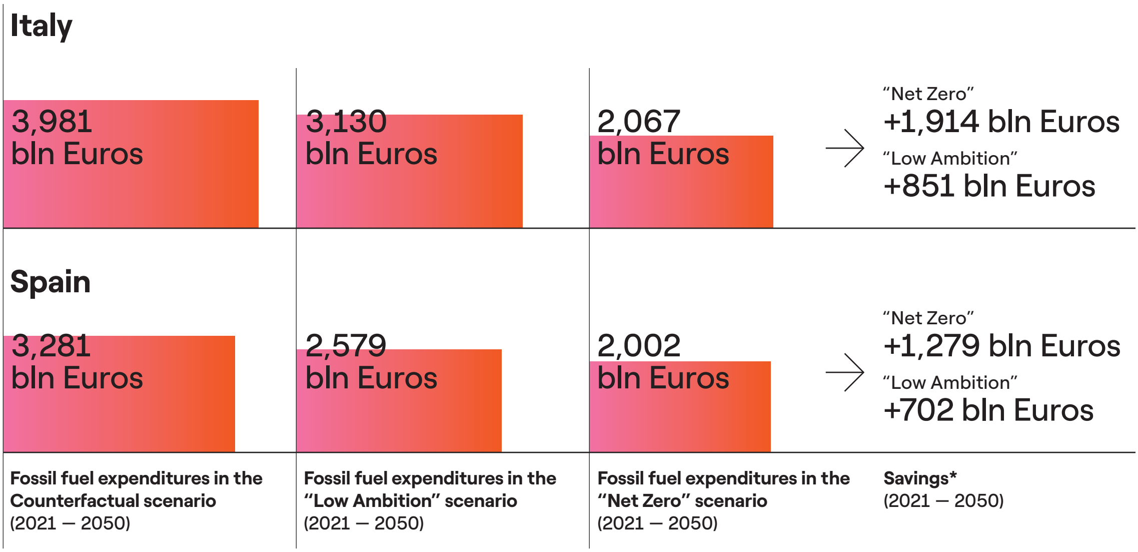
16
Public data (European Commission, BloombergNef and the study of Enel Foundation, Compass Lexecon and Enerdata "*Sustainable paths for EU increased climate and energy ambition*") were used for the projections of fuel prices.

17
The 2050 values of the Counterfactual scenario – in terms of energy consumption in the different sectors – correspond to the 2035 values of the "Low Ambition" scenario.

18
In addition to fossil fuel prices, the evolution of fossil fuel expenditures is influenced by the presence of gas, coal and oil in final energy consumption. Moving on from these considerations and taking into account the different hypothesis considered, it is worth mentioning that the trajectory in the "Net Zero" scenario involves a quicker and more significant reduction compared to the "Low Ambition" and Counterfactual scenarios.

Overall, the "Net Zero" scenario entails a cumulated saving in fossil fuels expenditures (compared to the Counterfactual scenario) of about **1.9 trillion Euros in Italy** and **1.3 trillion Euros in Spain from 2021 to 2050**.

FIG 19 → **Fossil fuel expenditures in the "Low Ambition", "Net Zero" and Counterfactual scenarios in Italy and Spain, 2021-2050** (billion Euros)



* The savings are calculated comparing the fossil fuel expenditures in the "Net Zero" and "Low Ambition" scenario with the Counterfactual scenario.

Source → The European House - Ambrosetti and Enel Foundation elaboration, 2022.

3.2.4 ENERGY SECURITY AND INDEPENDENCE

Lastly, on top of the benefits detailed in the previous paragraphs, it is worth mentioning that the "Net Zero" scenario would also make it possible to **increase and strengthen the energy independence** of both Italy and Spain.

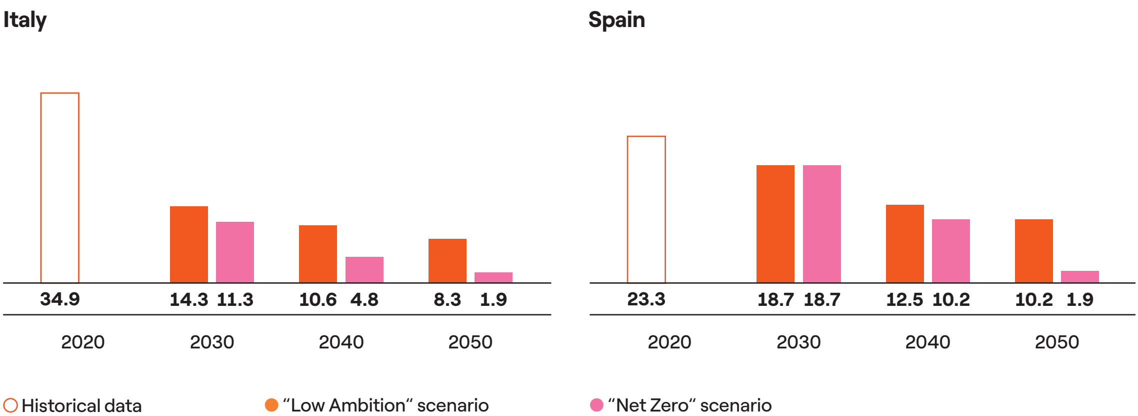
In this regard, **two further calculations have been performed** to stress this fact: the **gas intensity of GDP index** and the **energy dependence** trend. With regards to the former, the index has been projected up to 2050 for both Italy and Spain to understand the expected evolution of the energy mix over time in the "Net Zero" scenario and to see how far it is possible to reduce the dependence on gas.

To do this, 4 steps were performed:

1. Calculation of the **evolution of GDP up to 2050**[19].
2. Identification of the **share of natural gas in final energy consumption up to 2050**[20].
3. Calculation of **natural gas consumption** from 2021 to 2050 by comparing the amount of natural gas consumed in 2020 with the share of natural gas in final energy consumption in 2020.
4. Calculation of the **gas intensity of GDP index up to 2050** by dividing natural gas consumption by the corresponding GDP.

Moving on from these considerations, the data suggests that the "Net Zero" scenario will lead to a significant reduction in the gas intensity of GDP index: **-94% in Italy** and **-92% in Spain**.

FIG 20 → **Evolution of the gas intensity of GDP index in Italy** (left chart) **and Spain** (right chart) **in the "Low Ambition" and "Net Zero" scenario, 2020, 2030, 2040 and 2050** (toe per million Euros of GDP)



N.B. The gas intensity of GDP index has been calculated dividing the quantity of gas consumed in each country by the GDP. Therefore, the index evaluates the necessary gas consumption in the countries to produce a million Euros of GDP.

Source → The European House - Ambrosetti and Enel Foundation elaboration of BP, Eurostat, IMF, Long-Term strategies and Enel internal data 2022

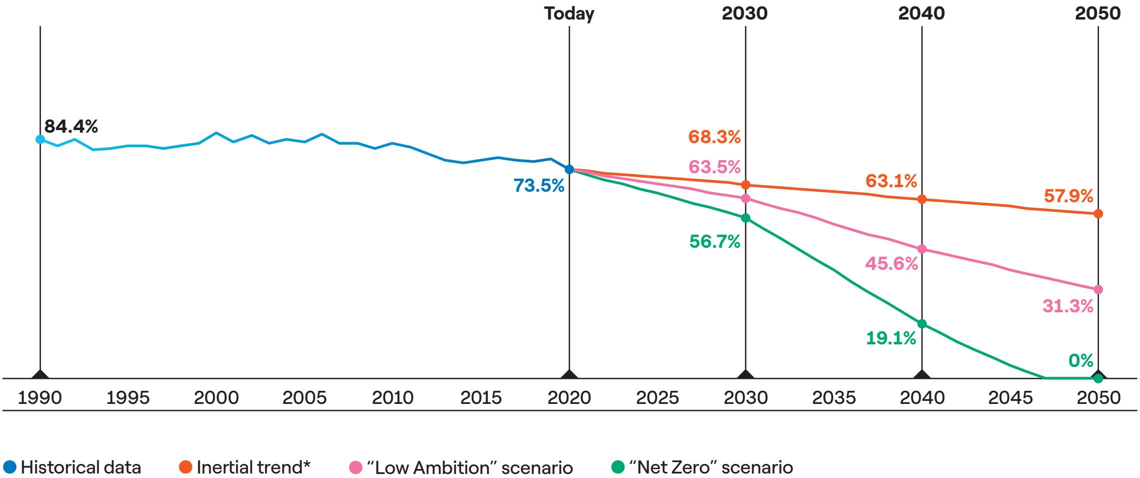
When it comes to the **energy dependence index**, The European House – Ambrosetti and Enel Foundation estimated the evolution over time in light of the Italian and Spanish "Net Zero" scenarios.

19
According to public and Enel internal data.

20
The estimation of the gas intensity of GDP index is based on Enel internal data, long-term strategies and IMF data.

First of all, it is important to mention that – as reported in Part 1 – Italy registers a high energy dependence value (in 2020 equal to 73.5%). Projecting the trend of the last 15 years (2005-2019), in 2050 the country will be still relying on energy imports by almost **58%** of its total consumption. However, an acceleration – especially in the next decade - can be achieved by pursuing the "Net Zero" scenario reported in this Study. In particular, the major penetration of RES in 2030 (63% of total generation) and 2050 (98% of total generation), together with electrification and energy efficiency, will reduce energy dependence to **56.7%** in 2030 (vs. 68.3% in the inertial trend and 63.5% in the "Low Ambition" scenario) and to **zero in 2050** (vs. 31.3% in the "Low Ambition" scenario). As for Spain, in the "Net Zero" scenario the energy dependence index is expected to reduce from 67.9% in 2020 to 61% in 2030 (vs. 62% in the inertial trend and 61% in the "Low Ambition" scenario) and **13% in 2050** (vs. 52% in the inertial trend and 50,1% in the "Low Ambition" scenario).

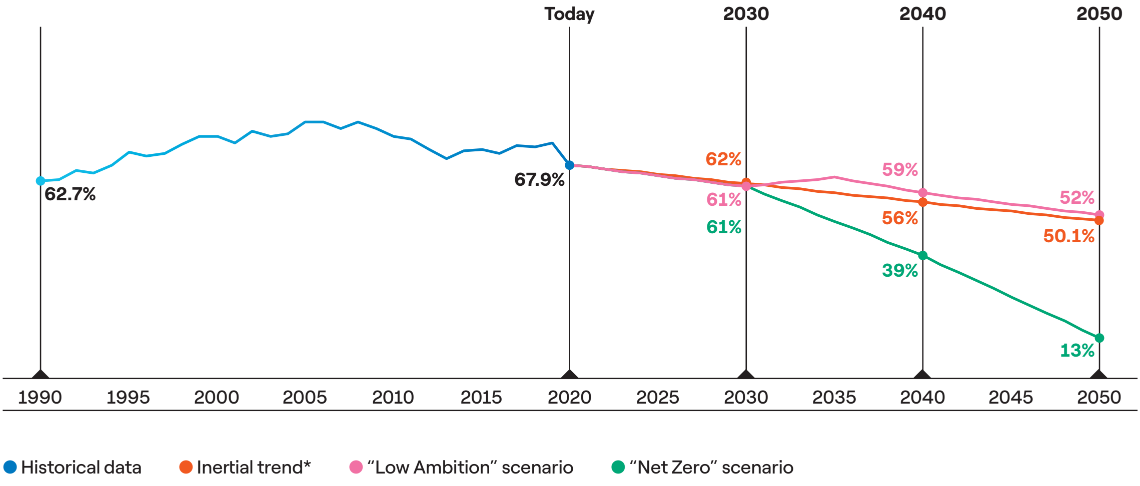
FIG 21 → **Energy dependence in Italy, 1990-2050^E** (% values)



* The inertial trend was calculated by projecting the CAGR from 2005 to 2019.
N.B. Energy dependence is calculated as net imports (solid fossil fuels, crude oil and petroleum products, natural gas, electricity, biomass, hydrogen) over gross available energy (which also includes primary production).

Source → The European House – Ambrosetti and Enel Foundation elaboration of Eurostat and Enel internal data, 2022.

FIG 22 → **Energy dependence in Spain , 1990-2050[E]** (% values)



* The inertial trend was calculated by projecting the CAGR from 2005 to 2019.
N.B. Energy dependence is calculated as net imports (solid fossil fuels, crude oil and petroleum products, natural gas, electricity, biomass, hydrogen) over gross available energy (which also includes primary production).

Source → The European House – Ambrosetti and Enel Foundation elaboration of Long-Term strategy data, 2022.

In Figure 23 the potential impacts of the "Net Zero" scenario (compared to the "Low Ambition" scenario) in Italy and Spain are summarized, highlighting their **relevant benefits on economic, social and energy dimensions**.

FIG 23 → **Summary of the impacts of the "Net Zero" and "Low Ambition" scenarios in Italy and Spain on different indicators, 2050** (difference to Counterfactual scenario impacts, unless stated otherwise)

	Higher economic return (billion Euros)	**Net activated jobs** (millions)	**Reduction of pollution** (billion Euros)	**Savings in fossil fuel expenditures** (billion Euros)	**Improvement in the gas intensity of GDP index*** (% values)	**Improvement in energy dependence*** (percentage points)
Italy "Net Zero"	328	+2.6	614	1,914	-94%	-73.5 p.p.
Italy "Low Ambition"	188	+2.1	495	851	-76%	-42.2 p.p.
Spain "Net Zero"	223	+1.8	317	1,279	-92%	-54.9 p.p.
Spain "Low Ambition"	136	+1.7	205	702	-56%	-15.9 p.p.

* Compared to 2020 values.
N.B. For economic and social benefits the Counterfactual scenario indicates a scenario in which the same level of investment considered in the scenarios ("Net Zero" and "Low Ambition") was used for another project or for other production purposes, allocating the investments on the basis of the **historical trend over the past 10 years**. For the reduction of pollution and savings the Counterfactual scenario corresponds to the 2035 values of the "Low Ambition" scenario.

Source → The European House – Ambrosetti and Enel Foundation elaboration, 2022.

Part

Policy proposals and recommendations to achieve a “zero emissions” economy in Europe, Italy and Spain

Part 4

Key Messages

1 → To foster the investments required and obtain the economic, social, and environmental benefits deriving from decarbonization estimated in the previous Part, some outstanding issues need to be addressed. To reach ambitious global climate targets, it is necessary to invest in the **electrification of final consumption** and, at the same time, to support the **massive deployment of renewable energy production and smart power networks. Electrification is the most cost-effective and efficient way** to decarbonize final energy consumption of transport, buildings, and industry. In particular, **the pace of electrification needs to accelerate substantially** to reach the Paris Agreement commitments. Electric technologies are ready to support the boost needed in coming years to follow a “Net Zero” pathway and governments should put in place consistent roadmaps to support the electrification process.

2 → To this end, **2 prerequisites and 5 policy proposals** have been identified to tackle the existing challenges. One proposal is meant to affect all the economic sectors analyzed, while the remaining four are sector-specific initiatives.

3 → **Prerequisites** for efficient and effective investments:
- o Ensuring stability, transparency and consistency of European, national and local energy policies and measures, so as to spread positive price and non-price signals to companies and final consumers ready to invest in the energy transition and to switch to green solutions.
- o Supporting both European and domestic industrial production in scaling up existing green technologies, developing and adopting new green solutions and stopping fossil fuels subsidies.

4 → **Cross-sectoral policy proposal**:
- o Guaranteeing a stronger form of cooperation and a greater degree of harmonization in the governance of the energy transition at the European level.

5 → **Sectoral policy proposals**:
- o Power sector: simplifying and digitalizing authorization procedures for RES plants and facilitating intervention on energy-related infrastructure and power grids. In addition, promoting demand-side management as well as deployment of storage facilities and flexibility solutions.
- o Transport: simplifying charging infrastructure installation procedures, strengthening collaboration between all the e-mobility actors, enabling interoperability, optimizing the time-to-market of grid connections, and promoting electric public urban mobility.

- Industry: leveraging on legal frameworks like ETS (free allowances) to support the technological shift of industry towards greener technologies (green hydrogen). In addition, creating national Tech Transfer Labs focused on technologies for direct and indirect electrification, to be coordinated at the European level, and favoring demand-response.
- Buildings: defining the phase out of fossil fuel boilers - through a just, stable and transparent framework with regards to heat pumps - and creating a one-stop shop to support the renovation of buildings.

4.1

Policy proposals and recommendations to achieve the desired targets in Europe, Italy and Spain

Beyond specific policies to ensure an efficient and effective decarbonization pathway to 2050, it is essential to define key prerequisites or enabling factors to guarantee the best investment conditions for European companies and final consumers. Indeed, on the one hand, companies should operate in a well-defined European legislative context, with clearly stated objectives and an energy policy aimed at ensuring consistent and stable investment planning; on the other hand, the energy transition has to factor in security of supply concerns and promote the preservation and development of European and national production of green technologies fundamental for the transition path.

The **first prerequisite** relates to the **stability**, **transparency and consistency of European, national and local energy policy and measures**, which necessarily reverberate at individual Member States level, to address long-term plan (and investments) and **design consistent remuneration mechanisms** (such as subsidies and auctions). As already seen in Part 3, on average, around 75% of the estimated investments for reaching carbon neutrality at 2050 should be deployed by the private sector, both in Italy and Spain. Private investment choices are the result of medium- to long-term strategic planning. The result is a carefully crafted set of integrated measures encouraging investors to overtake existing and new risks with a predictable expectation for fair rewards. Therefore, it is crucial for the EU and its Member States to be able to provide an adequate signal to investing companies and final consumers in the energy field if we wish the energy transition to happen. Energy objectives, policies, and instruments must be clear and well-defined. Finally, the picture takes on even more complexity when we consider the lack of standardization in the legal framework (also related to specific sectors) among Member States and in measuring mechanisms for the achievement of the targets. The first step to achieve a successful energy transition is to put companies in the right conditions to invest, through clarity and well-defined mechanisms and measures at European and Member States level to effectively achieve the medium- and long-term goals.

As for the **second prerequisite**, historically, despite their manufacturing vocation, Europe, and in particular Italy, have **not fully developed complete and integrated supply chains for several green technologies** considered key to the energy transition. They are lagging behind in scaling up the existing green technologies and developing and adopting new ones. The direct consequence is entering into global competition for the supply of raw materials and manufactured goods and products needed for the green transition. In May 2021, the European Commission updated the EU Industrial Strategy to ensure that its industrial ambition takes fully into account the new circumstances following the COVID-19 crisis and helps to drive the transformation to a more sustainable, digital, resilient, and globally competitive economy[1]. In particular, the Commission presented the results of six in-depth reviews on raw materials, batteries, active pharmaceutical ingredients, hydrogen, semiconductors, and cloud and edge technologies, providing further insights on the origin of strategic dependencies and their impact. Indeed, the EU does not produce all the raw materials needed to meet its demand. Therefore, European and national industries face **global competition in access to raw materials**. As examples, **rare earths** are used in magnets and batteries that move electric cars and make **wind turbines** work, **gallium** and **indium** are part of light-emitting diode (LED) technology in lamps, silicon is used in integrated circuits, and platinum group metals are needed in hydrogen fuel cells and electrolyzers. However:

- **98%** of the EU's rare earth element supply comes from China.
- **71%** of the EU's demand for platinum is covered by South Africa.
- The EU produces just **1%** of all battery raw materials.

FIG 1 → **Main countries for the supply of critical raw materials to the European Union, 2020**
(% dependence of EU, unless otherwise stated)

Americas

USA
Beryllium* **88%**

Mexico
Fluorite **25%**

Brazil
Niobium **85%**

Chile
Lithium **78%**

Europe

Norway
Silicon metal **30%**

France
Hafnium **84%**
Indium **28%**

Spain
Strontium **100%**

Germany
Gallium **35%**

Finland
Germanium **51%**

Africa

Morocco
Phosphorite **24%**

Guinea
Bauxite **64%**

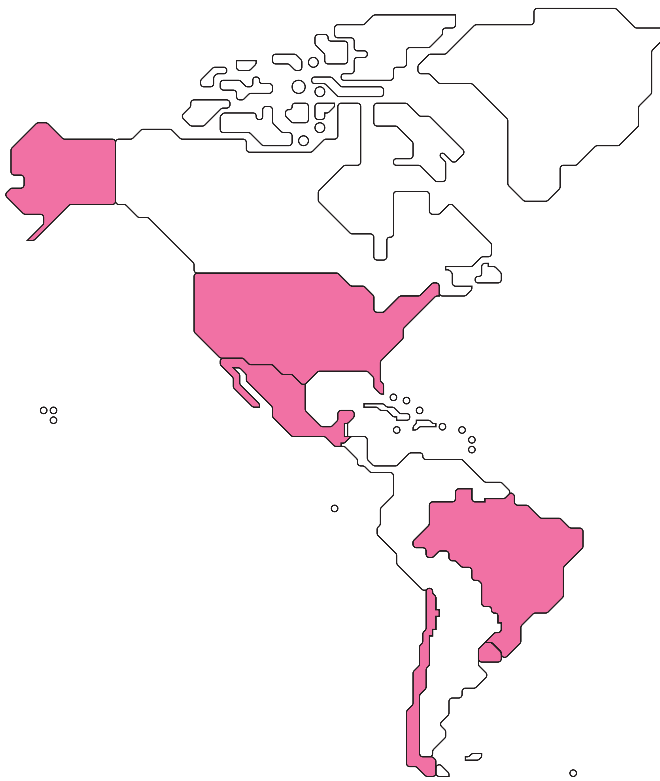
DRC**
Cobalt **68%**
Tantalum **36%**

South Africa
Iridium* **92%**
Platinum* **71%**
Rhodium* **80%**
Ruthenium* **93%**

Northern and Central Asia

Kazakhstan
Phosphorus **71%**

Russia
Palladium* **40%**



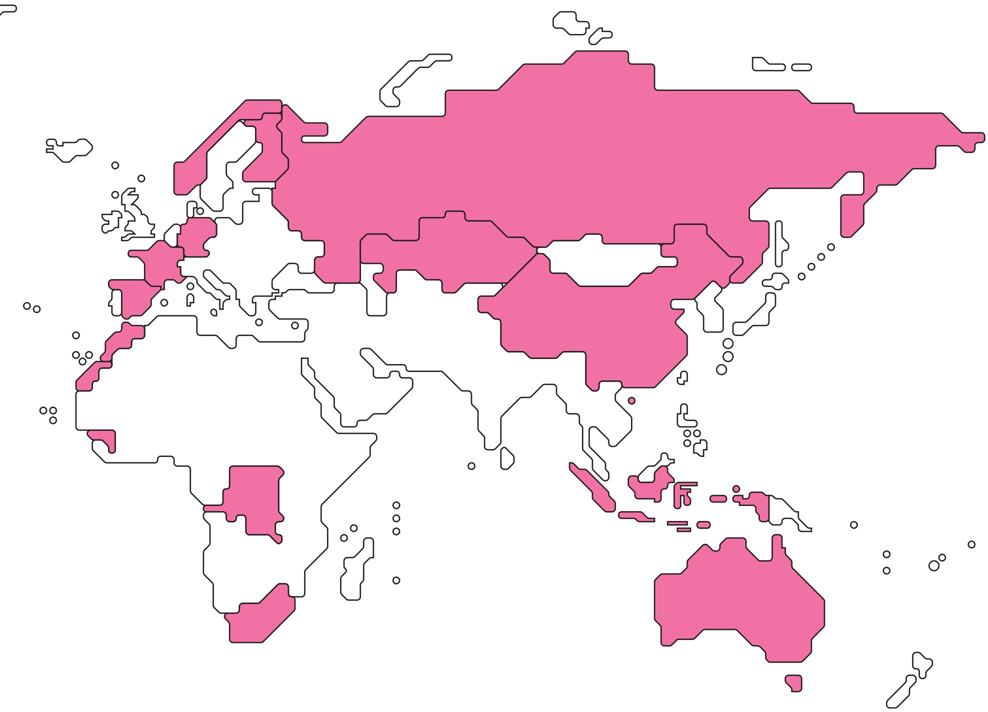
* Share of total global production
** Democratic Republic of the Congo

Source → The European House – Ambrosetti and Enel Foundation elaboration on European Commission data, 2022.

1
Source: European Commission, "*Updating the 2020 Industrial Strategy: towards a stronger Single Market for Europe's recovery*", 2020.

That said, one of the essential prerequisites to be in line with the decarbonization path is to **build an European industrial strategy and a resilient raw materials supply chain**, continuing to promote initiatives such as the European Raw Materials Alliance, European Battery Alliance and European Hydrogen Alliance, and favoring financial and economic schemes such as the Recovery and Resilience Facility, the Innovation Fund, the Connecting Europe Facility, the European Regional Development Fund and the Just Transition Fund.

Indeed, the need to ensure greater supply security must be accompanied by a **strong industrial policy** that facilitates the **re-shoring** of knowledge, know-how and processes for the production of goods such as PVs, batteries and electrolyzers.



East Asia & Pacific

China

Baryte	**38%**
Bismuth	**49%**
Magnesium	**93%**
Natural graphite	**47%**
Scandium*	**66%**
Titanium*	**45%**
Tungsten*	**69%**
Vanadium*	**39%**
Light rare earths	**99%**
Heavy rare earths	**98%**

Indonesia

Natural rubber	**31%**

Australia

Coke coal	**24%**

The production of these goods, in fact, will have **socio-economic as well as strategic impacts**. Hence, wise industrial policies could actually help Europe reduce its current reliance on imported goods for the transition with positive implications on energy autonomy, GDP and employment. The ability of country systems and institutions to accompany and to stimulate the **regionalization of production chains** (such as reshoring) will be a direct element in order to determine the evolution of the country's attractiveness in the next few years.

FIG 2 → **Two prerequisites and five policy proposals to accelerate the pathway towards a "Net Zero" economy**

I

Ensuring **stability**, **transparency** and **consistency** of European, national and local energy policies and measures

II

Supporting **industrial production** in scaling up existing green technologies, developing new ones, and stopping fossil fuel subsidies

1

Guaranteeing a **stronger form of cooperation** and a **greater degree of harmonization** in the governance of the energy transition at the European level

2

POWER SECTOR
Simplifying **authorization procedures** for RES plants, facilitating intervention on energy infrastructures and promoting **demand side** management as well as deployment of **storage** facilities and **flexibility** solutions

3

TRANSPORT
Simplifying charging infrastructure installation **procedures**, strengthening **collaboration** between all the e-mobility actors, enabling **interoperability**, optimizing **grid connections time-to-market**, and promoting electric **public urban mobility**

4

INDUSTRY
Leveraging on legal frameworks to support the technological shift of industry towards greener technologies, creating **Tech Transfer Labs** for direct and indirect electrification solutions, and favoring **demand-response**

5

BUILDINGS
Defining the **phase out** of fossil fuel boilers - through a just, stable and transparent framework with regards to heat pumps - and creating a **one-stop shop** to support the renovation of buildings

Source → The European House – Ambrosetti and Enel Foundation elaboration, 2022.

In addition to these two prerequisites, the achievement of a "Net Zero" economy by 2050 requires the European Union and Member States to make not only adequate investments, as described in the Part 3 of this Study, but also to set up a favorable **regulatory, legislative, and socio-economic framework**, both at the European and national level. Thus, this Study identifies **a cross-sectoral policy proposal**, aimed at increasing coordination among the EU policy actors and the different level of governance, and **sector-specific measures**, tailored for sustaining investment for the decarbonization of the power, transport, industry, and building sectors.

4.2

Cross-sectoral policy proposal

1 → **POLICY PROPOSAL**

Guaranteeing a stronger form of cooperation and a greater degree of harmonization in the governance of the energy transition at European level

Rationale

Energy is a **shared competence** in the European Union policy framework[2]. This means that both the European Union and its Member States can legislate on this subject and adopt legally binding acts. The normative activity implemented so far brought to a lack of standardization and the adoption of very heterogeneous policies (for example, a combination of 1,400 different measures related to energy efficiency), which hindered the effective deployment of the decarbonization process. In particular, the **Treaties** define the different competences of the Member States and of the European Union, the sphere of action of the actors, their interactions, and the legislative framework at European level. In matters where the European Union has not exclusive competence, the subsidiary principle states that the EU must not intervene, unless its activity is considered more effective than what Member States could do.

Therefore, energy transition involves significant and ambiguous questions of power attribution. On the one hand, Article 192 of the Treaty on the Functioning of the European Union, or TFEU (on the environment) and Article 194 of the TFEU (on energy) enable **EU legislation on energy transition through the ordinary legislative procedure**, including majority voting in the European Parliament and the Council. On the other hand, there are significant textual **limits for EU action in neighboring provisions with a 'sovereignty exception' for the Member States** in both Article 192 and Article 194 of the TFEU.

For example, for the decarbonization of transport, each EU Member State is investing in the technologies they consider most appropriate (e.g., battery or fuel cell). With regards to the building sector, the revision of the Directive on Energy Performance in Buildings (EPBD), aimed at overcoming the lack of standardization by upgrading the existing regulatory framework to reflect higher ambitions and more pressing needs in climate action, while providing Member States with the flexibility needed to take into account the differences in the building stock

2
See also: The European House – Ambrosetti & Enel Foundation, "*European Governance of the Energy Transition*", 2021.

across Europe. Specifically, the revision aims at introducing **common minimum energy performance standards at EU level** for the worst performing buildings. The proposal also provides a clear definition of "Net Zero" buildings, deep renovations and mortgage portfolio standards. Overall, even though the European policy measures and instruments to be used are clear and well-defined, **proper implementation by Member States appears to be missing**.

The recent COVID-19 health emergency has pushed the EU Member States' interactions out of the formal division of competences[3]. In fact, the pandemic management required a greater level of cooperation and coordination between the EU institutions and Member States, a greater capacity at European Union level, and the approval of huge investment packages out of extraordinary procedures and EU financial schemes. Hence, this extraordinary situation has enabled a faster form of cooperation among Member States to address the emergency, by bypassing all the delays entailed in European governance procedures.

The energy transition is key both to tackle climate change and to reach a higher degree of energy independence. The latter, following volatility in international energy market prices and the Russia-Ukraine war that has worsened the energy crisis, has emerged as a matter of great **urgency**. It is therefore natural to wish that similar forms of coordination put in place with the COVID-19 emergency can effectively be applied to the management of the energy transition.

→ **POLICY PROPOSAL**

Guaranteeing a **stronger form of cooperation and a greater degree of harmonization** in the governance of the energy transition at European level, by reviewing the European Commission's current enforcement mechanisms towards Member States regarding decarbonization targets, facilitating the implementation of the "REPowerEU" guidelines.

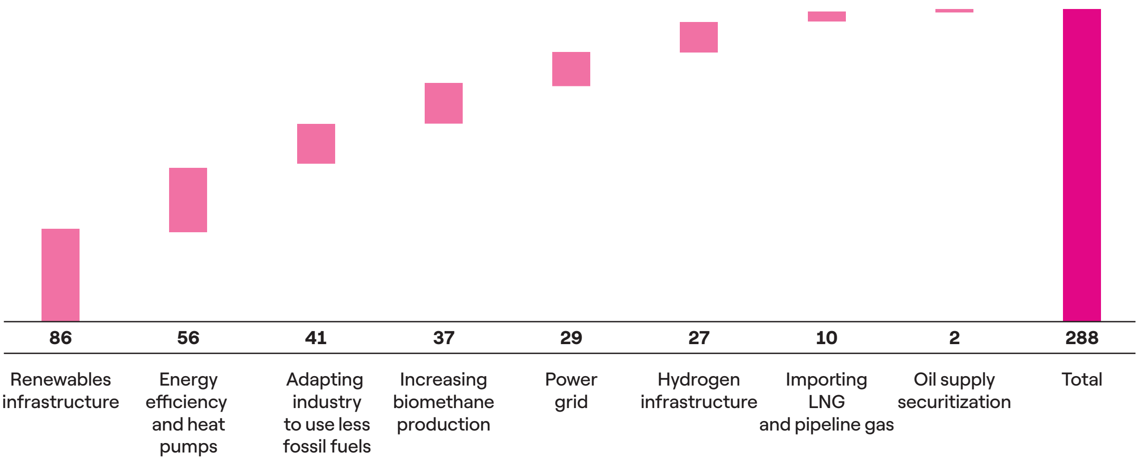
At present, the European Commission is required to oversee how the governance of the National Recovery and Resilience Plans is managed by Member States. The European Commission is monitoring how funds are spent and eventually it has enforcement powers to suspend or reallocate funds if they are not spent properly, through the **Governance Regulation**. The same logic of monitoring and enforcement could also be applied to decarbonization goals stated in the **national long-term strategies**, leveraging on the existing role of the European Commission in the monitoring phase reinforced by the experience of the National Resilience and Recovery Plans in which **the conditionality of funds becomes an indirect tool for enforcement** with the aim to maximize the benefits and ensure the achievement of the **EU common interest**. Moreover, time-efficient monitoring and enforcement should introduce a positive momentum for those who move first, by defining reward mechanisms.

3
Indeed, health is an issue of exclusive competence of Member States.

This proposal becomes even more urgent in the light of the more ambitious targets set out in the **"Fit for 55" package**, and the guidelines included in the **"REPowerEU" plan** released after the outbreak of the war in Ukraine. In fact, Member States will have to **revise their energy strategies to 2030 and 2050** and introduce a dedicated chapter on **energy independence in their National Recovery and Resilience Plans (NRRPs)** and thus an enforcement mechanism is needed to accelerate and keep the pace of this process.

As reported in the "REPowerEU" factsheets provided by the European Commission, to rapidly reduce the dependence on Russian fossil fuels by fast-forwarding the clean energy transition and adapting industry and infrastructure to different energy sources and suppliers, an additional investment of **210 billion of Euros is required by 2027**. The "REPowerEU" implementation falls within the extraordinary European funding framework set up to address COVID-19, as it is based on the investments channeled through the **Recovery and Resilience Facility (RRF)**.

FIG 3 → **Additional investments envisaged in the "REPowerEU" plan in the European Union, 2022-2030** (billion Euros)



Source → The European House – Ambrosetti and Enel Foundation elaboration on European Commission, 2022.

4.3

Sectoral policy proposals

The second set of proposals is designed specifically for each of the four sectors analyzed in this Study – power, transport, industry, and buildings – to exploit their contribution towards the decarbonization of Italy and Spain.

2 → **POWER – POLICY PROPOSAL**

Simplifying authorization procedures for renewable energy plants, facilitating interventions on energy infrastructures and promoting demand-side management as well as deployment of storage facilities and flexibility solutions

Rationale

Permitting procedures

As extensively seen in Part 1 of this Study, the goal of the European Union to become "climate neutral" by 2050 requires a strong penetration of renewable energy sources in the coming years. To achieve this goal, in July 2021, the European Commission presented the package of proposals called "Fit for 55", which foresees a greater contribution of RES (from a share of 32% to a share of **40% RES in overall final consumption**).

Within this context, the "REPowerEU" plan, set out by the European Commission to address the energy dependence on imports of Russian fossil fuels both in the short and medium term, has set **the more ambitious goal of 45% of renewable energy source penetration in final energy consumption by 2030**, with relevant implications for the power sector in coming years. That said, one of the main bottlenecks is represented by the **permitting procedures for renewable energy sources**. These are often too slow and their authorization process has uncertain timings and outcomes. The "REPowerEU" proposal to identify go-to-areas for which the Environmental Impact Assessment (EIA) should be simplified may grant a faster permitting procedure, since the EIA is the most time-consuming phase of the entire process.

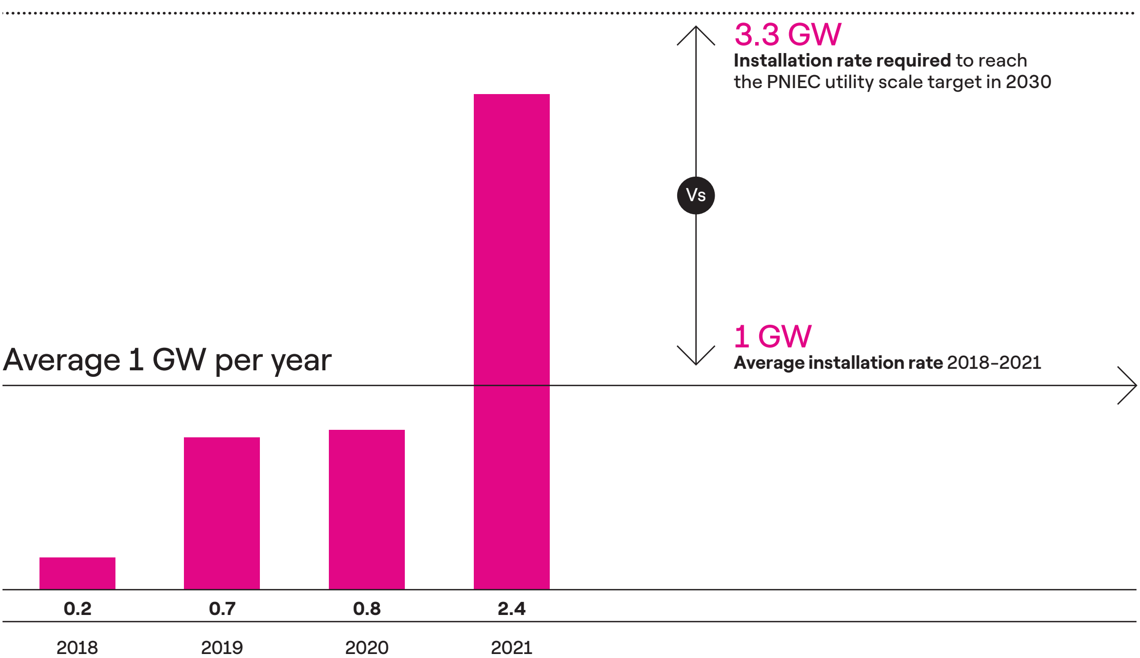
In Italy, for instance, the time needed to authorize **new photovoltaic systems** is approximately **between one and one and a half years**, while the time to authorize **new utility-scale wind projects** is equal, on average, to about **5 years**, with peaks of **up to 9 years**. In both cases, it is urgent **to speed up the process** to accelerate the achievement of decarbonization targets.

Moreover, in Italy there is a **significant fragmentation** in terms of competences along the process: regions, metropolitan cities, provinces, and municipalities. Each of these institutions involve **different actors with different responsibilities**, further slowing down the process. Among them, for instance, there is also the Italian Ministry of Culture, which can exercise **veto powers**, thus causing delays in the process.

These timelines imply a complete misalignment both with respect to the time needed for the country's energy transition process and to the rule approved in the Renewable Energy Directive - in the framework of the EU "Clean Energy Package" - which provides for a **maximum of two years** to obtain the authorization for the installation of renewable plants and one year for repowering. As a consequence, the **pipeline of authorized renewable projects is not enough to meet the Italian (and Spanish) decarbonization targets**.

Focusing on Italy, between 2018 and 2021 it is estimated that, on average, about **1 GW of authorizations were issued per year**, which means that - to achieve the 30 GW utility scale provided by the current PNIEC - it would take **30 years instead of 9**. Even assuming the 2.4 GW rate achieved in 2021, it would still take about 15 years to reach the PNIEC's utility scale of 30 GW. Finally, considering the need to update the current national plan in a more ambitious way, it is immediately clear how insufficient the current framework is.

FIG 4 → **Volumes authorized in the reference year in Italy for utility-scale projects** (GW) **and comparison between the average installation rate in 2018-2021 and the installation rate required to reach Italian "Net Zero" target in 2030**



Source → The European House – Ambrosetti and Enel Foundation elaboration on Enel internal data, 2022.

To tackle these authorization issues, remarkable actions have been carried out by the Italian government. The **DL Semplificazioni** (76/2020) and the subsequent **DL 77/2021**, also to fully take advantage of the NRRP resources, started to outline a more efficient administrative framework. They encompass ***ad hoc* technical committees** (e.g., technical committee for Environmental Impact Assessments connected to the NRRP and PNIEC, special supervisory committee at the Ministry of Culture, special committee for the evaluation of complex public interventions, etc.) and **new simplification procedures** (e.g., identification of PNIEC interventions, simplified meetings of administrations, valorization of tacit consent, promotion of public-private dialogue, introduction of permitting procedures for hydrogen, etc.). More recently, the **DL Energia** (DL 17/2022) further simplified the authorization procedures for the implementation of energy efficiency interventions and the installation of small RES systems in buildings. This can be framed within a context where the DL Milleproroghe (DL 162/2019) had already favored the deployment of energy communities, even before adopting the EU RED II (which then further accelerated the development of RES, e.g., by suggesting the identification of adequate installation sites in each region).

In Spain, the process appears to be smoother. In fact, unlike Italian auctions, **it is allowed to bid in a project even before a permit is granted**. Once awarded, RES projects in Spain are given a tight deadline to get final permits and be put in operation. A strong commitment by both institutional bodies and developers helps to finalize everything coherently with the auction results. In this sense, investors participate in auctions without permits because they know that **the risk of failure or delay in obtaining the permit is relatively low**, as the autonomous communities and the central government (depending on the type of project) are efficient, non-discretionary, and prone to attract investment. In Italy, even though the GSE allowed participation in auctions without permits, at present few investors would be likely to take such a risk, because **investors and developers are not confident to obtain a permit in a reasonable time**, regardless of the quality of the project itself.

Together with the incentive mechanism described above, it is important to take into consideration that the Spanish **authorization process** for RES plants seems to be effective and **efficient** - at least more than the Italian process - especially thanks to the small **number of stakeholders involved in the authorization process**: the Spanish Ministry for Ecological Transition, the Competition Authority (i.e., the independent regulator), the grid operator and the regions are involved, while the Spanish Ministry of Culture does not play any role (which may represent the main difference with the Italian permitting framework). In Italy, on the contrary, **there are many actors involved (10)** both at the central decision-making level (Ministry of Culture, Ministry of Ecological Transition and Ministry of Economic Development) and at the local decision-making level (regions, provinces and municipalities), as well as the regulatory authority, the technical administrative bodies and the operators.

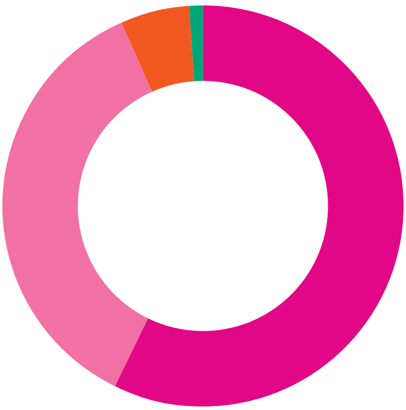
At the same time, however, it is important to underline that **in Spain the main bottleneck in the process is the environmental assessment**: there are currently **more than 700 projects waiting for the environmental impact assessment process**. As a final consideration, another criticality to be considered is the requirement of **participation of regional administrations**, whose reports are sometimes difficult to obtain.

Lastly, it is important to mention that – apart from working on permitting procedures – it will be crucial **to implement regulated schemes to incentivize investments**, which might head in the direction of the decarbonization.

Rationale **"Not in my backyard" syndrome**

According to the latest census carried out by the Nimby Forum, in Italy **317 complaints** are pending on infrastructures energy plants and plants for the management of the waste cycle, an increasing number compared to 2004 (when the monitorying began and disputes were 190). Analyzing the breakdown of these disputes by sector shows that **the energy sector accounts for 57.4% of the disputes**. In particular, focusing on the energy sector, 73.3% of the disputes are related to renewable plants. Within this category, the most disputed projects remain biomass power plants, followed by composting, geothermal, and wind plants.

FIG 5 → **Disputes by sector in Italy, last year available** (% values)



Energy industry
57.4%
Waste
36%
Infrastructures
5.7%
Other
0.9%

Source → The European House – Ambrosetti and Enel Foundation elaboration on Nimby Forum data, 2022.

As for the geographical subdivision of the disputes, **Northern Italy records the highest number of such disputes** (**46%** of the total), with 38 disputed sites (11% of the total) in Lombardy alone. Among the reasons expressed against the construction of the plants, the **negative implications associated with the quality of life** are the most common, followed by generic motivations related to the negative environmental impact of these assets.

FIG 6 → **Reasons against the construction of a plant in Italy, last year available** (% values)

Source → The European House – Ambrosetti and Enel Foundation elaboration on Nimby Forum data, 2022.

Social acceptance lies at the heart of the installation of RES technologies. As seen above, public opposition has caused delays or obstacles to their implementation. In Spain, for instance, there are difficulties in relation to the development of large projects as well as those located in **territories where tourism is a relevant pillar of the economy** (such as islands).

Overall, social acceptance is particularly evident for **wind technology**. In Europe, the rise of onshore wind is increasingly hampered by problems of **social acceptance**, mainly due to its perceived impact on the territory, which gives rise to **land occupation issues**. This aspect exposes them to risks of local opposition, primarily for reasons of visual encumbrance.

The emblematic case of onshore wind power in Germany

Germany has very ambitious targets for the development of wind energy. In order to increase the renewable share by 2030 **from 51% to 65%** (and up to 80% in the new government's recent statements), wind should cover **75% of the additional capacity**. Despite the current difficulties in the construction of onshore plants, the new law on renewables (EEG 2021) maintains the **target of 71 GW of onshore wind capacity by 2030**, a goal which would require an **annual installation of 2.5 GW**. However, since 2017 there has been a drastic decrease in annual installations: only **0.9 GW in 2019 and 1.4 GW in 2020**, much less than the average of **4.3 GW/year in the period 2014-2017**. An obstacle to the full development of the sector comes from **mounting local opposition**, which has its roots in the past, when the rapid spread of onshore wind energy – starting in 1995 – gave rise to **growing protest movements** that have become increasingly effective since the late 2010s. According to Windwahn.de, **more than 660 citizens committees have been created against wind power in the last 15 years**. Not only that: **national groups such as Vernunftkraft and specialized lawyers offer their services to local residents to oppose projects in court**, filing legal actions for the conservation of species, noise pollution, protection of monuments, radio interference, and the visual impact of increasingly taller pylons.

Source → The European House - Ambrosetti and Enel Foundation elaboration on various sources, 2022.

At the same time, it is worth mentioning that **by 2050 the wind farms will have an average of 8 MW of electrical power per km²**, and agricultural or livestock activities will not be affected by this. From the comparison of these values, for example, with the "Net Zero" Scenario for Italy, which encompasses the achievement of 117 GW of onshore wind energy by 2050, it follows that **the total area in non-exclusive land occupation would be only about 4.8% of the national territory** (14,625 km²).

→ **POLICY PROPOSAL**

Simplifying the authorization procedures for RES plants and power grids and increasing their **social acceptance** by:

- Further simplifying and digitalizing the **procedures for issuing authorizations**.
- Strengthening the **offices in charge of the authorization procedures** with **task forces staffed** with trained and competent personnel, and designing **"go-to" areas for renewables**.
- Recognizing the **status of national public interest** for the "development of renewables", as acknowledged by the Italian legislation[4].
- Directly **involving citizens** from the early stages of new projects, allowing them to participate, for example, in the capital of project companies with free or low-cost share transfers, or by making project companies pay a share of the profits generated by renewable plants, to be added to local taxes.
- In addition, promoting **demand side management** as well as the deployment of **storage facilities and flexibility solutions**.

4
See art. 18 of Decree n. 77/2021 which modified art. 7 bis of the Environmental Code.

In order to deal with the shortcomings highlighted above, it is appropriate – first of all – to **simplify the procedures for issuing authorization certificates for new renewable capacity**. This can be achieved through the use of silent consent, the exercise of substitute powers, and identification of commissioners *ad acta*. As for Italy, to do so, it is essential to: i) **define the charges** to be paid by the authorization applicant when submitting the application; ii) **identify**, within one week of the filing of the application, **the person in charge of the administrative procedure**; iii) obtain the binding and non-binding opinions required for the correct completion of the administrative procedure **within 30 days of the submission of the application**.

Overall, thanks to these amendments to the current Italian process, **after two months from the filing of the application, the commission will meet without delay to deliberate on the issue of the single authorization**.

The person in charge of the procedure, after the authorization of the plant, will assume the role of **commissioner *ad acta*** for the issuance of all the documents necessary for the construction of the plant and she/he will replace the various authorities that may be competent on specific implementing documents. In addition to the above, in Italy it will be necessary to strengthen the offices – both national and regional / territorial – in charge of the authorization procedures with **task forces staffed** with trained and competent personnel. In fact, the deployment of investments in the installation of RES requires expertise in energy, digital and sustainability issues, as well as project management skills.

The difficulties associated with the development of renewable plants also involves the fact that their deployment is not recognized as being of national interest. Indeed, **public interest in the "development of renewables" should be defined**, thereby recognizing the pivotal role that renewables play in the energy transition, combating climate change and strengthening energy security. Since the permitting procedures involve different institutions, it is necessary to assess – for every single procedure – which body is entitled to exercise "public interest" in RES development. This way, the interest promoted by an institutional body would be properly balanced with the interest in renewables development, equally promoted by another institution. As a matter of fact, this would make it possible to correctly balance the two interests by evaluating the relative merits case by case, reducing the impact of the specific veto power.

Generally speaking, when it comes to the NIMBY syndrome, a traditionally effective response to the lack of support and acceptance of local projects is the **direct involvement of citizens** from the preparatory stages of new projects. The involvement of citizens, within a structured debate and deliberation process, is a pivotal factor to increase awareness about the importance of bridging the gaps of renewable plants and favoring the achievement of decarbonization objectives in the long term.

The idea is to turn NIMBY into **PIMBY** (Please In My Backyard), provided that residents receive an adequate share of the benefits for installations. This can be done by allowing citizens to participate, for example, in the capital of project companies with free or low-cost share transfers, or by making project companies pay a share of the profits generated by renewable plants, to be added to local taxes (thus guaranteeing a reduction in taxes for citizens).

Finally, from the point of view of the media and public information, it is also essential to **strengthen the role of local institutions, environmental associations** and **parties** to support the construction of the plants and overcome the related **NIMTO** syndrome (Not In My Terms of Office) for which local administrations may not find incentives in supporting the construction of a project opposed by the territory.

In Spain, the situation looks a bit **more favorable**. The **Spanish 2018 New Regulation** and the "**pay as bid**" **mechanism** for auctions introduced in 2020 have created an adequate framework for investments in RES plants, mainly due to attractive conditions for participation in tenders and efficient permitting procedures with a limited number of actors involved. Overall, in Spain there is an effective governance model.

Lastly, given that the development of RES must be accompanied by greater system flexibility, it will be crucial to promote **demand side management** as well as deployment of **storage facilities** and **flexibility solutions**.

3 → TRANSPORT – POLICY PROPOSAL

Simplifying charging infrastructure installation procedures, strengthening collaboration between all the e-mobility actors, enabling interoperability, optimizing the time-to-market of grid connections, and promoting electric public urban mobility

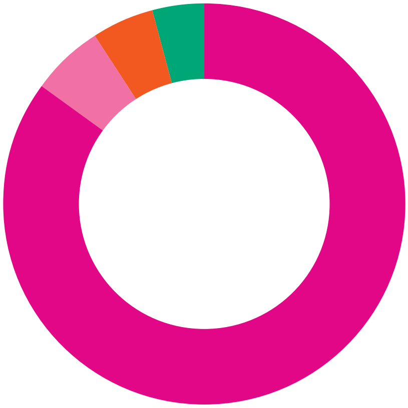
Rationale

The **collaboration between local authorities** (municipalities and regions), **Distribution System Operators** (DSOs) and **Charge Point Operators** (CPOs) is pivotal for the installation of charging infrastructures wherever charging needs arise, substantially reducing deployment times. Moreover, in the future, collaboration with DSOs is also expected to unleash the potential of Vehicle-to-everything (V2X) capabilities, such as in the development of local flexibility services, which will require the development of specific communication systems.

Indeed, various recharging networks are characterized by **different means of identification and billing systems**; simplifying them would make the charging experience of electric vehicle (EV) drivers smoother. As a matter of fact, users are required to sign up to more than one commercial scheme to get access to all the different charging networks.

Moreover, the electric vehicle market is expected to skyrocket in the next few years and, by nature, charging solutions will be widely differentiated: for instance, charging at home, at working premises, and on-the-go (both at low and high capacity). In 2021, **20%** of total new passenger cars registrations in Europe were **electric** and the total EV fleet (including cars, trucks, vans and buses) is expected to reach **130 million by 2035**. In Italy and Spain, the EV fleet is expected to reach 10.7 million and 11.4 million respectively by 2035 in the "Net Zero" scenario. In order to catch up with this rapid deployment of EVs, around 13 million **charging points** need to be installed in Europe by 2025, 32 million by 2030 and **65 million by 2035**. Moreover, 85% of charging points are expected to be residential, and thus a tight collaboration between municipal administrations, DSOs and CPOs is also key to support the installation of the infrastructure by citizens and local operators. In this context, it should be noted that the investments of the Italian government to develop mobility infrastructures and systems – including those of NRRP (which allocates €8,6 bn for sustainable local transport) – kept pace with regulatory interventions and reforms, aimed at making those investments more efficient in terms of socio-economic impact (addressing territorial inequalities), environmentally sustainable, and with simplified procedures.

FIG 7 → **Forecast of charging points per location in Europe, 2035** (% values)



Source → The European House – Ambrosetti and Enel Foundation elaboration on Eurelectric data, 2022.

→ **POLICY PROPOSAL**

- Simplifying and standardizing at national level the recharging infrastructure **installation and administrative procedures**, both for residential and public charging, also ensuring that new infrastructure can be installed in already existing buildings (e.g., through pre-cabling).
- Optimizing the time-to-market of grid connections, also by identifying adequate **preventive mechanism for grid planning and development** (also pivotal for RES deployment), considering recharging infrastructures as a support to grids and focusing on flexibility, ensuring that grid infrastructure can connect and manage the increasing capacity and flows (also on core and comprehensive transport network).
- Strengthening **collaboration, integration, and cohesion between all the e-mobility ecosystem actors** (players, platforms, systems, processes, and technologies), promoting interoperability, unlocking all business value and favoring the deployment of sharing mobility paradigm.
- Fostering **interoperability** (any vehicle, any contract, any payment mechanism) across charging networks.
- Promoting **innovative financial schemes** for public urban mobility (e-Buses), including leasing, Joint Purchasing Agreements between administrations, and **PPPs**.

The following proposals are designed to favor the deployment of charging points in Italy, overcoming the present roadblocks. Firstly, this could be pursued through simplification and standardization at national level of the **installation and administrative procedures**, both for residential and non-residential premises, and for public charging. As for residential charging, adequate measures (i.e., pre-cabling and the "right to plug") should ensure that already existing buildings are capable of installing new charging infrastructures, in line with the proposed revision of the EPBD.

Within this framework, **preventive grid planning** and development should be performed to guarantee that grid infrastructure can connect and manage the increasing capacity and flows (also on core and comprehensive transport network), ensuring overall **consistency between the several development plans of Charging Points (CPs)**. Moreover, recharging infrastructure should be considered as a support to grids and its deployment should focus on flexibility. It is also particularly important that regulated tariffs and levies are conducive to a greater penetration of electric vehicles.

Collaboration, integration and cohesion between all e-mobility ecosystems (players, platforms, systems, processes, and technologies) should be favored, so as to deploy charging infrastructure in a smart way, identifying charging needs based on traffic flows and the points in which the distribution network can accommodate high connection powers for every specific location. **Cooperation between private and local public actors** would be pivotal for the **analysis of needs in terms of number, type, and positioning of the charging infrastructures**, and the assignment of installation points to operators. In fact, the interaction of these actors will be the enabler for the use of planning tools that deliver a strategic view of energy and mobility management across real estate. Planned and progressive roll-out of charging infrastructure on public roads in each urban area will be accompanied by developing regulations and business models that are consistent with the electric vehicle penetration rate.

On the one hand, interoperability could be promoted by collaboration, integration and cohesion between all e-mobility ecosystems. On the other, **interoperability** could be further promoted in order **to grant the end user seamless EV usage**.

Lastly, to favor electric public urban mobility (i.e., e-buses) **innovative financial schemes** could be envisaged. In fact, despite the relevant financial resources allocated to sustainable transport, these are not always sufficient for local administrations to carry on a structural electrification of public transport. Moreover, electrification of public transport (including the substitution of the fleet) is a complex project that requires an integrated approach, and not a mere one-to-one substitution of ICE buses with e-buses. Therefore, administrations should consider innovative financial schemes to carry on their transport electrification strategies: for example, leasing (including the leasing of batteries), Joint Purchasing Agreements with other local administrations, and Public Private Partnerships (PPPs).

4 → INDUSTRY – POLICY PROPOSAL

Supporting the technological shift of industry towards greener technologies, creating national Tech Transfer Labs focused on technologies for direct and indirect electrification, and favoring demand-response

Rationale

As previously stated in the Study, the industrial sector accounts for **20%** of global CO_2 emissions, the highest share among the macro-sectors considered, with a share of 23% in Italy and 20% in Spain, and an average of 21% in the EU27+UK. Electrification of industrial manufacturing processes is crucial for sectorial decarbonization. In fact, electrification is expected to account for **46%** of industry final energy consumption by 2050 at global level .

In particular, in Italy **72% of industrial energy demand will come from electricity in 2050**, out of which 59% from direct electricity and the remaining share from indirect use deriving from **green hydrogen-related technologies,** whose development will be fundamental to decarbonize some specific **hard-to-abate industrial processes**, for instance, those that require very high temperatures, not reachable through electrified technologies but by power-to-hydrogen and hydrogen boilers. These sectors include chemical and steel, where hydrogen can be used as feedstock, but also the ceramic, glass, and cement industries, where hydrogen can replace fossil fuels to produce high-grade heat. Electrification will bring huge energy efficiency improvements, reducing the industrial sector's energy demand. Also, in Spain electrification is expected to skyrocket, reducing the energy demand of Spanish industries.

To promote the decarbonization of industry, one lever is the EU Emission Trading System **(EU ETS)**, a system based on the 'cap and trade' principle, where a cap is set on the total amount of certain greenhouse gases that can be emitted by installations covered by the system. Within the cap, companies receive or buy emission allowances which they can trade with one another as needed. This mechanism entails the **risk of carbon leakage** (defined as firms moving their activities to countries with less stringent climate rules to control costs), which distorts the trading system and is counterproductive to the process of reducing emissions. To overcome the carbon leakage risk, the EU started giving some **free ETS allowances** to industries at risk of carbon leakage. This is still happening as in 2020 when **50%** of allowances were given for free, relieving the most carbon intensive sectors from the need to curb their emissions. However, this mechanism is not sustainable in the medium and long run and does not comply with the 2030 energy and climate targets.

Besides introducing electrified and hydrogen-based technologies in its processes, the European and more specifically the Italian and Spanish industrial sectors are called to implement adequate industrial policies and investments for the manufacturing of **cutting-edge renewable technologies**, in order to provide the European economic ecosystem with domestically produced green solutions, gaining shares in those markets and not depending on non-EU manufacturers.

Thus, supporting Italian and Spanish industries in adopting electrified and green hydrogen-related technologies, such as low- and medium-temperature heat pumps or hydrogen boilers, and replacing polluting and less energy efficient fossil technologies in industrial processes is pivotal to reach sectoral decarbonization targets. In addition, developing European industrial manufacturing in emerging cutting-edge green technologies would guarantee Europe a competitive edge over Asian competitors, reducing the European Union's dependence on those countries for the supply of solar modules, wind turbines, batteries, etc. In order to do so, the introduction of an enabling entity for **technological and knowledge transfer from universities and R&D centers to industry consumers (including energy-related companies)** could be a very impacting policy, especially with regard to mature technologies (e.g., hydrogen, but also marine energy, etc.). The Tech Transfer Lab would offer entrepreneurs and the business community technological support, consulting services, technology-related risk assessment analysis and "go-to-market" strategies.

→ **POLICY PROPOSAL**

- Leveraging on legal frameworks like ETS (free allowances) to support the **technological shift of industry towards greener technologies** (green hydrogen).
- Creating national **Tech Transfer Labs** focused on direct and indirect electrification technologies, with the mission of acting as enablers of technological transfer from research institutions to industrial players (including energy companies), guaranteeing adequate collaboration at European level.
- Favoring the deployment of demand-response, by providing adequate **financial mechanisms** and increasing the **awareness** of industrial players.

To ensure that the EU ETS framework actually promotes the technological shift towards greener technologies (such as green hydrogen), adequate **free carbon allowances** should be designed to favor the deployment of the **most sustainable solutions and technologies**, still preventing carbon leakage. For instance, thanks to "Fit for 55", free carbon allowances have been introduced for green hydrogen or electrolyzer producers to level the playing field with producers of natural gas-based hydrogen. Given that the latter, at present, already receive free allowances to protect them from the potential risk of carbon leakage, free **carbon allowance schemes for greener solutions** could be strengthened, so as to ensure them an adequate competitive advantage.

On the other hand, the Tech Transfer Lab needs to be conceived as a **facilitator of technological transfer** to be realized in EU Member States. The Lab should be envisaged as a pivotal actor carrying out the role of reference point for academia, institutions and private players, guaranteeing effective **collaboration at European level** between the several national Labs and European centers, including the Innovation Centre for Industrial Transformation and Emissions (**INCITE**) that could be launched by 2024 as part of the proposal for a revision of the Industrial Emissions Directive (**IED**). The overall aim is to facilitate **the transfer of knowledge from universities/research networks to industrial players (including energy companies)**, to provide an enriched environment, suitable for career opportunities for national and international researchers, thus contributing to reduce the outflow of talented researchers towards other countries and to sustain the "go-to-market" mechanisms of the most promising end-use electric and hydrogen-fueled technologies. Effective tech transfer is crucial to deliver innovative products to market. At the same time, it is a **bidirectional process** that feeds R&D with critical data to help to continuously improve quality and drive costs down.

Fostering the transfer of new technologies would also allow companies to rely on external R&D structures. Instead of creating an internal division, firms could outsource, at least partially, these functions to the existing research center. Firms could then propose their needs and ideas to the Tech Transfer Lab, stimulating and supporting their realization and filling the communication gap between research and industry. Moreover, the Lab can also be enriched by the knowledge and experience of the energy sector's leading companies, which can spread and disseminate cultural and technological innovation and best practices to the market.

In order to do so, the Lab will undertake a set of activities, aimed at promoting:

- **Communication between researchers and investors**, which should be optimized.
- **Consulting activity** by experts, making it available for the several innovative projects.
- Entrepreneurial **risk assessment** analysis.
- Design of business plans for **projects related to the most promising and cutting-edge technologies** that are marketable, helping to define a "go-to-market" strategy.

The Lab may also support tech transfer in **other technological fields** not strictly related to industry, addressing development needs of other key sectors towards decarbonization (e.g., power and transport). Moreover, specific policy and regulation should be defined in order to sustain R&D activities, for instance with **regulatory sandbox** (for the regulated business) or financing **pilot projects**.

Lastly, considering that industries have the potential to deliver energy flexibility through demand-response, it will be crucial to increase the deployment of demand-response solutions. This could be done, for example, by providing adequate **financial mechanisms** (such as incentives for DR participation and subsidies in technology upgrade) and by increasing the **awareness** of industrial players.

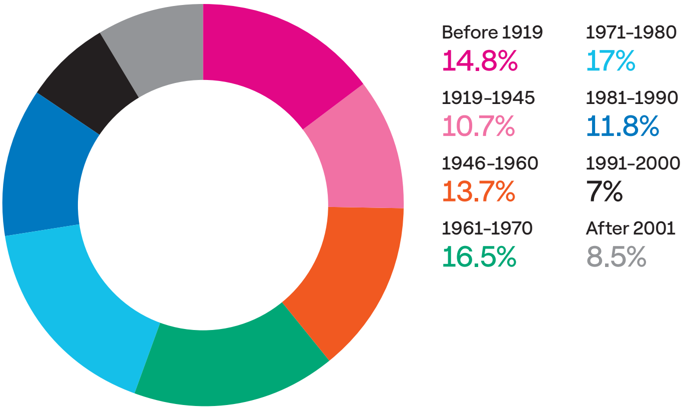
5 → BUILDINGS – POLICY PROPOSAL

Defining the phase out of fossil fuel boilers, leveling tax and levies with regards to heat pumps, and creating a one-stop shop to support the renovation of buildings

Rationale

Italy and Spain's residential building stocks are dominated by old buildings characterized by **low energy efficiency**. In Italy, for instance, more than 25% of total residential building stock was built before 1945, and 73% before 1980. In Italy, only 6.3% of total residential buildings falls within energy rating categories A or B, while more than 60% belongs to energy classes F and G (where energy class A buildings are characterized by thermal coating and renewable energy sources to satisfy their energy demand, lowering electricity and gas bills with respect to a very low energy efficient class G building).

FIG 8 → **Residential building stock in Italy by construction period, 2018** (% values)



Source → The European House – Ambrosetti and Enel Foundation elaboration on Strategia per la riqualificazione energetica del parco immobiliare nazionale, 2022.

Given the average age of the building stock in both countries, Italy and Spain have adopted a set of **incentivizing mechanisms** to support investments in building renovation and in boiler substitution projects aimed at improving energy efficiency class. However, there is the need to introduce mechanisms to make these mandatory in the medium-term and further finance these measures. For example, in June 2022 tax deductions granted by the Italian government under the Superbonus scheme to citizens who implemented renovation and energy efficiency interventions exceeded the allocated funds and amounted to **33.7 billion Euros**[5]. Similar plans and packages have been introduced in Spain.

5
Source: ENEA.

Overview of incentivizing mechanisms in Italy and Spain

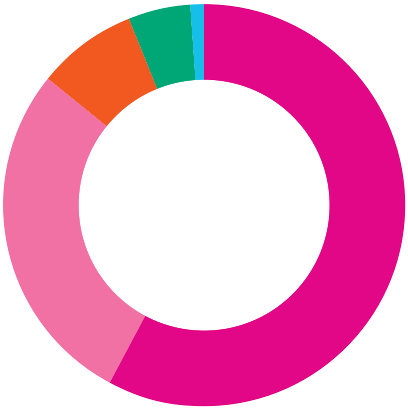
In **Italy**, the **110% Superbonus** represents the main financial instrument regarding energy efficiency in residential and commercial buildings. It consists in a 110% tax deduction granted to incentivize energy efficiency improvement or anti-seismic projects. The subsidized interventions include replacement of less energy efficient heat pumps with more energy efficient ones, solar thermal panels installation and thermal coating.
Ecobonus is another important financial instrument regarding energy efficiency in the residential sector in Italy, consisting in granting the **65%** incentive rate for technologies (like heat pumps, condensing boilers, solar thermal, etc.) while reducing it to a **50%** rate for the replacement of windows and shutters. In particular, the Air Conditioners Bonus includes a 50% of tax deduction in case of new efficient air conditioners with heat pump, which increases to 65% in case of heat pump replacement.

In turn, **Spain** has set up the **National Energy Efficiency Fund** (NEEF), aimed at financing economic and financial support mechanisms, technical assistance, training, information, or other measures in order to increase energy efficiency in different sectors, including buildings.
The **Program for energy rehabilitation actions in existing buildings** (PREE) aims at boosting the sustainability of the existing building through actions on thermal coating, and thermal and lighting installations. Finally, the 2018-2021 State Housing Plan, which includes the "**Program to foster improvements in energy efficiency and sustainability in housing**", aimed at supporting actions that concern the thermal coating of buildings, heating, air conditioning, hot water facilities and renewable energy devices, etc.

Source → The European House – Ambrosetti and Enel Foundation elaboration on ENEA and MURE, 2022.

Moreover, it is important to outline that most of the carbon emissions of the residential sector derives from heating systems. In fact, considering Italy, the energy consumption mix of heating systems is still dominated by gas (accounting for **58%** of total energy consumption for heating, as gas boilers are installed in **17.5 million houses**), followed by biomass (**28%**, with biomass boilers installed in 3.6 million houses) and oil (**8%** of the total energy consumption mix, since traditional oil boilers are installed in 2.5 million houses, including GPL and gasoil). The remaining share (6%) is made up by co-generation technology, which accounts for 5%, and solar thermal installations and electric heat pumps, which together represent around 1%. The data highlights the important initial investment needed to install energy efficient and green technologies, such as the electrification-driven technologies, which have already reached market maturity and offer medium- and long-term financial savings to households if compared to gas and oil boilers.

FIG 9 → **Heating system energy consumption mix by source in Italy, 2018** (% values)



Source → The European House – Ambrosetti and Enel Foundation elaboration on Eurostat, 2022.

In this context, the Recovery and Resilience Mechanism represents a key instrument to fund these interventions. In fact, "**Renovate**" is one of the seven flagship areas for investment and reforms defined by the European Commission, aimed at the improvement of energy efficiency of public and private buildings. In particular, Italy and Spain have allocated within their National Recovery and Resilience Plans (NRRPs) around 19 billion Euros and 7 billion Euros respectively to this area.

→ **POLICY PROPOSAL**

Defining the **phase out** of fossil fuel boilers in heating, levelling tax and levies with regards to heat pumps by overcoming year-by-year renewal and ensuring a **just, stable, and transparent regulatory framework** for consumers, by:

- Optimizing the **implementation procedures**.
- Devising **innovative financial schemes** inspired by European Union good practices, such as combining traditional mortgages with an *ad hoc* loan for energy efficiency technologies guaranteed by the financial institution under an agreement with an industrial player.
- Increasing citizens' energy efficiency **awareness** by introducing a "Household Maintenance Leaflet."
- Creating a **one-stop shop**, where citizens can be guided through the renovation processes, with integrated solutions and guarantees (e.g., qualified suppliers, granted permitting, access to support schemes and financing, quality control).

As some EU countries are doing (e.g., Germany, Netherlands and France), Italy and Spain should **define a phase out of fossil fuels** in heating. To make this viable, the ban could concern – at least in the first few years – only new buildings, exempting people doing a renovation project or changing the heating system; progressively, the ban should involve more and more buildings. Moreover, the phase out strategy should identify adequate **exemptions and incentives for more vulnerable citizens** in order to guarantee a **just transition**.

In order to do so and accompany citizens towards change, incentivizing mechanisms for heat pumps should be provided, at least in the short- and medium-term, and its regulatory framework should be kept stable and transparent in favor of consumers. Therefore, firstly, to promote a better distribution of the investments via the Ecobonus, the preliminary condition is giving continuity to the existing incentivizing measures. In other terms, to make a multi-annual investment plan easier for households, it is necessary to overcome year-by-year renewal in favor of **multi-annual planning**, providing adequate measures for vulnerable citizens and linking additional funds allocated for the multi-annual renewal of the incentivizing mechanisms to the ones granted by the European Union to sustain the Member States' actions for the "REPowerEU" priorities (after they **add a "REPowerEU" chapter to their NRRPs**).

Apart from the existing incentivizing mechanisms, innovative financial schemes should be introduced. For instance, one option could be combining **traditional mortgages with an *ad hoc* loan for energy efficiency technologies** guaranteed by the financial institution under an agreement with an industrial player. This solution could be a trigger for mature technologies able to deliver high energy efficiency gains with medium- and long-term payback periods. The overall objective of this recommendation, the first of this kind also due to the features of Italian and Spanish housing stock, is to **broaden the array of financial instruments available** in the residential sector by specifically targeting the necessities of those technologies that require an important initial investment.

Horizon 2020, the EU's research and innovation funding program from 2014-2020 with a budget of nearly 80 billion Euros (then replaced by the Horizon Europe program) provides best practice examples of innovative energy efficiency financing products and schemes: the **Energy Efficiency Mortgage** initiative aims at creating a standardized "energy efficient mortgage", through which building owners are incentivized to improve the energy efficiency of their buildings or acquire an already energy efficient property by way of preferential financing conditions linked to the mortgage. The granting of loans by banks to finance these types of mortgages represents a lower risk on the balance sheet of banks, due to their impact on a borrower's ability to service their loan and on the value of the property and could therefore qualify for better capital treatment.

In order to be more effective, governments' funding and incentivizing mechanisms must be supported by a communication strategy aimed at increasing the awareness of citizens and the business community on the benefits offered by energy efficiency. In fact, sustainable and energy efficient behavioral changes of public opinion and citizens are fundamental to achieve national long-term strategies' decarbonization goals. The "**Household Maintenance Leaflet**" is conceived to promote a systemic approach to energy management. In summary, the leaflet can help to increase **consumer awareness** about the benefits of energy efficiency by:

- Providing the owners with synthetic information on savings obtainable from the energy efficiency investment and their return.

- Introducing a mechanism that keeps track of all the interventions made by the owners, with the potential to be "**priced by the market**," allowing to increase the value of energy efficiency investments in the housing market.
- Increasing the awareness of energy efficiency throughout the value chain related to buildings (intermediaries, installers, and financial institutions).

Hence, although its main target are householders, the leaflet can be an awareness-raising tool for all the players in the value chain of buildings.

As regards capacity building, skills and simplification, **one-stop shops (OSS)** could represent a key element to make a successful transition in buildings, and the more than 60 one-stop shop models that have appeared across the EU over the last 10 years prove it[6]. One-stop shops are **transparent and accessible advisory tools for citizens** that allow them to be guided through the renovation processes, accessing integrated solutions and guarantees (e.g., qualified suppliers, granted permitting, access to support schemes and financing, quality control). In particular, an OSS is effective because:

- It is local.
- It accelerates building refurbishments by informing, motivating, as well as assisting building owners to follow through energy efficiency investments, by standing beside them from start to end.
- It can facilitate interested, but not yet committed energy users/asset owners to actually implement an energy saving or other type of sustainable project.
- It can facilitate access to financing and occasionally offer better rates.
- It can be one of the tools to increase the renovation rate.
- It can also improve the average renovation depth in terms of energy performance because an OSS supports users through the complete renovation path[7].

Moreover, the promotion of OSSs is strictly in line with **Directive 2018/844/EU**, according to which Member States are required to facilitate access to appropriate mechanisms for accessible and transparent advisory tools, such as one-stop shops for consumers and energy advisory services, on relevant energy efficiency renovations and financing instruments.

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