The energy transition in Italy and the role of the gas and power sectors

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The world, European and Italian energy scenarios

By cdp

1.1
Global macro-trends and energy transition.

1.1

The world is buffeted by powerful forces of change. **Global mega-trends** are radically redefining the structure of **political, economic and social balances at the international level.** The growth and development trajectories of the entire planet depend substantially on the answers that institutions, governments, corporate entities, markets and civil society will be able to provide.

Over the next three decades, demographic dynamics, socio-economic changes, the acceleration of technological innovation, the spread of digitalization and the growing impact of anthropic activities on the environment and on the exploitation of natural resources, if not properly governed, will transform the world into a place that bears no resemblance to Earth as we know it.

The energy sector is affected by these trends under multiple dimensions and directions. As a consequence of changes in geo-political balances, energy consumption is gradually shifting from America and Europe to South East Asia. The economic expansion of developing countries, in addition to significantly increasing demand, will bring to the markets an ever-greater share of the billion people who still do not have access to electricity today. Population growth will have an increasing impact on access to scarce resources, including energy resources responsible for the most significant share of climate-changing emissions.

Technological innovation and digitalization can contribute to accelerating the energy transition towards a carbon neutral economy, which has marked the first important steps over the last two decades. It is ever more necessary, if the planet wants to achieve sustainable, lasting and inclusive growth, that represents the core of the seventeen Sustainable Development Goals (SDGs) adopted by the UN through the 2030 Agenda.

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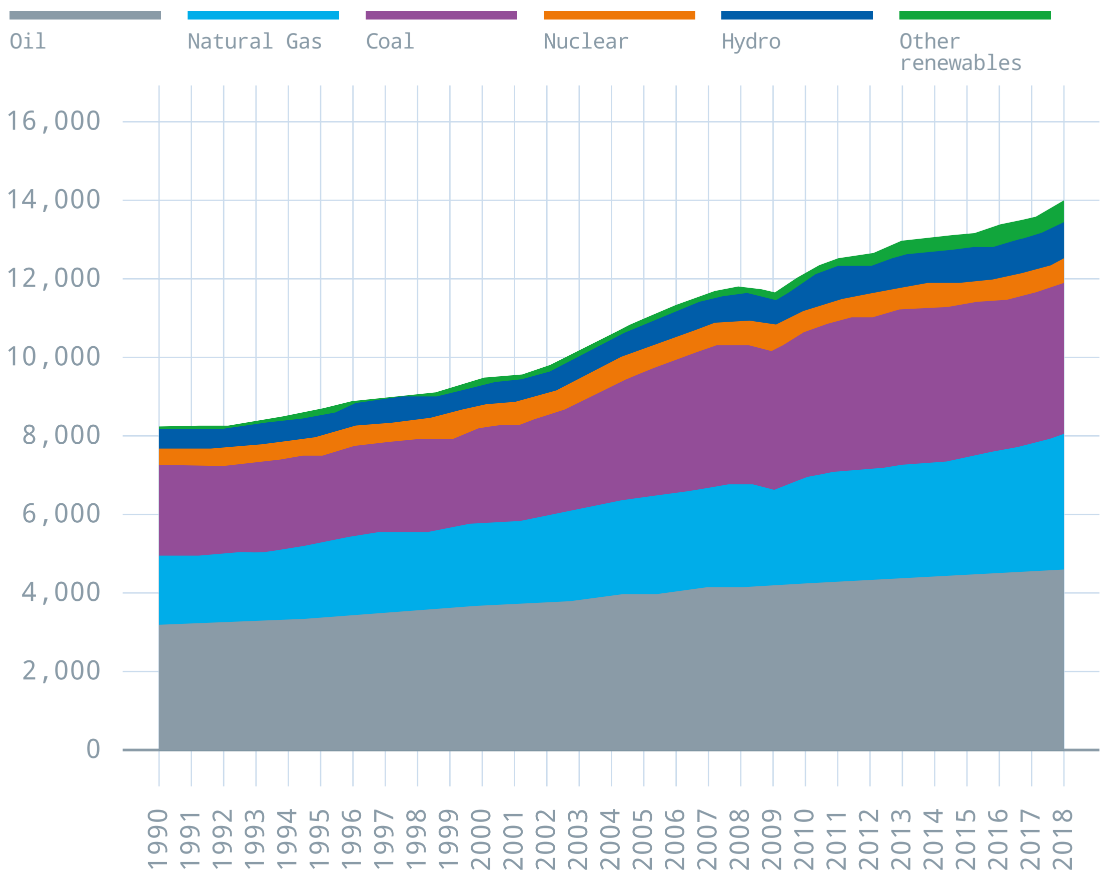
1.2
The global energy market.

Over the last thirty years, **global energy consumption has experienced a constant expansion** that has led to an absolute value increase of over 70%, with average annual growth rates of 1.9%.



▲ **Figure 1.**
Global primary energy consumption by source (Mtoe), 1990-2018.

Source: CDP elaboration on BP data, 2019.

Although the trends recorded in recent years have highlighted the increasingly important role of natural gas and the progressive growth of renewable energies, **the impact of different sources on global primary energy consumption mix remained relatively stable** between 1990 and 2018. Fossil fuels, which accounted for about 88% of the total, continue to have a share close to 85%, while renewables other than hydropower still cover only 4% of total consumption despite the recent acceleration (+16.3% per year since 2009 to date).

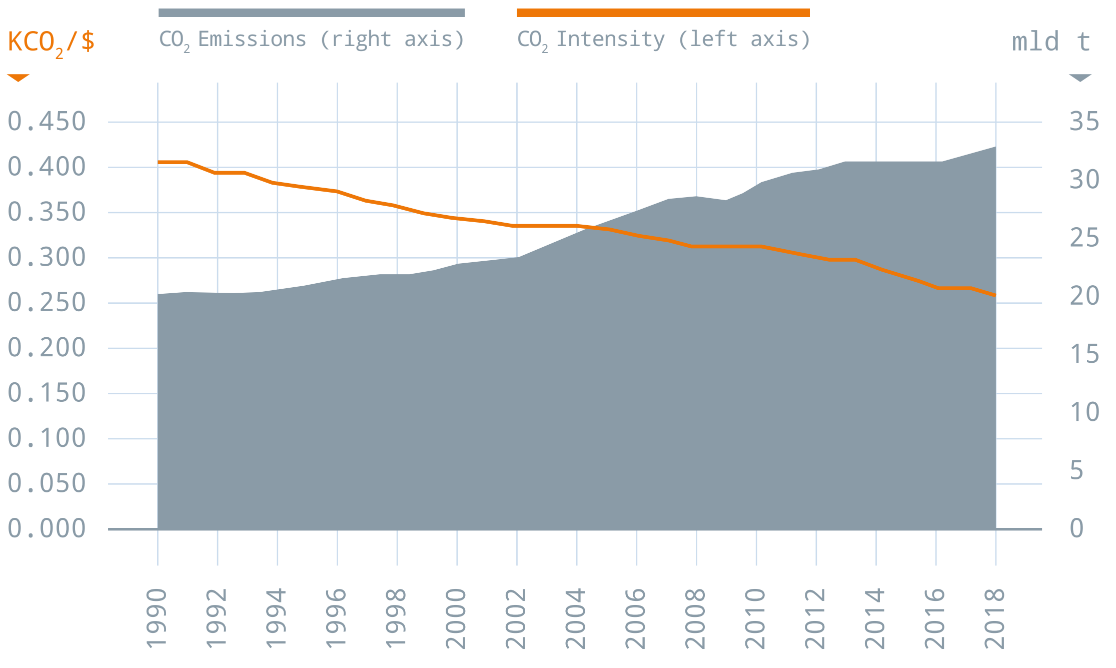
One of the main reasons is the radical change in the geography of energy consumption. North America, which was the most significant area in 1990, with more than 28% of the world total, represented just over 20% in 2018, while Europe declined from 26% to 15%. On the other hand, the countries of the Asia-Pacific region have almost doubled their share from 22% to 43%.

This change has been due to the **different dynamics that have characterized the composition of the energy mix,** partly because of the different degrees of economic development and the different environmental policy choices . While Europe has experienced a reduction in the share of fossil fuels from around 85% in 1990 to around 74% in 2018 and a simultaneous increase in renewables of 10 percentage points, variations in North America and Asia-Pacific were much smaller, with change more modest.

1.3

1.3
CO_2 and carbon emissions.

Thanks to these phenomena, despite the constant improvement in the carbon intensity of GDP that has experienced a contraction of over 35% since 1990, **CO_2 emissions have continued to grow,** reaching a record level of nearly 33 billion tons in 2018, mostly due to the simultaneous major increase in the consumption of fossil fuels[1].



▲ **Figure 2.**
CO_2 emissions (Gigatonnes) and carbon intensity of GDP (Kilograms of CO_2 on GDP – US$), 1990-2018.

Source: CDP elaboration on Enerdata data, 2019.

[1] *Enerdata (2019). The figure refers to CO_2 emissions related to the burning of fossil fuels (oil, gas and coal), which represent around 80% of total emissions.*

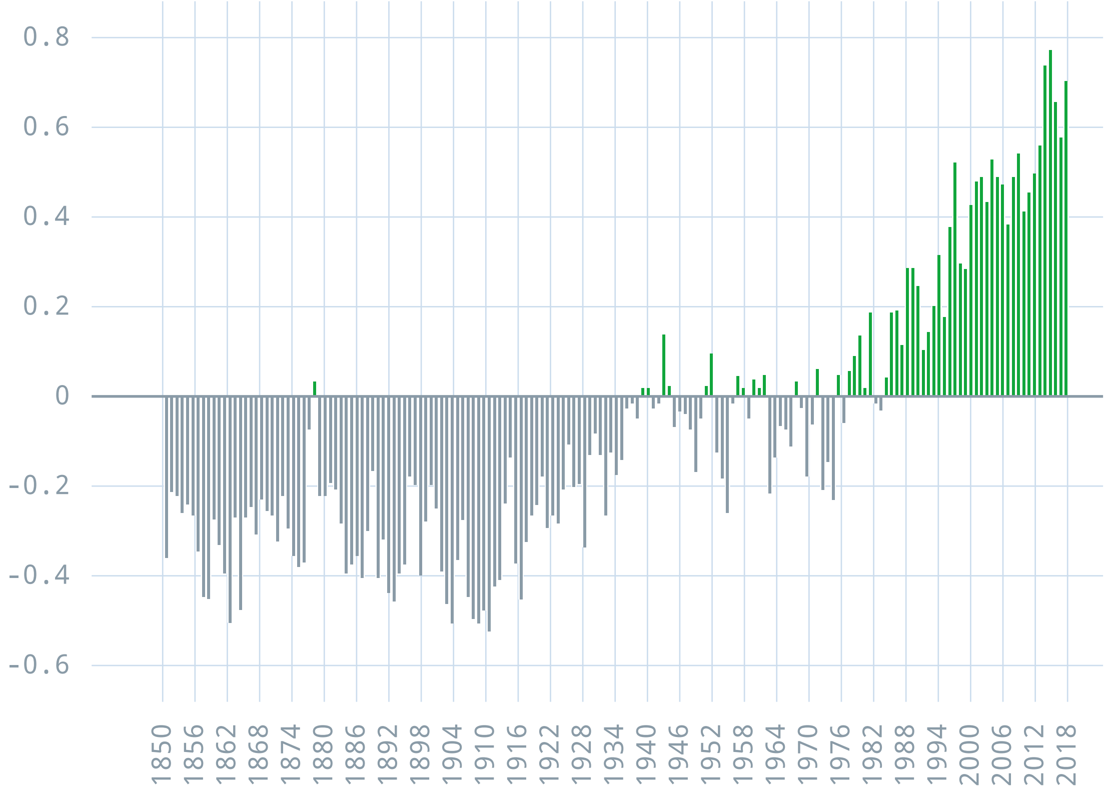
1.4
Global temperatures.

The most immediate effect of this trend is the increase in global temperatures which, according to the latest estimates, are 1°C higher on average than those recorded in the pre-industrial era. 2018 was the fourth warmest year since 1880, with a temperature of 1.5°C higher than the average calculated over the period between 1951 and 1980. Overall, the last 5 years have been the warmest since records began[2].

Furthermore, extreme climatic phenomena with ever-greater impacts are growing in number and intensity. Between 1990 and 2018, there were more than 15,000 catastrophic events of a geophysical, meteorological, hydrogeological or climatic nature, with the loss of more than 1.5 million lives and damage to economies and territories estimated at over 4.2 trillion dollars[3].

▼ Figure 3.
Anomalies in global temperatures (°C), 1850-2019.

Source: CDP elaboration on Climatic Research Unit, University of East Anglia data, 2019.
Note: The anomalies in global temperatures are calculated considering the deviation from the average temperature recorded in the period 1960-1990.



[2] *NASA GISS (2019).*
[3] *MunichRE, NatCatSERVICE (2019).*

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1.5
The Earth Overshoot Day.

Apart from global warming, demographic growth and global economic development are closely correlated to global sustainability. In 2019, the **Earth Overshoot Day**[4], which measures the environmental footprint of humans by identifying the date when all available resources are consumed for a given year, fell on 29th July; only 20 years ago it was on 1st October. This means that today' s world population already need the resources of about 1.75 Earthhs to satisfy their needs for a year without compromising the security of future resources.

These data clearly show that the model on which the development of the planet has been built over the last few decades will be unsustainable in the future. This requires a global commitment to a **progressive and more rapid decarbonization** of all energy sectors. If we do not change the current path, energy consumption in 2040 will be 38% higher than today, CO_2 emissions will increase by 23% and global temperatures could rise to a level that would make environment impacts irreversible, exposing the planet to a systemic risk of catastrophic climatic events, with disruptive effects on economic growth, social stability and geopolitical balances[5].

Thanks to the growing and widespread awareness of these factors, international debate has increasingly focused on identifying the development paths needed to deliver a decent world to future generations. Within this framework, the need to define global policies aimed at containing emissions has crystallised. This long process began with the adoption of the United Nations Framework Convention on Climate Change in 1992, was followed by the partial failure of the Kyoto Protocol signed in 1997 and culminated with the signing of the Paris Agreement on climate change in 2015, ratified by 185 countries to date.

[4] *https://www.overshootday.org/.*
[5] *IEA (2018). The estimates of growth in energy consumption and CO_2 emissions refer to the "Current Policies Scenario" which considers the expected evolution with unchanged policies.*

1.6
The Paris Agreement.

1.6

The Paris Agreement is the first with a global reach and a binding character in the field of climate change and aims **to keep the average increase in temperatures well below 2°C compared to pre-industrial levels** and to intensify efforts to limit this increase to 1.5°C in order to significantly reduce the risks and impacts of human activities on the environment[6].

These thresholds are considered by the international scientific community to be those which, with a probability of 50% and 66% respectively, would make the process of raising the concentration of greenhouse gases in the atmosphere reversible[7]. Nevertheless, reaching these goals would require a **radical transformation of the global energy system with the taking of concrete actions** in all sectors, a commitment focused on the production of electricity from renewable sources, the development of renewable gases, hydrogen and the electrification of final consumption. It is estimated that, if a share of 66% and 50% of renewable sources and electricity with respect to final energy consumption could be achieved, with a total of 2,200 TWh of hydrogen in the energy mix, this might result in a substantial reduction in emissions, reaching values of 48% lower than 2016 levels in 2040 and around 70% lower in 2050[8].

To implement the objectives assumed under the Paris Agreement, the signatory countries are required to adopt **"Nationally Determined Contributions"** (NDC), aimed at identifying the quantitative targets, strategic plans and energy policy tools needed to the gradual decarbonization process. However, according to preliminary estimates based on the expected effects of the proposed NDCs, climate-changing emissions would continue to grow over the next decade, albeit at a slower pace[9].

The COP 26, to be held in 2020 in the United Kingdom, will represent a key opportunity to review the NDCs presented by the parties involved and to calibrate the commitments made to ensure consistency with the final objective.

[6] *Paris Agreement, art. 2.*
[7] *IPCC (2018).*
[8] *IRENA (2019).*
[9] *UNFCCC (2016).*

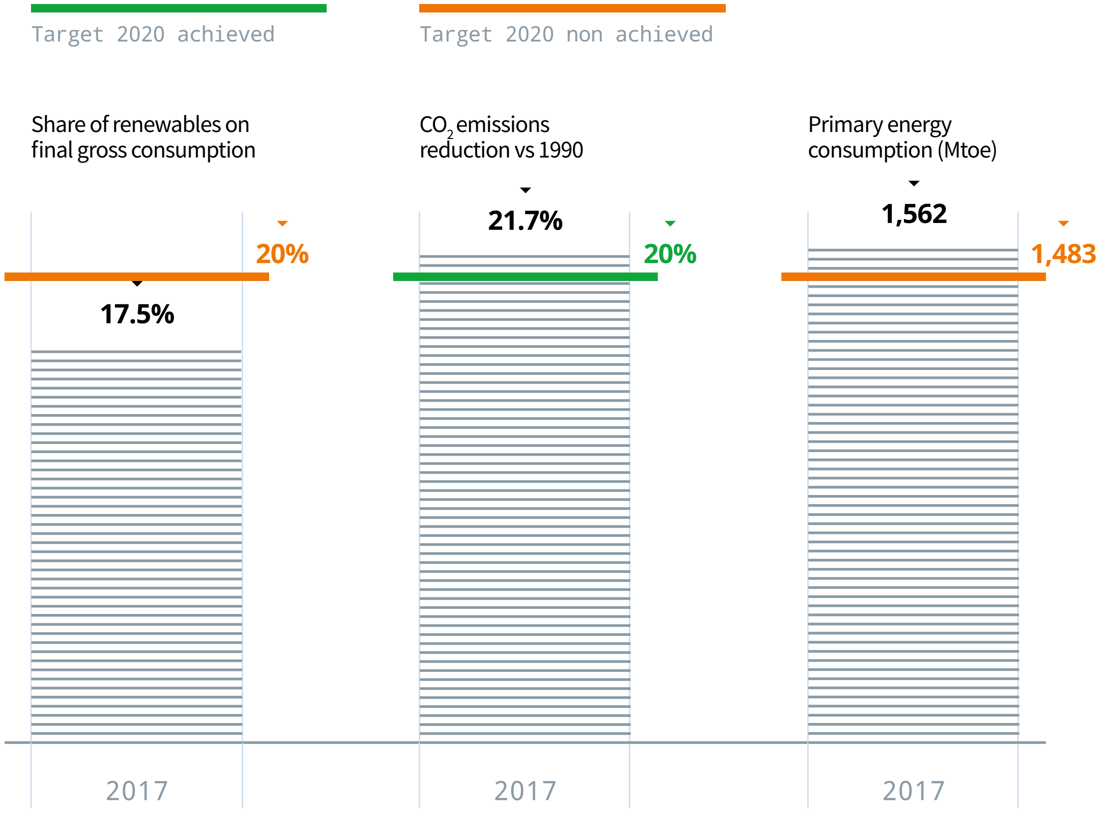
1.7

1.7
European policies to fight climate change.

In fighting against climate change, the European Union has taken a leading international role since the 1990s in designing environmental energy policies that promote innovation, combining economic growth with the protection of ecosystems. **The EU, together with its Member States, is the only Party to have ratified the Kyoto Protocol which is in the process of reaching the three objectives set for 2020** for containing emissions, increasing the use of renewable energy sources and promoting energy efficiency. Furthermore, this process has had positive socio-economic implications in terms of increased employment in the energy sector and reduction of energy costs from renewable sources, to the point that photovoltaic and wind power are beginning to compete with conventional fuels on today' s energy markets.

▼ Figure 4.
Distance of the European Union from the 2020 targets (percentage values).

Source: CDP elaboration on Eurostat data, 2019.



1.8
“Clean Energy Package” and 2030 target.

1.8

To meet the challenge of decarbonization over the next decade and follow up on the commitments made in the Paris Agreement, the European Union has developed the "Clean Energy for all Europeans" Package, also known as the **"Clean Energy Package".** This is a system of rules that acts simultaneously on all the 5 dimensions of the Energy Union: energy security, internal market, energy efficiency, decarbonization, research, innovation and competitiveness. The Clean Energy Package has set **three new goals to be achieved by 2030:**

- reduction of at least 40% of greenhouse gas emissions compared to 1990 levels;
- at least 32% share of final energy consumption represented by renewables;
- improvement in energy efficiency, with a reduction of at least 32.5% of primary energy consumption compared to the business-as-usual scenario.

Under the new governance of the Energy Union, by December 2018, each Member State has drawn up a proposal for an **integrated National Energy and Climate Plan (NECP) for the 2021-2030** period which establishes the necessary policies to effectively reach the targets set at European level. Following the evaluation process envisaged in the legislation, the Commission has provided a series of recommendations to strengthen the commitments, which the countries will have to take into consideration in the final version of the NECP, expected by the end of this year.

1.9

1.9
"Green Deal"

This approach, aimed at speeding up this process, seems to be reflected in the orientation of the energy policy by the new Commission that will be established in November 2019. In her first official communications, President Ursula von der Leyen outlined a **European Green Deal** rooted in raising the emissions reduction target to 50% and relaunching international negotiations to increase the level of ambition of the other countries most responsible for global warming. In this context, the European target could subsequently be revised to reach 55%.

This commitment has already had a national impact. In **Italy,** the newly formed Government has announced its intention to promote a **"Green New Deal"** that "involves a radical change of cultural paradigm and leads to the introduction of environmental and biodiversity protection as one of the fundamental principles of our constitutional system"[10].

All these objectives - national, European and global – are extremely ambitious. If they are to be achieved, the following will be necessary: i) a rapid transition towards completely new production and consumption models, relying on increasingly more established technologies and the innovations that will take place over the next few years; ii) an unprecedented mobilization of resources. **The most challenging scenarios currently estimate an investment requirement at global level of around 3 trillion dollars per year until 2050,** while this value has been just over 1.8 trillion dollars in the last two years[11].

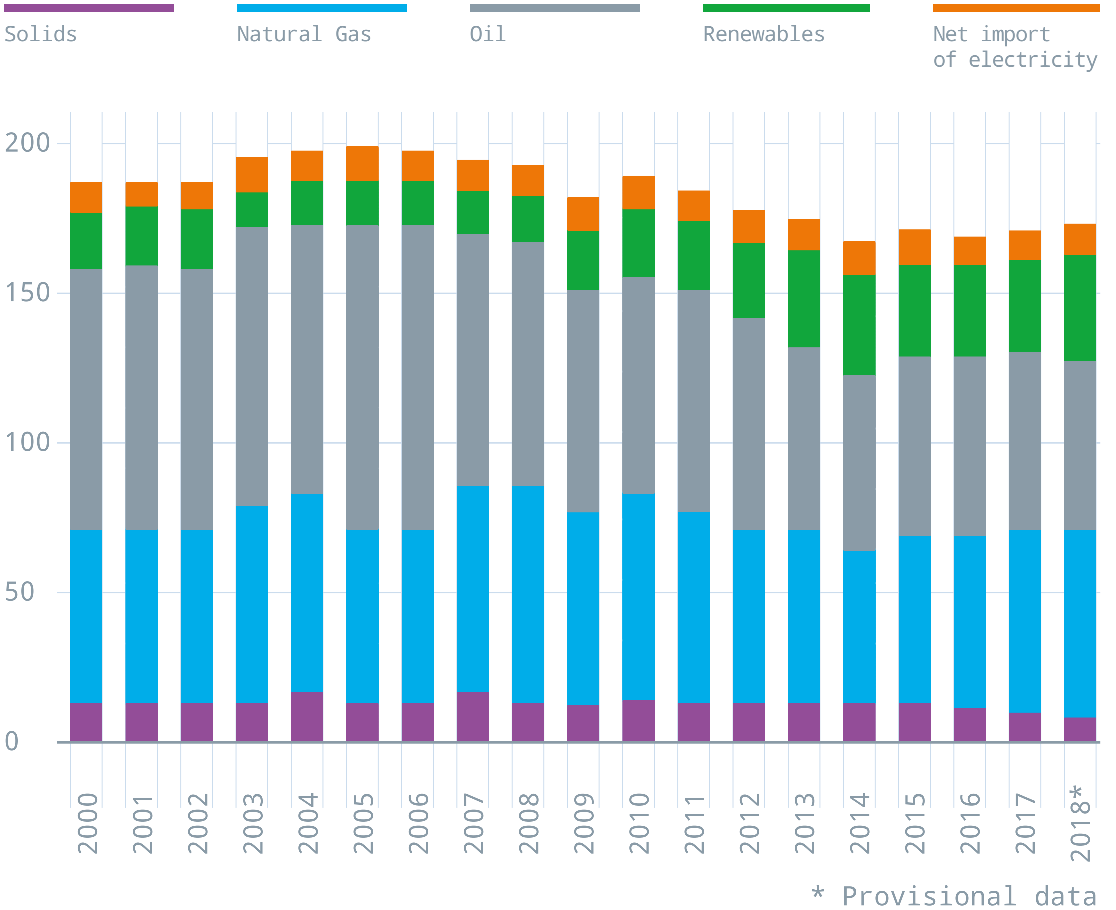
To achieve such an ambitious target, the international community needs to promote a convergence of objectives and commitments involving all the stakeholders. International institutions, national policy makers, the financial world, industrial sectors and civil society must make a greater contribution, aware that the sustainable development of the planet depends on a successful transition to a low carbon impact economy.

[10] Government program PD-M5S, 4 September 2019.
[11] IEA (2018); IRENA (2019).

1.10
Primary energy consumption in Italy.

1.10

In Italy, total primary energy consumption reached 172.3 Mtoe in 2018, a rise of 1.6% compared to the previous year due to the expansion of GDP (+0.8%) and climatic conditions characterized by a particularly harsh winter. By analyzing trends in overall demand, we can highlight a contraction of more than 7% in absolute terms between 2000 and 2018, with a peak of 197.8 Mtoe in 2005 and a minimum of 166 Mtep in 2014.



▲ **Figure 5.**
Italian energy balance (Mtoe), 2000-2018.

Source: CDP on Ministero dello Sviluppo Economico data, 2019.

1.11

1.11
Italian energy mix.

The structural reduction of energy consumption reflects on the one hand the gradual evolution of the production structure with a contraction of activities in the industry and construction sectors and, on the other, the improvement in the efficiency of end uses, as evidenced by the gradual reduction in energy intensity which fell by -10.7% over the 2000-2018 period[12].

Analysis of the trends of the various energy sources, in 2018, shows:

- The persistent **decline in the use of non-renewable solid fuels,** which reached an all-time low of 9.2 Mtoe in 2018, a value 46% lower than that recorded in 2006-2007. This trend is due to the gradual closure of coal-fired power plants and the reduced use of those still in operation, thanks to national energy policies and the high production costs linked to the changing cost of raw materials[13] and a reduction in the use of fuels solids in industrial end uses, such as for steel mills;
- After three years of significant increases that had brought consumption from 50.7 Mtoe in 2014 to 61.7 Mtoe in 2017, a **3.4% reduction in natural gas,** reaching 59.5 Mtoe. The economic trend is due to the lower appeal of natural gas as an input for electricity generation. The latter benefited from particularly favorable hydraulic conditions, leading to an increase in hydroelectric production of over 30%. Consumption is growing once againin 2019;
- **An increase of 1.6% in oil consumption,** equal to 58.6 Mtoe, due to persistently heavy use in the transport sector, where it covers a portion of over 92% of demand. Net of last year's trend, the use of oil has fallen by more than 35% compared to the values recorded in the early 2000s;
- **A significant increase in the contribution of renewable sources,** which reached 35.3 Mtoe, a rise of 11.4% compared to 2017. The trend in hydroelectric generation more than compensated for the setback suffered by wind and photovoltaic. Between 2000 and 2018, renewables more than tripled their volumes, with an average annual growth rate close to 6%;

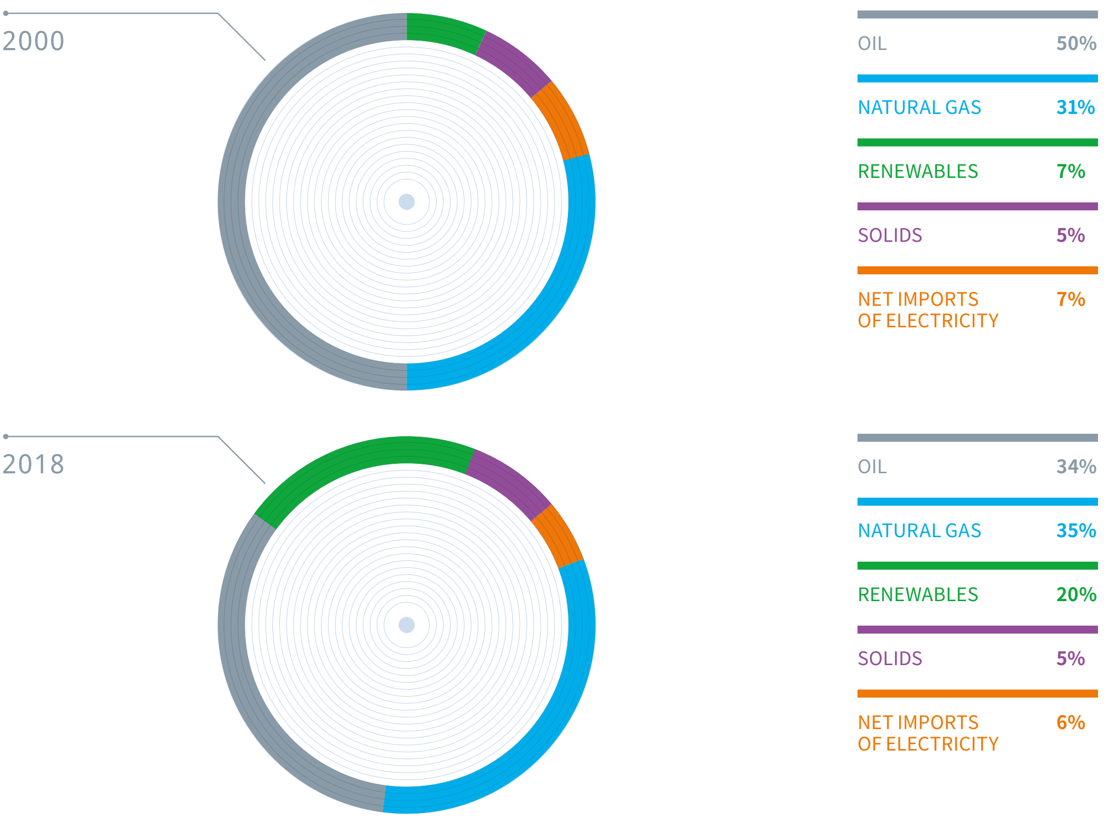
[12] *Ministero dello Sviluppo Economico (2019).*
[13] *Unione Petrolifera (2019).*

- **A rise in net imports of electricity,** which returned to grow up to 9.7 Mtoe, in line with the values recorded before the tensions in Europe in the 2016-2017 winter period due to the unavailability of the French nuclear park.

Overall, the long-term dynamics of the different supply sources have led to a **significant change in the production mix.** Whereas fossil fuels covered about 88% of the total energy demand in 2000, with oil representing 50%, this share fell to 74% by 2018, with oil falling by 16 p.p. and natural gas consolidating its leadership position with 35%. In this context, renewable sources recorded a significant increase, reaching 20% of the total.

▼ **Figure 6.**
Italian energy mix (%), 2000-2018.

Source: CDP on Ministero dello Sviluppo Economico data, 2019.



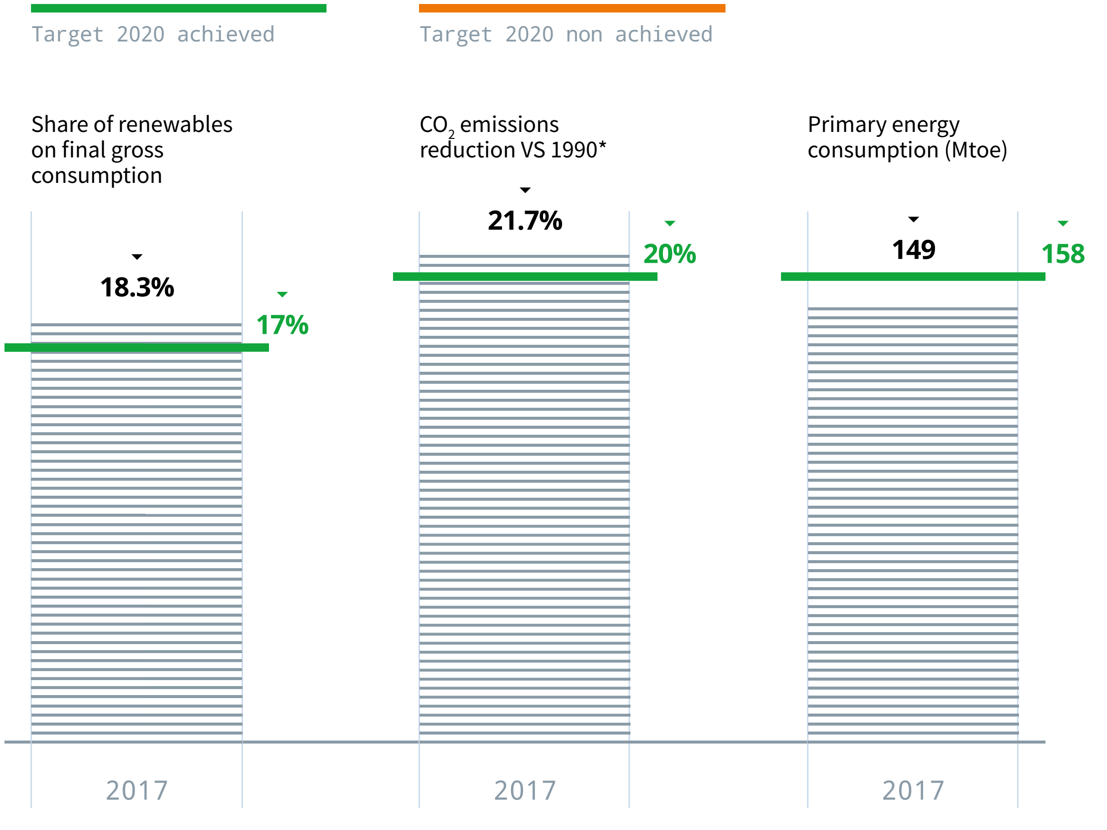
1.12

1.12 Italy and 2020 target.

The reduction of energy consumption - also due to the improvement of energy efficiency, the evolution of the production mix with a significant decrease in fossil fuels in favor of natural gas and the simultaneously increasing penetration of renewables, **enabled Italy to achieve the goals set for Europe by the 2020 Energy Climate Package as early as 2017.**

▼ **Figure 7.**
Italy and 2020 target.

Source: CDP on Eurostat data, 2019.



* The overall objective of reducing CO_2 emissions is set at European level. With reference to the sectors included in the "Effort Sharing" regulation, subject to a specific objective for each country, Italy achieved a reduction of 19.6% in 2017 against a target of -13%.

2.0

The Scenario Description Document (SDD 2019)

By snam Terna

2.1

2.1
Players of the Scenario Description Document.

The achievement of the Italian policy targets requires the joint and coordinated work of the main actors of the Italian energy sector, in order to reach a coherent vision of the conceivable future trends of the Italian energy system. For this purpose, Snam and Terna developed **the Scenario Description Document (DDS 2019)*,** whose outcome is preparatory to the **national transmission grids development plans** of electricity and natural gas sector at national level. This work allowed the two system operators to put together their specific expertise, being aware that the interaction between electricity and gas scenarios represents, at both national and European level, a new element characterised by a high degree of complexity.

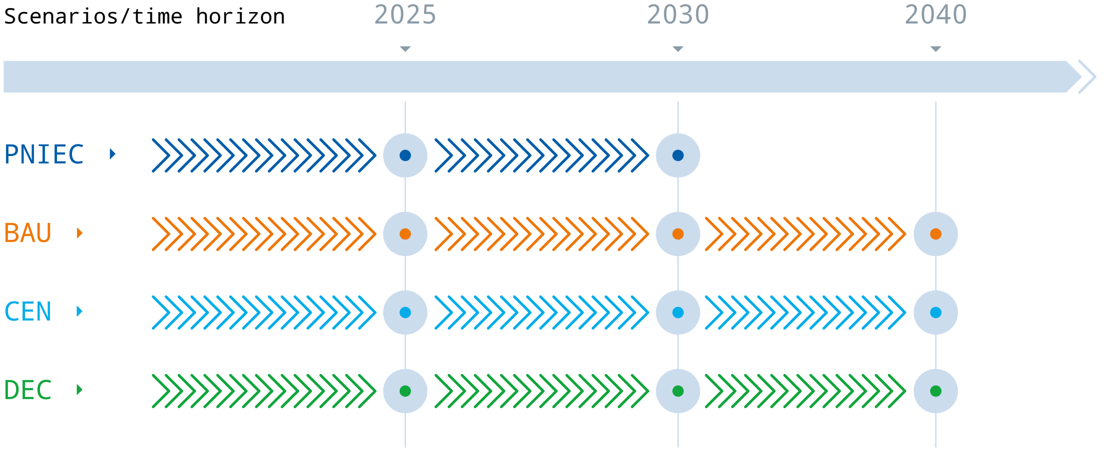
The working activities have been carried out in compliance with ARERA resolutions 654/2017/R/eel and 689/2017/R/gas, in line with the process developed at European level, in which the two associations of electricity and gas transport (ENTSO-E and ENTSOG) build joint energy scenarios, essential to the relative Ten-Year Network Development Plans for electricity and gas infrastructure (TYNDP).

The scenario elaboration process lasted for almost two years and was organised in three different working groups, committed respectively to **technological aspects, scenarios elaboration e regulatory,** with the help of many analytic tools, specific models and databases. Furthermore, Snam and Terna working group received the support of several stakeholders, including institutional players, sector operators, research institutes, by means of three workshops, held in coincidence with the key decisional moments.

* *The Scenario Description Document is available on the dedicated web pages of Snam and Terna web sites.*

▼ Figure 8.
Scenarios and time horizons used in DDS 2019.

Source: Terna and Snam elaboration, 2019.



2.2

2.2
The methodology of the Scenario Description Document.

The DDS 2019 includes 3 different and contrasting scenarios on a 2040 time horizon:

- **a Business-As-Usual (BAU)** scenario, which inertially projects actual trends and where technological development is purely based on economic merit order;
- two so-called development scenarios, **Centralized (CEN) and Decentralized (DEC), that reach 2030 decarbonisation, RES share and energy efficiency targets and comply with the non-binding provisions of long-term CO_2 emissions reduction**[14] using a minimisation of the decarbonisation costs and alternative technological developments approaches.

The two development scenarios are based on the same macro-economic background, characterised by a relatively high growth of GDP (1,2% annual) and population (+2,4 million inhabitants in 2040), as well as by crucial investments in energy efficiency and technological development.

Targets are achieved in CEN scenario mainly through energy consumption reduction and renewable energy development, particularly dispatchable RES, such as green gases, taking advantage of the existing gas infrastructure utilization.

DEC scenario reaches the same long-term targets as the CEN one, by means of a faster development of electricity as energy carrier and of non-dispatchable renewable energy sources, such as wind and solar energy.

Both development scenarios envisage a crucial role for every suitable technology and for emissions reductions techniques, especially in the long-term. This underlines one more time the intrinsic challenge that characterises the deep decarbonisation process.

In addition to BAU, CEN and DEC scenarios, a scenario, based entirely on the **Italian National Energy and Climate Plan (PNIEC),** in its preliminary version sent to the European Commission in December 2018, has been built. The PNIEC scenario **has been adopted as Italian policy scenario for 2030,** and used as touchstone for energy efficiency, RES share and emissions reduction targets.

[14] *Established by the European Commission 2050 Long-term strategy.*

				✓	✗		✓		✓	
		Target		PNIEC	BAU		CEN		DEC	
	2017	2030	2040	2030	2030	2040	2030	2040	2030	2040
CO_2 emissions reduction vs 1990 [%]	17.4	40.0	~ 65	40.0	28.4	32.0	42.9	64.1	41.4	63.7
Final energy consumption [Mtep]	113.6	103.8	N/D	103.8	114.3	115.3	103.8	93.4	103.1	90.2
RES share on final energy consumption [%]	18.1	30.0	N/D	30.0	20.0	22.7	30.0	44.3	31.3	50.5

▲ **Figure 9.**
Decarbonisation, final energy consumption and RES share target.

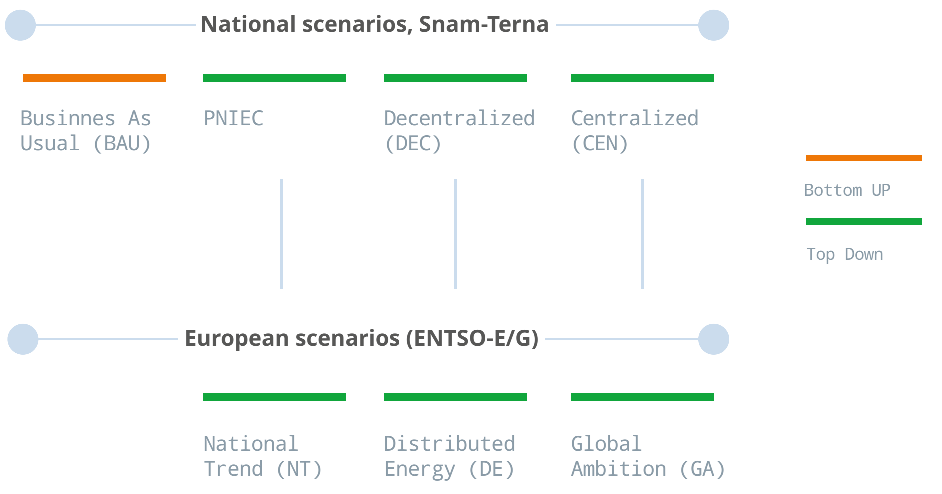
Source: Terna and Snam elaboration, 2019.

The scenarios building process started with an initial stage of storylines definition and inputs set-up, followed by a final energy consumption forecast phase, an electricity market analysis phase and, for development scenarios, the verification of the accomplishment of policy targets.

Final energy consumption has been modelled with an analytic tool, using macroeconomic parameters and commodity prices as input forecasts, and performing an economic optimisation process, based on technology Total Costs of Ownership (TCO) and technical constraints related to their potential diffusion. **Power sector** has been analysed with another **analytic tool** which forecasts the optimum dispatchment according to the merit order of electricity generation fleet, including the techno-economic sustainability evaluation and the optimisation of renewable sources based on the evaluation of Levelized Cost of Energy (LCoE) and technical, adequacy and policy constraints.

In the definition and elaboration of the scenarios, the working group put consistent effort into assuring the highest grade of coherence with the analogous long-term European scenario building processes, yet under development by ENTSO-E and ENTSOG. The following Figure shows the logical correlation between European and Italian scenarios. The temporal mismatch between the activity roadmaps, together with a higher level of detail in the national scale analysis, led to slight discrepancies between national and European scenarios.

2.2



▲ Figure 10. Correlation between Italian and European scenarios.

Source: Terna and Snam elaboration, 2019.

The main findings of the scenarios are summarised below:

- **Electricity consumption grows in every scenario:** PNIEC and CEN results are similar and characterised by a lower electricity consumption with respect to DEC scenario, which predicts a higher use of electricity as energy carrier.
- **Overall gas consumption is increasing in BAU scenario, steady in CEN scenario and slightly decreasing in DEC scenario.** The role of gas remains crucial in every scenario, in order to enable energy transition, also by means of the gradual substitution of natural gas with green gases (biomethane[15], green syngas[16] and hydrogen). Particularly, natural gas fulfils a key-role in assuring adequacy and programmability of electricity generation.
- **DEC scenario is characterised,** especially in the long-term horizon, by a **final energy consumption lower** than CEN scenario, thanks to the higher intrinsic efficiency of electricity.
- **DEC** scenario heavily relies on **non-dispatchable renewable energy sources:** their integration requires relevant investments in network development; on the other hand, **CEN** scenario rely on higher diffusion of **green gases,** contributing in maximising the utilisation of the existing infrastructure.

[15] Methane produced by anaerobic digestion, gasification and other processes that involve biomass.
[16] Renewable methane produced by hydrogen methanization process.

- The achievement of 2030 and, even more, 2040 targets implies a wide diffusion of **efficient and low emission technologies** in the residential & commercial (R&C) (i.e. heat pumps) and in the transport sector (i.e. electric vehicles and CNG/hydrogen vehicles), besides the large-scale implementation of energy efficiency measures in R&C and industrial sector.
- After 2030, the ambitious decarbonisation targets require the **gradual penetration of green gases** in the Italian energy mix, enhancing usage of biomethane, hydrogen and green syngas. Sector coupling is therefore crucial to provide enabling instruments for **energy system decarbonisation.** Power-to-Gas may be the key technology of this process, enabling the decarbonisation of the most problematic energy intensive sectors and representing a seasonal storage resource for renewable electricity.
- In 2040 both CEN and DEC scenarios foresee the utilisation of **carbon capture and storage techniques (CCS/CCU)** in order to achieve decarbonisation targets higher than 60%.
- The achievement of decarbonisation target implies a gradual "alignment" in the European generation mix (coal phase-out, nuclear power plant decommissioning, RES penetration); the consequence is a **progressive transformation in the electricity cross-border flows, in all the scenarios.** In particular, the results remark an increase in the total amount of energy exchanged between Italy and border countries, with a growing contribution of electricity exported from Italy to border countries. In this increasingly integrated European market, interconnection capacity becomes a fundamental tool for maximizing the penetration of renewable sources and guaranteeing the safety and quality of service in the interconnected European electricity system.
- **Electricity peak load** increases to a greater extent in DEC and PNIEC scenarios, both characterised by higher diffusion of electric vehicles. Furthermore, electrification of energy consumption and spread of renewable energy sources emphasize the complexities related to residual load ramp and overgeneration management, **confirming the need for new flexibile technologies for electric system** (storage systems, demand-response management, distributed generation management, Power-to-Gas).

- **While Daily peak demand of gas** decreases in every scenario, its volatility increases because of the relevant change in the sectorial composition. Gas peak demand in R&C sector, easily predictable due to its strong dependency on temperature, decreases; on the contrary, thermoelectric peak demand increases and so does its variability because of the higher share of non-dispatchable renewable sources. Higher volatility of thermoelectric demand is also proved by the increase of the peak/ off-peak ratio.

[17] Electricity demand includes final usage consumption and transmission losses; hydrogen volumes are expressed in bilion cubic meters of equivalent methane.

	2025				2030				2040		
	BAU	CEN	DEC	PNIEC	BAU	CEN	DEC	PNIEC	BAU	CEN	DEC
Final energy consumption - Mtep	115	110	109	109	114	104	103	104	115	93	90
Electricity demand - TWh	330	326	338	325	340	332	356	330	371	352	391
Peak load - GW	55	55	57	54	56	57	62	62	62	60	72
Total RES - GW	59.5	62.4	72.2	66.1	70.7	80.3	94.3	93.3	92.7	99.0	123.1
Wind	*11.5*	*13.7*	*15.2*	*15.7*	*13.6*	*17.1*	*18.9*	*18.4*	*17.6*	*22.1*	*25.4*
Solar	*22.5*	*23.8*	*31.7*	*26.8*	*30.5*	*37.6*	*49.3*	*50.9*	*47.5*	*50.6*	*69.8*
Hydroelectric	*20.1*	*20.1*	*20.1*	*19.1*	*20.8*	*20.8*	*20.8*	*19.2*	*21.8*	*21.8*	*21.8*
Other RES	*5.4*	*4.8*	*5.2*	*4.5*	*5.8*	*4.8*	*5.3*	*4.8*	*5.8*	*4.5*	*6.1*
Thermoelectric - GW	54	50	50	49	50	50	50	50	50	50	50
Electric storage - GW	7.4	10.7	10.4	12.7	7.4	12.7	13.4	17.9	7.4	14.3	18.9
Pumped Hydro Storage	*7.4*	*10.4*	*8.9*	*10.4*	*7.4*	*11.9*	*10.4*	*11.9*	*7.4*	*11.9*	*11.9*
Electrochemical Batteries	*0.0*	*0.3*	*1.5*	*2.3*	*0.0*	*0.8*	*3.0*	*6.0*	*0.0*	*2.4*	*7.0*
Gas total - bn m^3	75.9	77.5	73.7	70.7	79.6	73.5	68.6	62.0	84.4	76.5	67.2
Natural gas - bn m^3	*75.9*	*74.6*	*72.6*	*70.0*	*79.6*	*65.2*	*64.8*	*61.0*	*84.4*	*58.0*	*54.0*
of which CCS	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*7.8*	*7.6*
Green gases - bn m^3	0	3.0	1.1	0.7	0	8.3	3.7	1.0	0	18.5	13.2
Biomethane	*0*	*3.0*	*1.1*	*0.7*	*0*	*8.1*	*3.7*	*1.0*	*0*	*12.0*	*12.0*
Hydrogen	*0*	*0*	*0*	*0*	*0*	*0.2*	*0*	*0*	*0*	*3.0*	*1.2*
Green Syngas	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*3.5*	*0*
Gas peak demand - mln m^3 / day	467	458	451	N/A	461	429	423	N/A	454	399	388

▲ **Figure 11.** Main parameters and results of BAU, CEN, DEC e PNIEC scenarios in 2025, 2030 e 2040[17]. Source: Terna.

2.3

2.3
The Business As Usual (BAU) scenario.

The **BAU** scenario has been developed with a **bottom-up** approach, characterised by regressive forecast models and switching technology mechanisms, purely based on economic merit order with technology-driven methods (i.e. switching from traditional to condensing boilers when the condensing boiler is economically cheaper).

BAU scenario is a **current policy scenario,** built considering moderate economic growth. **It does not accomplish the policy targets achievement** set for 2030, neither the long-term indications.

Overall, the scenario is characterized by:

- Moderate GDP growth and slight decrease in population.
- Value Added structure consistent with the current situation.
- Technology switching based on Total Cost of Ownership (TCO).
- Minimal incentive measures in energy efficiency.
- Renewables growth based on Levelized Cost of Electricity (LCoE).
- Economic phase-out of coal generation plants.
- Minimal investments in electrochemical storage systems.

	BAU 2030	BAU 2040
Target	Final energy consumption (Mtep) **114** Final energy consumption RES share (%) **20** Electric RES share (%) **44** CO_2 reduction VS 1990 (%) **~28**	Final energy consumption (Mtep) **115** Final energy consumption RES share (%) **23** Electric RES share (%) **48** CO_2 reduction VS 1990 (%) **~32**
Demand	Demand (TWh): **340** Electrification (%): **24** Peak load (GW): **56** Demand (bn m³): **80** Share on final use (%): **33** Daily peak (Mm³): **461**	Demand (TWh): **371** Electrification (%): **26** Peak load (GW): **62** Demand (Mm³): **84** Share on final use (%): **34** Daily peak (Mm³): **454**
Supply	Wind (GW): **14** PV (GW): **31** Other RES (GW): **25** Thermal (GW): **50** Natural gas (bn m³): **79.6** Biomethane (bn m³): **0** Green syngas (bn m³): **0** Hydrogen (bn m³): **0**	Wind: **18** PV (GW): **47** Other RES (GW): **28** Thermal (GW): **50** Natural gas (bn m³): **84.4** Biomethane (bn m³): **0** Green syngas (bn m³): **0** Hydrogen (bn m³): **0**
Generation	PV, Wind and Hydro (TWh) **126** Thermoelectric (TWh) **197** *(of which 27 renewables)*	PV, Wind and Hydro (TWh) **160** Thermoelectric (TWh) **201** *(of which 26 renewables)*
Technologies	Electric vehicles **+ 1.7M** CNG/H_2 vehicles **+ 1.7M** Electric HP **+ 1.8M** Gas HP **+ 0.6M**	Electric vehicles **+ 3.8M** CNG/H_2 vehicles **+ 3.6M** Electric HP **+ 2.5M** Gas HP **+ 3.0M**

** Electric vehicles include BEV (Battery Electric Vehicle) and PHEV (Plug-in Hybrid Eletric Vehicles); CNG: Compressed Natural Gas*

▲ **Figure 12.** Key parameters and results of BAU scenario at 2030 and 2040. Source: Terna and Snam elaboration, 2019.

2.4

2.4
The CENTRALIZED (CEN) scenario.

The **Centralized** scenario has been built with a **top-down** approach, characterised by technology-pull technology switching mechanisms (i.e. technology diffusion as a function of the targets) and characterised by a check on target achievement and eventually by iterations.

It is a **development scenario,** built considering high economic growth. **It accomplishes the target achievement** set for 2030 in the Clean energy for all Europeans Package and the long-term indications. The name "Centralized" refers to a **higher development in centralized renewables/low carbon technologies** (i.e. higher development in utility-scale wind and solar and higher usage of traditional thermal plants with green gas).

Overall, the scenario is characterized by:

- High economic growth and slight growth in population.
- Binding decarbonisation, RES share and energy efficiency targets.
- Coal plants phase-out by 2025.
- High growth in renewable/low carbon dispatchable and centralised technologies.
- Potential usage of CCS/CCU in industrial sector and electricity production.
- High penetration of gas heat pumps and condensing boilers in residential sector.
- Fast expansion of CNG and LNG vehicles.
- Fast diffusion of biomethane and green/decarbonized gas in order to decarbonise transport, industry and residential sectors.

	CEN 2030	CEN 2040
Target	Final energy consumption (Mtep) **104**; Final energy consumption RES share (%) **30**; Electric RES share (%) **55**; CO_2 reduction VS 1990 (%) **~43**	Final energy consumption (Mtep) **93**; Final energy consumption RES share (%) **44**; Electric RES share (%) **62**; CO_2 reduction VS 1990 (%) **~65**
Demand	Demand (TWh): **332** Electrification (%): **26** Peak load (GW): **57** Demand (bn m^3): **74** Share on final use (%): **36** Daily peak (Mm^3): **429**	Demand (TWh): **352** Electrification (%): **30** Peak load (GW): **60** Demand (Mm^3): **77** Share on final use (%): **38** Daily peak (Mm^3): **399**
Supply	Wind (GW): **17** PV (GW): **38** Other RES (GW): **26** Thermal (GW): **50** Natural gas (bn m^3): **65.2** Biomethane (bn m^3): **8.1** Green syngas (bn m^3): **0** Hydrogen (bn m^3): **0.2**	Wind: **22** PV (GW): **51** Other RES (GW): **27** Thermal (GW): **50** Natural gas (bn m^3): **58.0** Biomethane (bn m^3): **12.0** Green syngas (bn m^3): **3.5** Hydrogen (bn m^3): **3.0**
Generation	PV, Wind and Hydro (TWh) **149** Thermoelectric (TWh) **161** *(of which 40 renewables)*	PV, Wind and Hydro (TWh) **181** Thermoelectric (TWh) **172** *(of which 58 renewables & 41 CCS)*
Technologies	Electric vehicles **+ 2.8M** CNG/H_2 vehicles **+ 4.8M** Electric HP **+ 2.8M** Gas HP **+ 1.7M**	Electric vehicles **+ 6.4M** CNG/H_2 vehicles **+ 7.7M** Electric HP **+ 3.8M** Gas HP **+ 5.5M**

** Electric vehicles include BEV (Battery Electric Vehicle) and PHEV (Plug-in Hybrid Eletric Vehicles); CNG: Compressed Natural Gas*

▲ **Figure 13.** Key parameters and results of CEN scenario at 2030 and 2040. Source: Terna and Snam elaboration, 2019.

2.5

2.5
The DECENTRALIZED (DEC) scenario.

The **Decentralized** scenario, as the CEN, is a **development scenario,** built using a **top-down approach. It accomplishes the target achievement** set for 2030 in the Clean energy for all Europeans Package and the long-term indications. The name "Decentralized" refers to a **higher development in decentralized renewables/low carbon technologies** (i.e. small-scale solar plants and electrochemical storage systems) and a higher electrification in final consumption (i.e. penetration of electric heat pump and electric vehicles).

Overall, the scenario is characterised by:

- High economic growth and slight growth in population.
- Binding decarbonization, RES share and energy efficiency targets.
- Coal plants phase-out by 2025.
- High growth in non-dispatchable renewables, mainly in distributed generation.
- Potential usage of CCS/CCU in electricity production.
- Fast technology process in storage system paired with solar plants, in terms of costs, lifetime and efficiency.
- High penetration of electric heat pumps in the residential sector.
- Fast expansion in electric vehicles[18].
- Diffusion of biomethane and green/decarbonized gas to decarbonise transport, industry and residential sectors.

[18] *Electric vehicles include Plug-In Electric Vehicles (PEV) and Plug-In Hybrid Electric Vehicles (PHEV).*

	DEC 2030	DEC 2040
Target	Final energy consumption (Mtep) **103** Final energy consumption RES share (%) **31** Electric RES share (%) **55** CO_2 reduction VS 1990 (%) **~41**	Final energy consumption (Mtep) **90** Final energy consumption RES share (%) **51** Electric RES share (%) **66** CO_2 reduction VS 1990 (%) **~65**
Demand	Demand (TWh): **356** Electrification (%): **28** Peak load (GW): **62** Demand (bn m^3): **69** Share on final use (%): **32** Daily peak (Mm^3): **423**	Demand (TWh): **391** Electrification (%): **35** Peak load (GW): **72** Demand (Mm^3): **67** Share on final use (%): **32** Daily peak (Mm^3): **388**
Supply	Wind (GW): **19** PV (GW): **49** Other RES (GW): **26** Thermal (GW): **50** Natural gas (bn m^3): **64.8** Biomethane (bn m^3): **3.7** Green syngas (bn m^3): **0** Hydrogen (bn m^3): **0**	Wind: **25** PV (GW): **70** Other RES (GW): **28** Thermal (GW): **50** Natural gas (bn m^3): **54.0** Biomethane (bn m^3): **12.0** Green syngas (bn m^3): **0** Hydrogen (bn m^3): **1.2**
Generation	PV, Wind and Hydro (TWh) **170** Thermoelectric (TWh) **161** *(of which 33 renewables)*	PV, Wind and Hydro (TWh) **214** Thermoelectric (TWh) **175** *(of which 51 renewables & 40 CCS)*
Technologies	Electric vehicles **+ 5.7M** CNG/H_2 vehicles **+ 2.7M** Electric HP **+ 3.7M** Gas HP **+ 1.5M**	Electric vehicles **+ 9.9M** CNG/H_2 vehicles **+ 3.0M** Electric HP **+ 8.9M** Gas HP **+ 2.3M**

** Electric vehicles include BEV (Battery Electric Vehicle) and PHEV (Plug-in Hybrid Eletric Vehicles); CNG: Compressed Natural Gas*

▲ **Figure 14.** Key parameters and results of DEC scenario at 2030 and 2040. Source: Terna and Snam elaboration, 2019.

2.6

2.6
The PNIEC scenario.

The PNIEC scenario is the current **Italian policy scenario,** based on the National Energy and Climate Plan proposal. It sets the Italian target of decarbonization, RES share and energy efficiency for 2030 in accordance with the Clean energy for all Europeans Package.

It is a **top-down** scenario, built by the working group using data from the plan and other public documents.

Overall, the scenario is characterized by:

- Economic growth and growth in population.
- Binding decarbonization, RES share and energy efficiency goals.
- Coal plants phase-out by 2025.
- High growth in non-dispatchable renewables, mainly wind and solar.
- High growth in storage system, both electrochemical and pumped hydro.
- Penetration of electric heat pumps in the residential sector.
- Penetration of electric vehicles and starting development of hydrogen mobility.

	PNIEC 2025	PNIEC 2030
Target	Final energy consumption (Mtep) **109** Final energy consumption RES share (%) **23** Electric RES share (%) **N/A** CO_2 reduction VS 1990 (%) **N/A**	Final energy consumption (Mtep) **104** Final energy consumption RES share (%) **30** Electric RES share (%) **55** CO_2 reduction VS 1990 (%) **40**
Domanda	Demand (TWh): **325** Electrification (%): **23** Peak load (GW): **54** Demand (bn m^3): **70.7** Share on final use (%): **28** Daily peak (Mm^3): **N/D**	Demand (TWh): **330** Electrification (%): **25** Peak load (GW): **62** Demand (Mm^3): **62** Share on final use (%): **28** Daily peak (Mm^3): **N/D**
Offerta	Wind (GW): **16** PV (GW): **27** Other RES (GW): **24** Thermal (GW): **49** Natural gas (bn m^3): **70** Biomethane (bn m^3): **0.7** Green syngas (bn m^3): **0** Hydrogen (bn m^3): **0**	Wind: **18** PV (GW): **51** Other RES (GW): **24** Thermal (GW): **50** Natural gas (bn m^3): **61** Biomethane (bn m^3): **1** Green syngas (bn m^3): **0** Hydrogen (bn m^3): **0**
Generazione	PV, Wind and Hydro (TWh) **116** Thermoelectric (TWh) **185** *(of which 23 renewables)*	PV, Wind and Hydro (TWh) **164** Thermoelectric (TWh) **146** *(of which 23 renewables)*
Tecnologie	Electric vehicles **~ + 2.0M** CNG/H_2 vehicles **~ + 0.7M**	Electric vehicles **+ 6.0M** CNG/H_2 vehicles **+ 1.5M**

** Electric vehicles include BEV (Battery Electric Vehicle) and PHEV (Plug-in Hybrid Eletric Vehicles); CNG: Compressed Natural Gas*

▲ **Figure 15.** Key parameters and results of PNIEC scenario at 2025 and 2030. Source: Terna and Snam elaboration, 2019.

3.0

The role of gas sector in energy transition

By snam

3.1
The demand for gas in Italy and uses by sector.

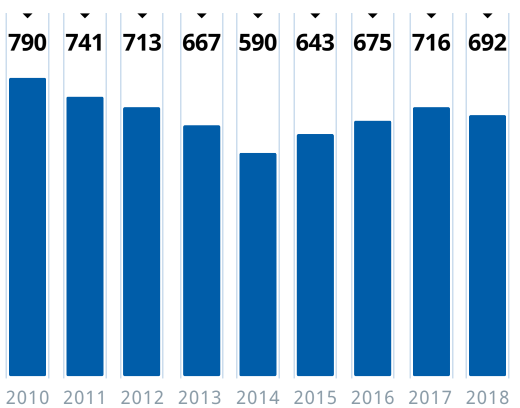
3.1

Natural gas plays a fundamental role in the Italian energy system. As **the country's major source of primary energy**[19] it satisfied **35% of primary energy demand in 2018.** Gas consumption is growing: after a low of 590 TWh (61,9 billion cubic meters) in 2014 due to the economic crisis and mild and rainy weather conditions, demand picked up to reach 692 TWh (72,7 billion cubic meters) in 2018. In 2019, gas demand continues to grow at a trend rate of 5%, driven by the thermoelectric sector' s reduction in coal generation and low electricity imports.

▼ Figure 16.
The total demand for gas in Italy (TWh) and share by segment (percentage values).

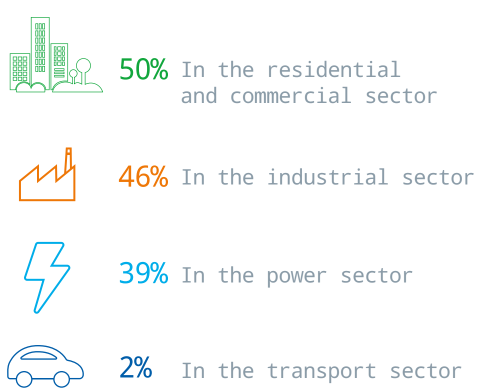
Source: Snam elaboration, 2019.

The gas system
Evolution of gas demand in Italy
(TWh)



Gas satisfies 35% of the primary energy demand

Natural gas share in demand sectors:



The residential and commercial sector, where gas accounts for **50% of total energy consumption,** is characterized by a high seasonal variation in demand, which during an exceptionally cold winter can be **seven or eight times higher** than the minimum summer demand.

This essential role of capillary flexibility is ensured by the size and meshing of the network, as well as the storage capacity - equal to about **170 TWh** of storable gas or a quarter of the annual demand.

[19] *MEF, La Situazione Energetica Nazionale nel 2018.*

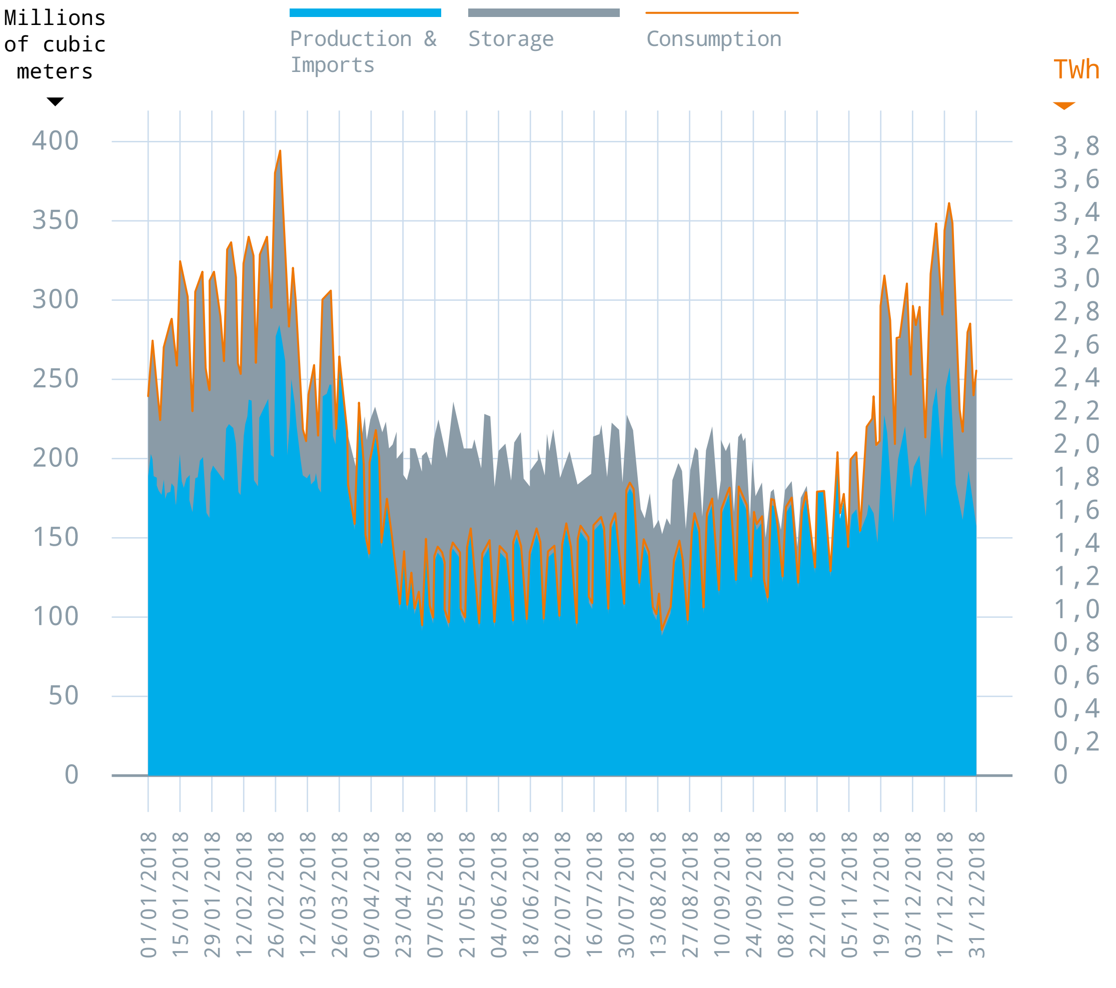
3.1

Storage can cover a large part of this seasonal demand variation: in times of need, natural gas storage can release 2 TWh / day. Storage provides an hourly, daily, monthly, seasonal and multi-year service.

As for the **industrial sector,** natural gas today covers **46% of energy consumption.** Across all industries, more than 60% of gas is consumed in sectors involving high temperature processes. In those sectors, security of gas supply, which guarantees the continuity of the production process, and lower gas costs, if compared to other fuels, are key elements for national manufacturers to be competitive on international markets.

▼ Figure 17.
Daily values for consumption, production, imports and storage of natural gas (millions of cubic meters and TWh), 2018.

Source: Snam elaboration, 2019.



In the **thermoelectric sector,** gas is replacing other fossil fuels with high carbon content and pollutants. The addition of approximately 35 GW of gas combined cycle plants from 2000 to 2010, has almost completely replaced fuel oil generation, helping to avoid **around 100 MtCO_2** of emissions over the decade. In addition, they favoured the displacement of coal, decreasing its electricity generation from 55.5 TWh in 2012 to 32.1 TWh in 2018. As a result of the above-mentioned development, the share of the electricity production from gas rose from 37% in 2000 to 44% in 2018.

In the early months of 2019, thanks to the strong decrease in natural gas prices and the increase in the cost of CO_2, the switch from coal to gas in the power sector accelerated again with a further 30% decline in coal generation. Permitting processes have also started for the construction of 3.2 GW of flexible gas power, with the aim to totally displace coal by 2025.

Finally, gas also plays a key role in **mobility.** A cumulative consumption in the transport sector of 1.1 billion cubic meters makes Italy the leading European country in gas mobility: 1300 refuelling stations supply approximately 900,000 cars and 100,000 commercial vehicles.

[20] The price of CO_2 has moved from € 15.9/ton in 2018 to € 24.5 /ton in the period January-August of 2019.

[21] In the period January-August 2019 compared to the same period in 2018.

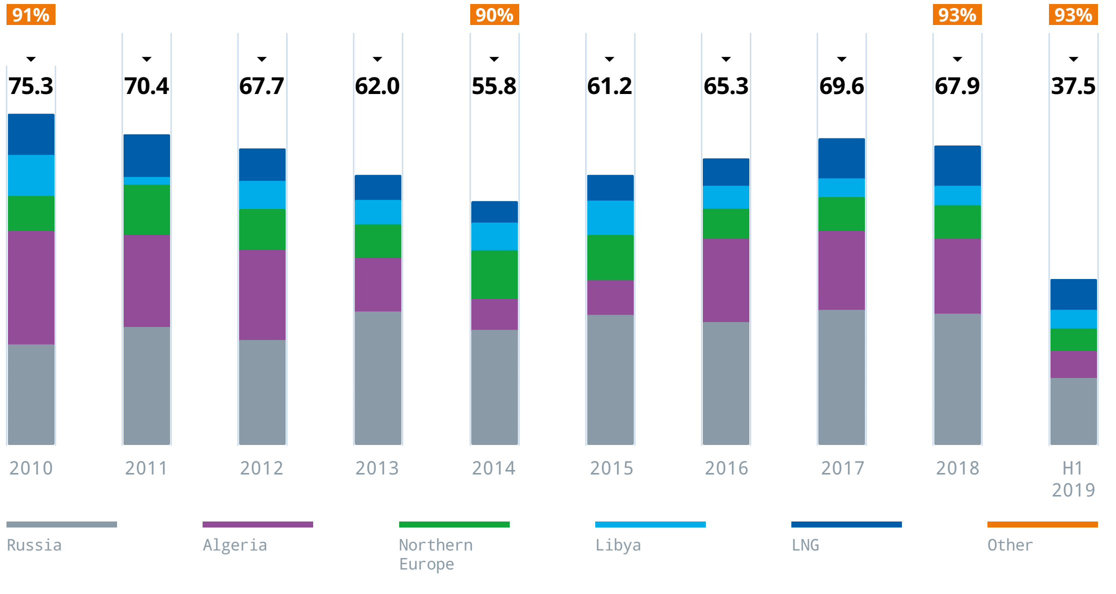
3.2

3.2
The supply of gas in Italy.

The Italian gas infrastructure system is able to manage fluctuations on both the demand and supply sides. Italy has several sources of supply, with two routes from Northern and Eastern Europe, two from North Africa, and three LNG terminals, which allow to connect the country to the global market.

The supply portfolio mix has shifted towards more flexible and integrated sources from global markets, such as LNG (volumes in the first half of 2019 have increased by 90% compared to 2018). A further diversification of the supply will be guaranteed by the almost-complete Southern Corridor connecting Italy with Turkey and Azerbaijan. In addition, new export capacities are available at the Tarvisio and Passo Gries Exit Points, for a total daily value of 40 million cubic meters.

The ample portfolio of supply options, as well as the startup of biomethane national production, compensate for the progressive reduction of national natural gas production and contribute to the security of the national and European gas system[22].



▼ Figure 18.
Italian natural gas imports (billions of cubic meters), 2010-2019.

Source: Snam based on data from the Ministry of Economic Development, 2019.

[22] *ENTSOG, "TYNDP 2018", 2020 Best Estimate: Italy has the highest index of access to the supply source (SSA) which measures the number of supply sources a country can access.*

3.3
The contribution of the gas system to decarbonisation.

3.3

The long-term goal of containing global warming to well below 2°C calls for the energy system to undertake an effective, sustainable and deep decarbonisation path in all sectors while ensuring security of supply and affordable energy cost for both household and enterprises.

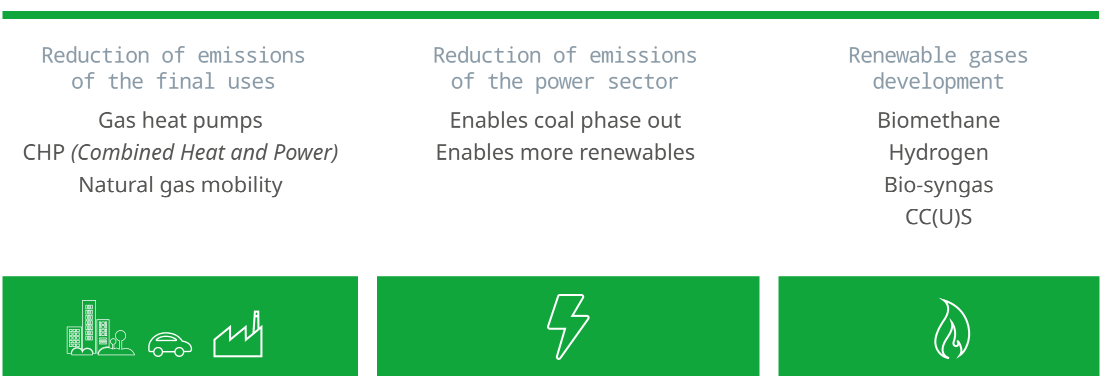
Snam and Terna' s development scenarios, illustrated in Chapter 2, comply with the long-term deep decarbonisation targets (-40% of CO2 at 2030 and -65% at 2040) and highlight the strategic value of the gas system. According to the scenarios, total gas consumption (renewable, low carbon and natural), **will be between 642 and 724 TWh in 2040.**

The gas system can contribute to the decarbonisation of the system by:

1. providing immediately available efficiency options **to reduce both primary and final energy consumption;**
2. enabling a progressive **decarbonisation of the power sector;**
3. allowing **an efficient decarbonisation of end use sectors** through the development of renewable gases in an increasingly complementarity manner to traditional renewables (sector coupling).

▼ **Figure 19.** Contribution of the gas system to the energy transition.

Source: Snam elaboration, 2019.



3.3

This approach can fully exploit the value of the gas system' s flexibility, competitiveness of transport and storage (even seasonal), and capillarity making it available to the electric grid and contribute to an efficient energy transition.

1 ▸ ENERGY SAVINGS IN END USE SECTORS

Energy efficiency policies foresee energy savings of at least 0.8% per year in end use sectors. This will require a wide diffusion of **efficient and low-emission technologies.**

In the heating and cooling sector, **gas heat pumps** can bring primary **energy savings and lower greenhouse gas emissions of up to 40%** compared to traditional boilers. Furthermore, gas heat pumps can be installed in new buildings and during significant renovations without the need, in the latter case, to replace the house heating system as would be necessary with electric heat pumps.

A growth in **cogeneration** (CHP) is expected in the tertiary and industrial sectors where there is still an unexploited economic potential for this technology. Thanks to significant heat recovery, CHP allows primary energy savings of up to 20% compared to the separate production of electricity and heat.

The gas demand is also expected to increase in the **transport sector.** The transport sector in Italy accounts for approximately 31% of total final energy consumption with 92% of this consumption based on oil products. Natural gas, both in gaseous compressed form (CNG) and in liquid form (LNG), ranks among the least emissive options for all types of mobility: light road transport, heavy road transport, and sea and rail transport where electrification is not possible or viable. For example, in the car segment the reduction in greenhouse gas emissions by utilizing gas as opposed to diesel or gasoline amount to 7% and 23%, respectively.

Also, gas mobility is attractive to drivers, as it has a lower Total Cost of Ownership while maintaining performance comparable to traditional petrol/diesel models.

2 ▸ DECARBONIZATION OF THE POWER SECTOR

The phase-out of coal by 2025 and the increasing penetration of intermittent renewable sources, both of which have been enabled by the gas system, are the two developments that contribute most to the decarbonisation of the power sector.

In the Snam-Terna scenarios, the permanent closure of about 8 GW of coal-fired power plants and of about 5 GW of other high-carbon fuel power plants will lead to an **increase in gas consumption** between 24 and 33 TWh over the period 2017-2025. At the same time, flexible gas-fired power plants helps integrate up to 14 GW of new intermittent renewable capacity.

3 ▸ EFFICIENT DECARBONIZATION OF THE FINAL USES.

A deep decarbonisation of the energy system would be very difficult without a significant development of green and low carbon gases, due to the significantly higher costs and technological barriers that would be necessary to overcome.

Renewable and low-carbon gases are dependable sources, whose high energy density generates significant transportation, storage and conversion economies. This makes them particularly suited to provide short-term flexibility to the power sector and seasonal flexibility to the residential system, generate high temperatures in many industrial processes, and store large amounts of energy in long-range vehicles.

The supply of a significant amount of renewable and low carbon gas will allow the gas infrastructure to play an active and permanent role in the energy transition.

In Snam-Terna scenarios, different options for decarbonising the gas grid are considered:

- **Biomethane,** obtained from sustainable agricultural biomass, organic waste and solid biomass. Being chemically identical to natural gas, it does not require any infrastructural modification. It is produced mainly by anaerobic digestion and thermochemical gasification technologies. **Bio-syngas or synthetic biomethane,** which have an identical composition to biomethane, can be obtained from methanation of renewable hydrogen with CO_2 recovered from many types of emissive processes. The support scheme now in place in Italy incentivizes the production of advanced biomethane for the transport sector. To date, the connections to the gas grid have been signed amount to around 4 TWh. However, it is estimated that potential supply could reach 76 TWh in 2030. Both of the Snam-Terna development scenarios forecast a biomethane supply of 114 TWh from anaerobic digestion and thermochemical gasification in 2040. The Centralized scenario also contemplates 33 TWh of bio-syngas from methanation, for a total supply of 147 TWh.

- **Renewable hydrogen,** obtained through the electrolysis of water with renewable electricity. Its chemical-physical characteristics, including a high energy density per unit of mass, make it very competitive for all activities that involve transport and storage of energy, especially over long distances and for long time-lags between production and use (e.g.: for transporting and storing electricity converted into gaseous form; to decarbonise sectors that have high-temperature thermal processes; or use fuels as a feedstock for non-energy conversions). The continuous reduction of investment costs for wind, photovoltaic and electrolysers will allow to reduce the production costs of renewable hydrogen down to 1.5-2.5 eur/kg (38-63 €/MWh). Hydrogen can be transported and stored both in mixture with natural gas and in pure form in dedicated pipelines. Analyses are under way to enable the grid injection of higher amounts of hydrogen "blended" with natural gas, allowing a first phase of large-scale development at a minimal infrastructure costs and enabling sector coupling already in the medium term.

- **Low-carbon hydrogen,** obtained from various processes such as "gas steam reforming" associated with CO_2 capture and storage. The advantage of this process is that the separation of CO_2 (and CO) from H_2 is easier than in the post-combustion capture process: CO_2 concentration and pressure are relatively high, allowing very efficient separation methods.

[23] *Biomethane Decree of 2 March 2018.*

- **Post-combustion carbon capture and storage (CCS),** in which CO_2 is extracted from the flue gas of combustion (a mixture of CO_2, N_2, H_2O and O_2). The advantage of CCS post-combustion is that it can be applied to existing installations, such as power plants or large industrial installations.

3.4 The challenges of the energy transition for the gas system.

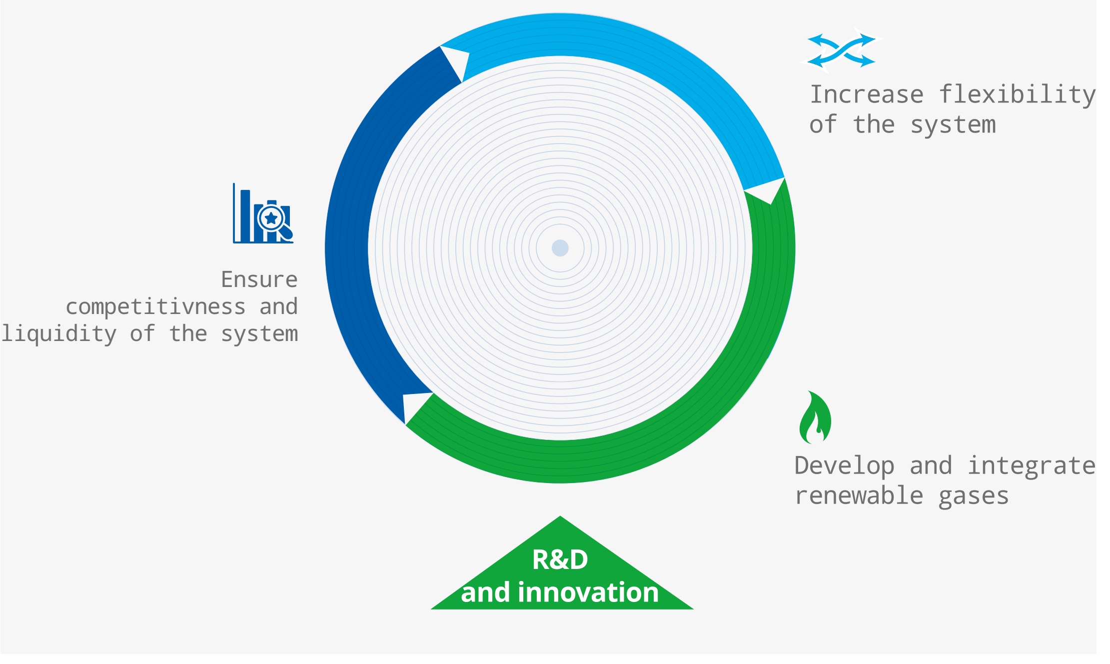
In order to face the challenges of energy transition the gas system has to undertake three different courses of action:

1. **Ensuring competitiveness, liquidity and sustainability** of the system, being the enabler of the energy transition, integrating renewable electricity and thermal sources and replacing high-carbon fuels, while maintaining and improving security and adequacy of supply and quality of service.

2. **Increasing the flexibility of the system** through a growing availability of flexibility resources that will have to be activate quickly and on specific locations of the network to integrate a growing share of intermittent renewable electricity sources, pursuing a joint gas-electricity adequacy condition.

3. **Supporting a sustained growth of renewable gases** by 2040, with a foreseeable further increase to 2050, creating the regulatory and industrial conditions to support their development; guaranteeing their quality; allowing their transport, storage and distribution; and enabling their penetration in end use sectors.

3.5



▲ Figure 20. The courses of action for the gas system.

Source: Snam elaboration, 2019.

3.5 Enabling factors for the gas system transition.

At the same time, it is necessary to create the conditions useful for the realization of **four enabling factors for the energy transition of the gas system in Italy** and achieve the results desirable from the courses of action.

1 ▸ INCREASING COMPETITIVENESS AND EFFICIENCY OF THE GAS SYSTEM

It is necessary to increase **the security of supply, European market integration, and liquidity of the Italian market** (e.g. the interconnection project with the TAP and the increase in interconnection capacity between Germany and Switzerland).

At the same time, it will be necessary to **preserve the functionality of gas infrastructure assets** over time, develop **the LNG supply chain** for maritime and terrestrial transport where feasible by modifying existing terminals and infrastructures, and also develop **the CNG supply chain** for sustainable mobility by boosting the penetration of BioLNG and BioCNG in the transport sector.

The reduction of emissions and the increase in energy efficiency should take place both in the network and in buildings. It is noteworthy the potential contributions offered by both the project of gas-electric hybrid compressor stations and by the actions planned to reduce **fugitive methane emissions,** for which Snam has already set voluntary targets **(-15% in 2022 and -25% in 2025).**

Fundamental support for the maintenance and development of gas infrastructures, linked to the transformation towards renewable gases and decarbonisation, will have to come from **long-term financing sources** based on a principle of **technological neutrality.**

2 ▸ INCREASING THE FLEXIBILITY OF THE SYSTEM

It is necessary to make the **storage system more responsive to the hourly and daily peak demand,** which is expected to grow because of an increasing share of intermittent renewable sources in the power sector. Moreover, a greater withdrawal from storage in the winter period would allow gas imports to be reduced in the months of higher consumption and higher prices, and increased during the summer period when prices tend to be lower.

The flexibility needed to integrate renewable energies can be created also through coordinated actions on gas and electricity systems, such as the possible **conversion of transport and storage compressor stations from gas to electricity** to reduce energy consumption and CO_2 emissions.

3 ▸ ENABLING THE GROWTH OF RENEWABLE GASES

The development of renewable and low carbon gases, also through new emerging technologies, requires:

- **Support for research and development** activities, aimed to increase the maturity **of the most suitable technologies along the value chain, as well as at guaranteeing the "readiness" of gas infrastructure** to receive growing shares of hydrogen. Technical regulations will have to be modified accordingly.
- **A sound market design** able to reveal and value the positive externalities of these resources, such as dependability.
- **Innovative ways to monitor and guarantee the quality** of the various renewable gases from diverse producers, as well as - for transport / storage activities of hydrogen blended with methane - the appropriate physical concentration along the infrastructures.

- **A legal and regulatory framework that facilitates the connection** of renewable gas plants to the network (e.g. simplifying the permitting processes and enhancing the benefits for the system).
- An active and liquid **market for cross-border exchanges of renewable and low carbon gases** both between EU Member States and as well as involving non-EU countries. This should also be promoted by appropriate modifications of the network codes and by establishing a pan-European scheme of **Guarantees of Origin** based on the mutual recognition of national schemes. Such schemes could also be extended to third countries, able to generate price references for traders, investors and policy makers.

4 ▸ PROMOTE RESEARCH AND DEVELOPMENT IN THE GAS SYSTEM, INNOVATION AND DIGITALIZATION

In order to boost the diffusion of renewable and low carbon gases, in particular of hydrogen for which the value chain is still under development, it is advisable to evaluate and promote research and development activities in the gas system according to the following cornerstones:

- **Readiness of assets:** assessing the capabilities of the current infrastructures to incorporate increasing percentages of hydrogen mixed with natural gas. **The studies already in progress** (in particular the blending tests in the network with ever greater amounts of hydrogen in the mixtures), and **new investigative activities** both on the transportation network (e.g. steel and line components, gas turbines in compression stations, use of membranes for gas separation) and on the storage fields (e.g. the behaviour of porous rocks in the reservoirs) **will highlight any necessary retrofitting interventions and/or the need to realize new dedicated pipelines.**
- **Identification and dissemination of technologies along the entire gas chain,** in order to promote the necessary solutions to allow the development of low carbon gas, also in coordination with the electric grid.
- **Adoption of new data analysis, automation and artificial intelligence tools** to improve efficiency and minimize

operational risks. The main areas of interest are: **Big Data & AI,** to extract the maximum value from data for the purpose of optimizing operational activities, such as asset maintenance, guaranteeing reliability and increasingly improving security; and the **IIOT (Industrial Internet of Things),** to optimize with the use of sensors the performance of network control, and to manage activities and **Automation** for optimal review of business processes.

4.0

The role of the power sector in the energy transition

By Terna

4.1
The power sector in the energy transition.

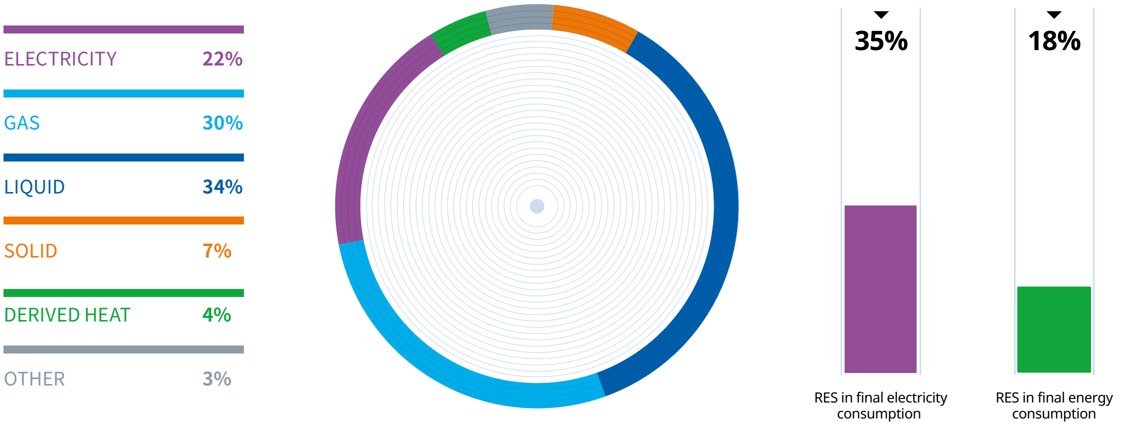
4.1

The exponential increase in global primary energy consumption, the persistent increase in CO_2 emissions and their effects on the ecosystem and the growing attention of international institutions to climate and environmental issues are evidence that **the current energy model that fuelled the recent growth of the global economy is no longer sustainable.** A worldwide commitment is required to progressively decarbonise all energy sectors and reduce overall consumption by increasing energy efficiency. Moreover, it is essential to achieve these goals as soon as possible.

The **power sector** plays a **central role in decarbonizing** the whole energy system, thanks to the intrinsic efficiency of electricity and the technological maturity of renewables such as wind and solar. Even though today electricity ranks third in final energy consumption coverage (around 1/5 of the total), it is the sector with the **highest share of renewables already today (35%), much higher than the overall share of renewables in final energy consumption (18%).**

▼ Figure 21.
Final energy consumption by energy vector and share of RES in final electricity consumption and final total energy consumption.

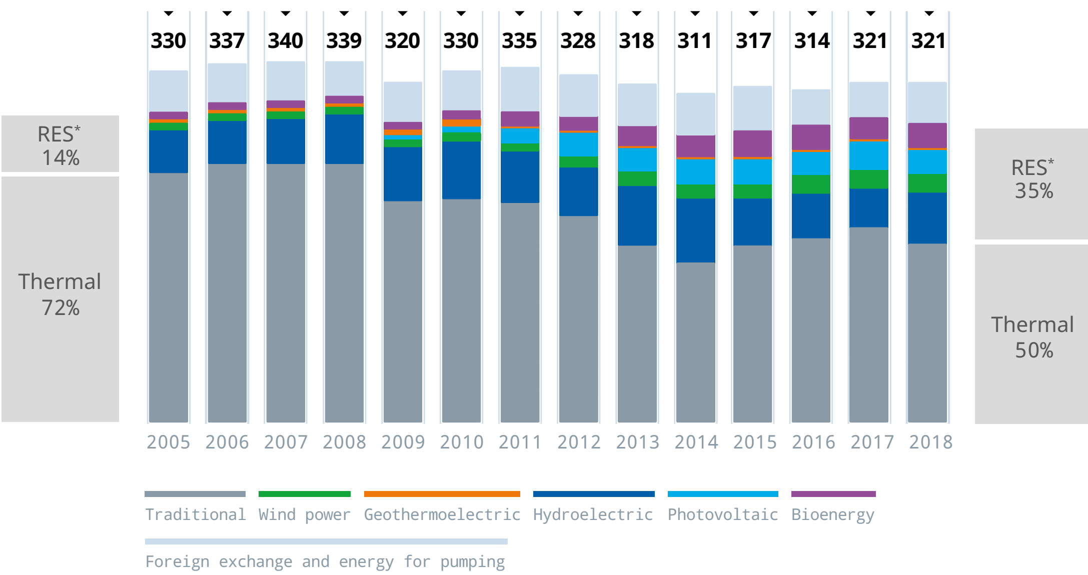
Source: Terna data based on Eurostat 2017 and MiSE data.



The greater penetration of electricity in the residential, industrial and transport sectors, together with an **increasing share of renewables in the energy production mix** are essential elements in radically changing the current energy paradigm and improving the quality of life in big cities, where already today and even more in the future an ever-increasing share of the global population is concentrated.

4.1

Electrification and the increasing diffusion of renewables are trends that have already been on-going for several years in many OECD countries. In Italy, in particular, the share of electricity in final consumption has grown from 17% in 1990 to 22% in 2017, while **the RES share in electricity consumption increased to 35% in 2018** thanks to the integration of more than 30 GW of new renewable capacity into the Electricity System.



RES does not include energy produced by hydroelectric pumping

▲ Figure 22. Evolution of electricity demand and production mix (TWh), 2005-2018.

Source: Terna data, 2019.

Despite these results, the road to decarbonisation is still long and **the objectives to be achieved in the coming years remain extremely challenging.**

In fact, the ambitious goals set out in the draft National Integrated Plan for Energy and Climate (NECP) include a complete phase-out of coal by 2025 and a RES coverage of more than half of gross electricity consumption (55.4%) by 2030. To this end, by 2030 it will be necessary to install approximately **40 GW of new RES capacity, relying almost exclusively on intermittent renewables** such as wind and solar. Moreover, the Terna – Snam scenarios indicate a further growth in the RES share by 2040, ranging from 62% in the Centralized scenario to 65% in the Decentralized scenario.

4.2 Impacts on the power sector.

4.2

This transformation will have a substantial impact on the Electricity System and will lead to a series of challenges to be faced in order to carry out the energy transition process in a decisive and effective manner, maintaining the current high levels of service quality and, at the same time, avoiding excessive cost increases for society.

The on-going changes affecting the system (increase in RES, the decommissioning of thermoelectric plants, climate change) already cause - and will do so to a greater extent in the prospective scenarios - significant impacts on the grid management functions performed by the Transmission System Operator, which has to carry out the delicate and complex task of balancing electricity production and demand at all times, ensuring that consumers have access to a secure, constant and reliable supply of energy. **These impacts can be summarized in four macro-categories:**

▼ **Figure 23.** The new energy context and the impacts on the Electricity System.

Source: Terna data, 2019.

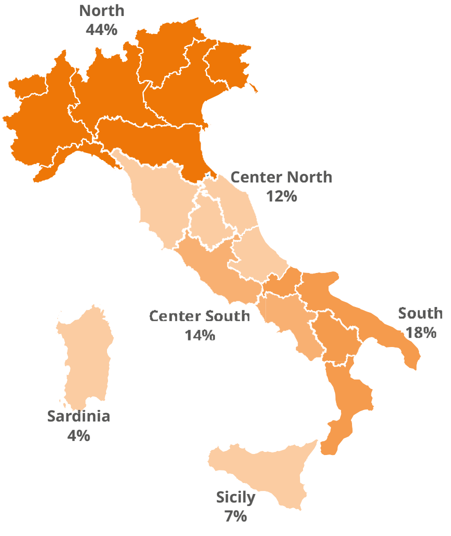
CLUSTER	IMPACTS ON ELECTRICITY SYSTEM MANAGEMENT
TECHNICAL CHARACTERISTICS OF RES	Reduction of **system inertia** Reduction of resources providing **voltage regulation** Reduction of **short-circuit power**
INTERMITTENCY OF RES	Reduction of resources providing **frequency regulation** Decrease of **adequacy margin** Growing **over-generation** periods during noon hours Increasing steepness of **residual load evening ramp**
LOCATION OF RES	Increasing **grid congestions** due to geographical distance between RES supply and consuption centers Growing **system operation challenges,** due to the growing of Distributed Generation
CLIMATE CHANGE	Increasing risk of **electricity network disruptions**

4.2

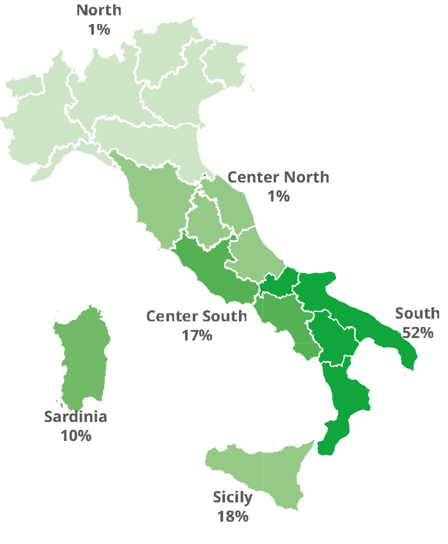
- **Technical characteristics:** RES plants usually interface with the network through the use of static machines (e.g. inverters), which, unlike the typical rotating machines of traditional generation, do not have the same capability to support the **stability of fundamental network parameters** (frequency and voltage) and to cope with disruption caused by the sudden and unexpected loss of generation capacity or load or other grid elements;
- **Intermittency:** electricity production from intermittent RES does not follow demand, but rather the availability of the underlying energy resource, such as sun or wind, which is subject to weather conditions. In an electricity system with increasing RES penetration, this can lead to **challenges in balancing production and consumption** because of the reduction of resources able to provide balancing services, especially during critical moments for the electricity system such as **peaks and load ramps.** The system will also be "structurally" exposed to periods in which production from RES exceeds electricity demand **(over-generation),** especially around noon, when the solar generation reaches its maximum, with the consequent need to implement an adequate level of storage to avoid the curtailment of energy;
- **Location:** RES plants, in particular wind power, are often located far away from consumption centers, causing an increase in **transmission network congestion,** especially from South to North (Figure 24). In addition, due to most of RES plants being **connected to MV/LV distribution networks**, which are traditionally characterized only by electrical loads, **new challenges are emerging in the management of the electricity system.** Among these are the reduced selectivity of protection systems, the reduced effectiveness of Defens Plans and the possible inadequacy of monitoring systems and automatisms designed for unidirectional operation;
- **Climate Change:** the higher frequency of extreme weather events, already perceivable today, results in a higher probability of significant damage to the country's infrastructure, including electricity transmission assets, augmenting the **risk of service interruptions.**

The effects of the above-mentioned challenges are amplified by the **structural characteristics of the Italian power grid** resulting from the geography of the country (e.g. the limited possibility for interconnection with the European continent, transmission constraints between Northern and Southern Italy and the islands), which will make management of the electricity system even more complex under the new conditions.

Photovoltaic



Wind

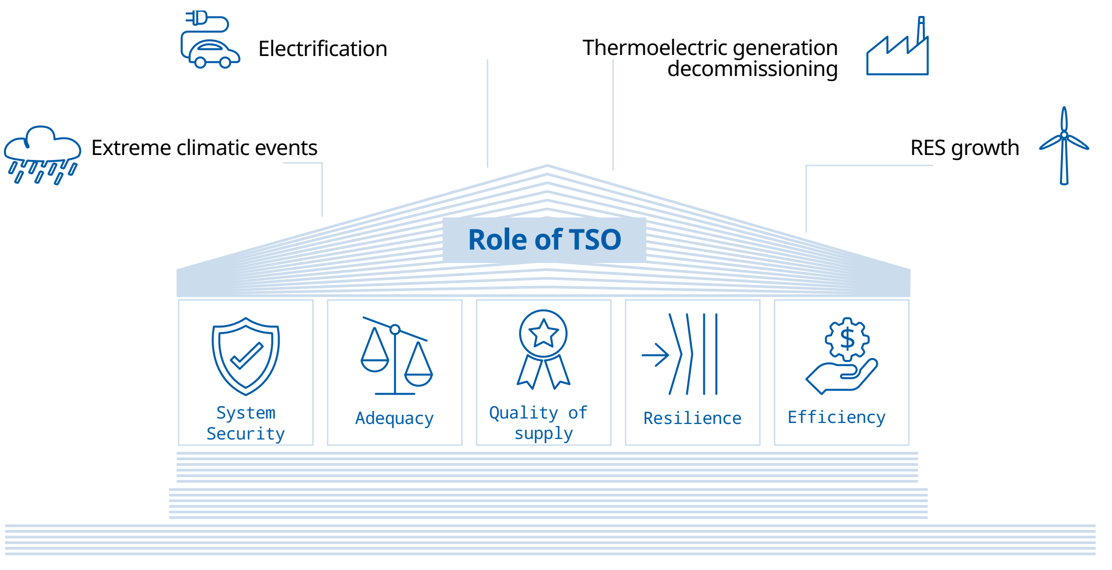


◀ **Figure 24.**
Photovoltaic and wind power installed in Italy by market area.

Source: Terna data, 2019.

4.2

The new context puts pressure on all the **key dimensions** that the TSO must closely observe in order to manage the electricity system:



▲ **Figure 25.**
Key dimensions of the Electricity System.

Source: Terna data, 2019.

- **System security,** i.e. the ability of the electricity system to withstand changes in the operating status due to sudden disruption, avoiding violation of the system's operating limits;
- **Adequacy:** The Electricity System is considered adequate if it has production, storage, demand control and transportation capacity resources able to satisfy expected demand, with a margin of adequacy in any given period;
- **Quality of supply,** i.e. the ability to guarantee continuity of the service (i.e. avoiding interruptions) and to ensure quality of service (i.e. keeping frequency and voltage within their limits);
- **Resilience,** i.e. the capability to withstand stress on the grid that is exceeding its design limits, and to return to normal operating status, if necessary through temporary measures;
- **Efficiency,** which means the ability to manage the Electricity System meeting the requirements of system security, adequacy and quality, at the lowest possible total cost for the citizen/user.

4.3
Factors enabling the Electricity System transition.

4.3

Given the above, Terna takes the view that a full integration of renewables into the electricity system can only be achieved by implementing **a set of essential, coordinated and coherent actions.** The actions and interventions identified by Terna for the achievement of the national decarbonisation objectives can be grouped into four categories:

▼ **Figure 26.**
Factors enabling the Electricity System transition.

Source: Terna data, 2019.

1 TRANSMISSION GRID DEVELOPMENT	• Strengthening of North-South backbone and grid reinforcements in the South of Italy and the Islands • Foreign interconnections • Investments in voltage regulation and to increase the inertia of the electricity system • Interventions to strengthen grid resilience
2 LONG-TERM PRICE SIGNALS	• Capacity market to deliver long-term price signal to encourage investments in new efficient and flexible thermal generation • Auctions and Power Purchase Agreements (PPAs) for RES capacity • Long-term contracts through competitive procurement for new storage capacity, hydroelectric included
3 MARKET EVOLUTION	• Evolution of the structure of the ancillary services market to cope with new needs (voltage regulation, inertia...) • Participation of new flexible resources in ancillary services market, i.e. demand, distributed generation, variable renewable energy sources and storage, including electric veichle-to grid • Progressive integration with European ancillary services markets
4 INNOVATION AND DIGITALISATION	• Digitalisation of the Transmission Grid (Assets and processes) and of the Electricity System management

1. Investment in the National Transmission Grid and in Interconnections with foreign countries, as set out in the Development Plan, prepared annually by Terna and based on the current network situation and the future needs of the electricity system. All the network interventions planned by Terna are prepared taking into consideration the key drivers of decarbonisation, safety, quality, market efficiency and sustainability, as well as the need to boost network resilience.

More specifically, work on the **internal transmission network** will be necessary for the **optimal use of national production plants** and to **minimize inter-zonal congestion risk.** Therefore, interventions are planned not only to upgrade existing assets and build new ones but also to install devices aimed at ensuring high quality and safety standards (for example FACTS and new synchronous compensators).

In addition, it will be necessary to i**ncrease interconnection capacity** with neighbouring countries in order to **ensure security** and **reduce Italy' s electricity procurement costs** by augmenting the link to markets with lower prices, such as France and Germany.

Furthermore, in a context of increasing intensity of extreme weather events, it will be necessary to improve and increase the resilience of the network through **infrastructural, mitigation and emergency management interventions.**

A key factor in ensuring that network interventions are deployed in line with national objectives is the opportunity to access **fast-track authorization,** i.e. a preferential authorization process for strategic interventions, in order to reduce the time required for their development.

2. Introduction of long-term price signals, fundamental to stimulate investment in new efficient capacity (thermal, RES and storage) in a market context that does not provide sufficient guarantees on returns on capital employed, especially considering that upfront investment costs prevail over operating costs for most technologies to be deployed in the coming decades. Today, in fact, the energy and ancillary services markets are predominantly short-term spot markets and are almost exclusively focused on remunerating energy (MWh) instead of availability (MW). Given the distinct characteristics of the new capacity to be deployed, we argue that this difference should also be reflected in the mechanisms providing efficient long-term price signals:

- **Capacity Market:** due to the intrinsic characteristics of RES, keeping an adequate level of conventional and efficient thermal sources, capable of providing grid services and backup capacity, will remain fundamental, even in a context in which the largest share of energy is supplied by RES, as in the NECP scenario. The Capacity Market, through the **remuneration of capacity,** will provide a long-term price signal aimed at triggering investment in new generation capacity and ensuring system adequacy in the long run.

- **PPAs and RES auctions:** the deployment of new RES plants, essential for the achievement of national and international energy and climate objectives, has slowed down dramatically in recent years, in particular due to significant uncertainty about future energy prices. **Auction mechanisms** (such as those envisaged by the recent RES decree) and **long-term contracts between producers and a typically non-regulated counterpart** (long term Power Purchase Agreements - PPAs) are effective mechanisms to stimulate new investment.
- The draft National Energy and Climate Plan envisages, by 2030, the deployment of **new utility-scale storage capacity** (both pumped hydro plants and electrochemical batteries) of at least 6 GW. The realization of new storage capacity, in particular storage technologies capable of performing charge-discharge cycles in the order of hours / days / weeks, is in fact **key to managing the electricity system in the short to medium term** (2030), although to date the price signals for investment in this capacity are not sufficient. It will therefore be necessary to build an ad-hoc regulatory and contractual framework, also by means of long-term contracting with counterparties selected through competitive bidding procedures organized by the TSO. Given the complexity of the topic and the plurality of subjects involved, Terna strongly believes that it is necessary to establish **a central coordination body** with all the Ministries (Economic Development, Environment, Infrastructure), institutions and local authorities that are involved in the planning, authorization and realization of pumped hydro plants. It would also be desirable to adopt dedicated legislation that simplifies the authorization process for the construction of new pumped hydro plants and for the use of water.

3. Market evolution and integration, in order to develop new grid services needed for the energy transition and foster the participation of new flexibility resources in electricity markets, promoting their integration at European level.

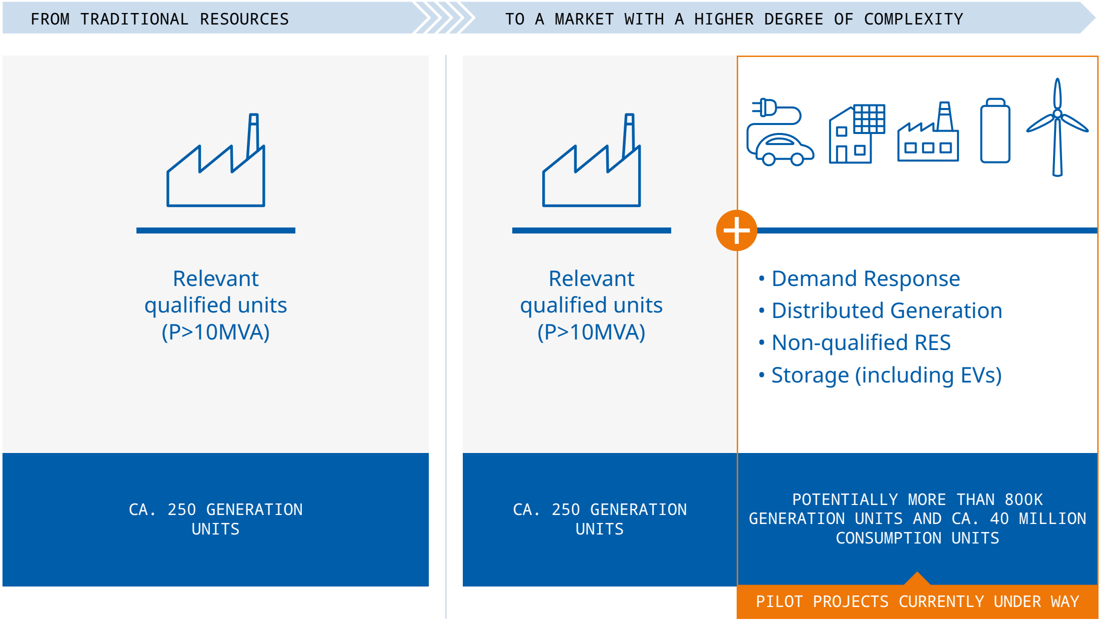
In fact, the electricity system to date has relied on a set of **"implicit" services,** supplied by a fleet of conventional plants with rotating masses, in particular thermoelectric plants. In the near future, the availability of resources that can provide grid services of this type will significantly decrease. Therefore, it becomes an **essential requirement** for a secure power system operation to **design and introduce new grid services** that explicitly provision services that were previously provided implicitly.

Moreover, the **growing penetration of RES** and the consequent reduction in the running hours of traditional thermal plants **increase the need for flexibility** in the future electricity system and make it necessary to provision grid services from new flexibility resources. Consumption resources (demand response), distributed generation, renewable resources not currently enabled and storage systems constitute a large pool of resources (over 800,000 production plants and about 40 million consumption units) potentially useful in offering the flexibility services necessary to guarantee the adequacy and safety of an increasingly broad and complex electricity system.

4. Investment in digitalization and innovation for the management of an increasingly complex, integrated and distributed electricity system, characterized by a soaring number of active, grid-connected resources and exchanges between each other. In light of the exponential increase in the number of production (especially small-scale intermittent RES) and consumption plants, as well as the growing intermittent RES contribution to total production, we are already observing how the complexity of system operation is growing and how forecasts are becoming more challenging and subject to greater uncertainty. These trends will only continue.

In order to mitigate the effects of these phenomena, it is essential to guarantee **timely and reliable information to grid operators about the increasing number of resources that can actively be managed and are connected to the electricity system**, primarily to the national transmission grid operator who is responsible for the security of the electricity system.

Enabling factors are, on the one hand, the **new digital technologies,** which allow information to be collected at a low cost (IoT, smart meters), the transfer of large data streams with reliable connectivity solutions (optical fibre, 5G) and the effective storage and analysis of data (using, for example, advanced analytics), and, on the other, **investment in innovation** projects that put together new digital tools, thereby allowing us to deal with the new challenges in the energy sector.



▲ **Figure 27.**
Evolution of the electricity system and opening up of the services market to new resources.

Source: Terna data, 2019.

4.4

4.4
Phasing out coal.

Moreover, Terna has also defined a set of short-term measures and solutions necessary to achieve the goal of **completely phasing out coal by 2025,** while ensuring system adequacy and security. These interventions are summarized in Figure 28. In particular, it should be noted that **the Italian electricity system,** in addition to the deployment of 12 GW of new RES capacity, **has a significant need for new efficient thermal capacity** in order to replace the capacity which is expected to be decommissioned (primarily coal-fired). In fact, Terna's analysis shows that the power system requires around 55 GW of installed thermoelectric generation capacity to meet the adequacy criteria adopted at national and EU level. To guarantee this level of installed capacity in 2025 it will be necessary to build 5.4 GW of additional gas-fired power plants (in line with the NECP), taking into account both the increase in demand and the decommissioning of the residual oil-fired power plants. Moreover, to guarantee adequacy and security of the power system it is also necessary to install 3 GW of new storage facilities, such as pumped hydro or electrochemical batteries.

In order to implement these measures by 2025, in line with the objective to phase-out coal, it will be essential **to reduce the authorization time for grid infrastructure projects** (also subject to the approval of the National Grid Development Plan) **and of new generation capacity,** particularly thermal and pumped hydro capacity.

Actions by 2025

GRID INVESTMENTS

- **2019 National Development Plan and 2019 Security Plan**
- **+4500 MVAr** synchronous compensators

FLEXIBLE GENERATION

- **+5,4 GW** new natural gas capacity

RES

- **+12 GW** new RES capacity

DSR

- **+1 GW** demand-side response

STORAGE

- **+3 GW** new storage capacity

◀ Figure 28.
Actions needed for the coal phase-out in 2025 (compared with 2017), Recap.

Source: Terna data, 2019.