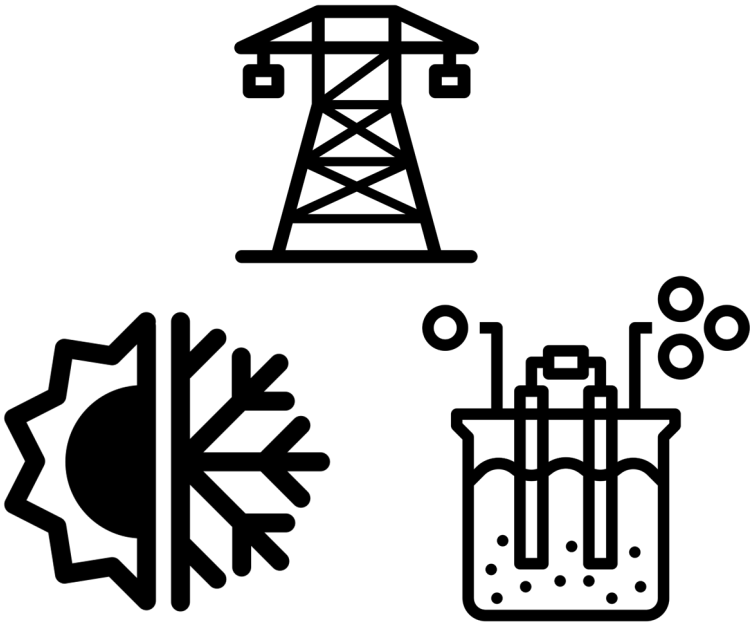
INTERNATIONAL ENERGY AGENCY
TECHNOLOGY COLLABORATION PROGRAMME ON
DISTRICT HEATING AND COOLING



IEA DHC ANNEX TS3: HYBRID ENERGY NETWORKS

APPENDIX E
COUNTRY REPORT
ITALY

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CONTENT

1 INTRODUCTION

This Appendix is part of the IEA DHC Annex TS3 guidebook. The full guidebook is available at https://www.iea-dhc.org/the-research/annexes/2017-2021-annex-ts3

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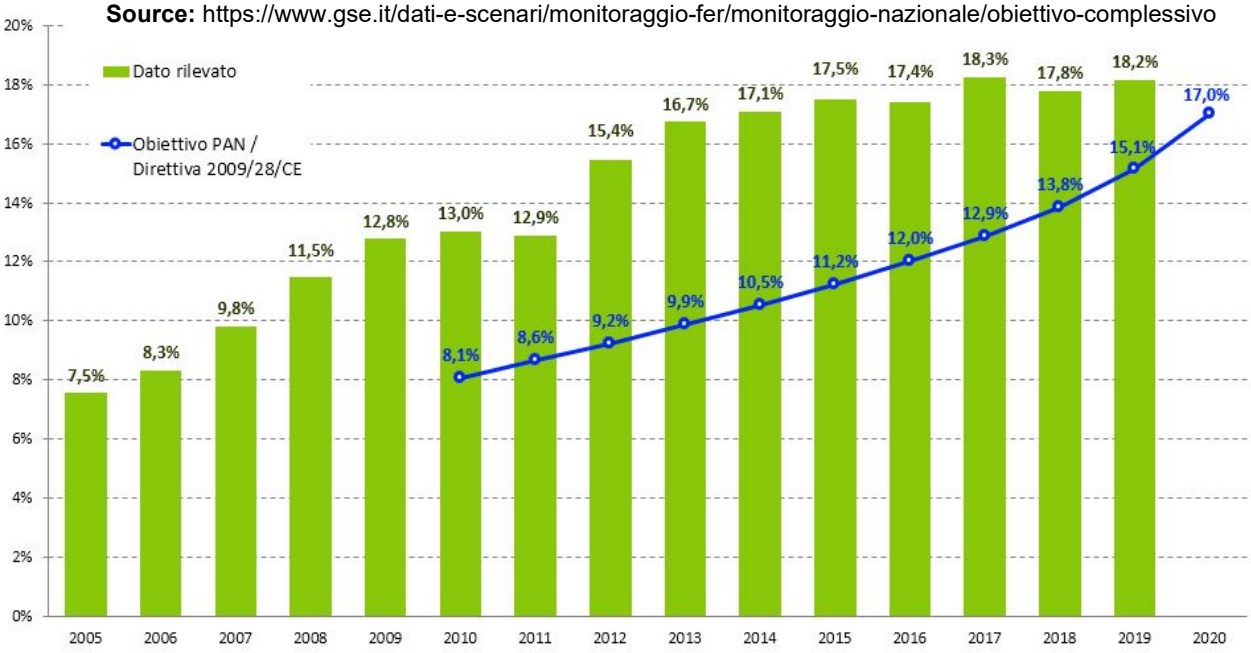
1. CURRENT ENERGY SYSTEM OF ITALY

In 2020, according to the estimates of the Italian Minister for Ecological Transition, the gross final energy consumption accounted for 1251 TWh in Italy. Almost 20% of this quota (thus 250 TWh) is covered by renewable energy sources, surpassing the target of 17% defined by the Ministry of Economic Development in the National Action Plan (PAN) of 2009.

Monitoring of the quota of gross final energy consumption covered by renewable sources (%). Comparison between the measured values (light green) and the values foreseen in the national action plan (PAN).

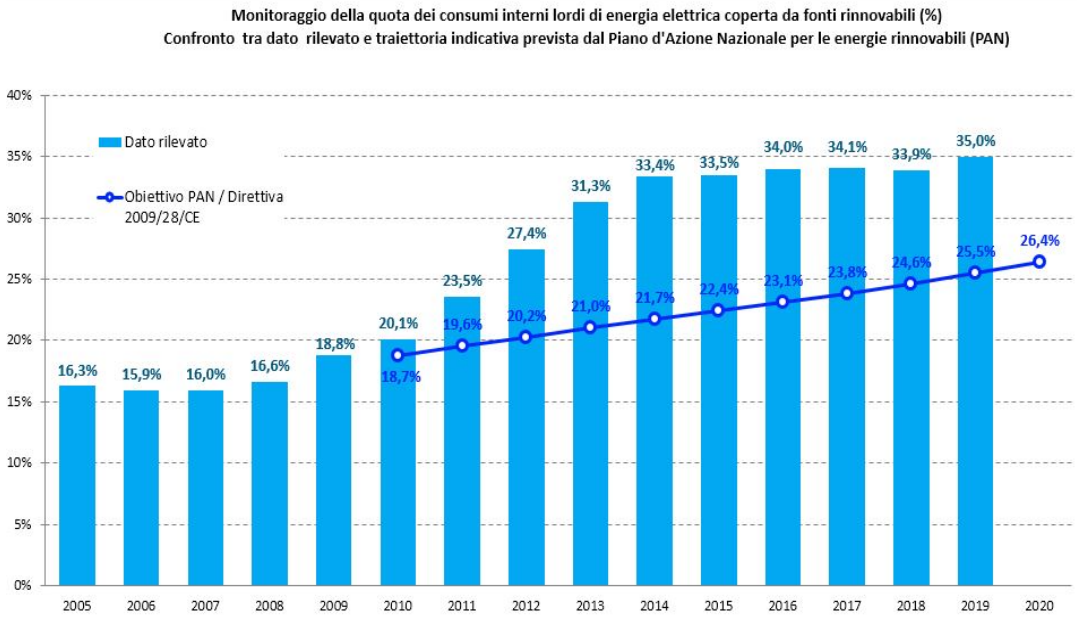
Source: https://www.gse.it/dati-e-scenari/monitoraggio-fer/monitoraggio-nazionale/obiettivo-complessivo



- The contributions of the energy consuming sectors to the gross final energy consumption of 250 TWh are: 117.5 TWh for the power sector, 117.5 for the thermal sector and 15 TWh for the transport sector.
- The following table presents the 2020 Italian energy context outlined by the Minister for Ecological Transition in the report (MITE, 2021).
-

1 Power sector:

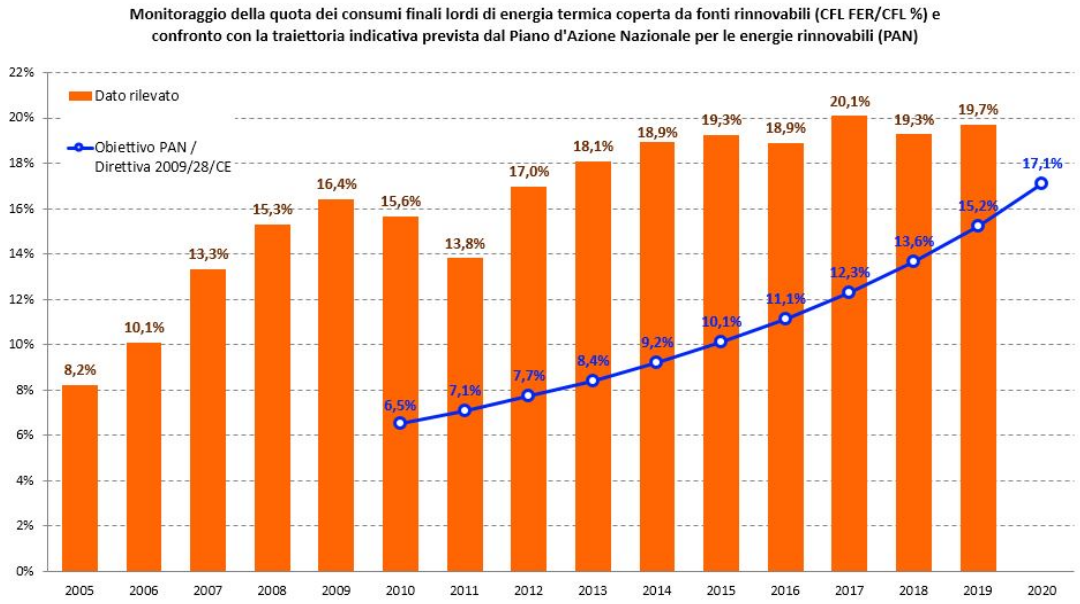
The electricity demand in 2020 in Italy amounted to 301.7 TWh, in decline compared to 2019 because of Covid-19 pandemic. The national gross production of electricity has been equal to 279.6 TWh, of which 163.5 TWh **(58.5% of the total) has been generated by fossil-fueled thermoelectric plants**. The remaining quota has been produced by renewable energy sources: 46.6 TWh hydro, 18.7 TWh wind, 24.9 TWh solar PV and 26 TWh geothermal energy and bioenergy. The total **power production from RES** therefore accounted to 116 TWh, representing **37% of the total**.



Monitoring of the quota of gross final electric energy consumption covered by renewable sources (%).
Comparison between the measured values (light blue) and the values foreseen in the national action plan (PAN).
Source: https://www.gse.it/dati-e-scenari/monitoraggio-fer/monitoraggio-nazionale/settore-elettrico

2 Heating sector:

The thermal energy consumption in 2020 from renewable energy sources amounted to 117.4 TWh, of which 106 TWh is given by the direct use of the renewable sources and 11.4 TWh by derived heat, mainly associated to district heating systems. Among the renewable energy sources **the biggest contributor was bioenergy, with 87 TWh,** mainly given by solid biomass as pellet and firewood used for heating in the residential sector. **The renewable quota given by heat pumps was equal to 26 TWh, 1.7 TWh by geothermal energy and 2.7 TWh by solar thermal.** The contribution of renewable energy sources in the heating sector registered a very slight decrease with respect to 2019 (-4% for biomass and -2% for heat pumps) and therefore an overall share of almost 20% as registered for the year 2019 can be assumed. The overall gross final thermal energy consumption in 2020 in Italy is therefore about 600 TWh and it includes the civil and the industrial sectors. It represents 50% of the overall gross final energy consumption (1251 TWh).



Monitoring of the quota of gross final thermal electric energy consumption covered by renewable sources (%).
Comparison between the measured values (orange) and the values foreseen in the national action plan

3 **Combined heat and power (CHP) production:**

Up to 2014 the plants for only electricity production represented the majority in the Italian thermoelectric sector. It is since 2016 that the CHP plants became the largest share of the total and in 2020 they were responsible of **105.9 TWh of electricity produced**, against 77.3 TWh produced in plants for power generation only. Regarding the heat production, the **thermal energy produced by CHP plants in 2020 amounted to 0.06 TWh**, of which 82.2% was obtained from traditional, fossil-based fuels and the remaining 17.8% from bioenergy.

4 **Transport sector:**

The consumption of vehicle fuels in 2020 accounted for 298 TWh, with a relevant decrease (-17.4%) with respect to 2019 because of covid-19 pandemic mainly**. Petrol registered a drop of 21% and diesel of 16%.** Conversely, **the fleet of vehicles fueled by natural gas grew by 1.6%** with respect to the previous year. More and more car manufacturers in Europe identify methane as the most efficient and already available fuel for automotive purposes with which it is possible to meet the ever-tighter constraints on CO_2 and particulate emissions. Environmental policies in the automotive sector envisaged CO_2 emissions reduction from 130 g/km, estimated in 2020, to 95 g/km, together with a relevant reduction in particulate emissions that will mainly penalize diesel engines.

5 **Natural gas:**

In 2020, the demand for natural gas in Italy has been equal to 71.3 billion cubic meters, with an overall reduction of 3.2 billion m^3 with respect to 2019. The most relevant reductions have been registered in the civil sector, with a drop of 1.6 billion m^3, and in the thermoelectric and CHP generation sector, with a drop of 1 billion m^3. Again, these declines are due to reduced consumption in the service sector and to reduced electricity demand in 2020 because of covid-19 pandemic.

The demand of natural gas has been met by national production for 7% only, with the remaining quota being imported. Very relevant is **the national production of bio-methane, that in 2020 accounted for 99 million cubic meters**, mostly coming from urban wet waste and in part from the agricultural sector. **Bio-methane is increasingly ensuring that gas network can become a vector of renewable energy**.

6 Hydrogen:

In order to promote the hydrogen uptake on the national energy system, the Italian Government foresees the **installation of 5 GW of electrolysis capacity by 2030**. The focus is on decarbonized hydrogen, to be combined also with imports and other low carbon hydrogen technologies. This measure will offer concrete options for the decarbonization of industrial processes, mainly in the chemical sector and in refineries, in which hydrogen of fossil origin is already used. Industry is a very promising sector for the production and the utilization of hydrogen and there are already many ongoing experimentations in the field.

7 Efficiency measures in buildings:

The 2012/27/UE directive about energy efficiency foresees an annual final energy saving of 1.5%. With the aim to respect these requirements, in Italy it is mandatory to install condensing boilers and thermovalves on radiators and there are incentives and tax relief, in the order of 50-60%, for the refurbishment of buildings and the replacement of heating systems with high-efficiency technologies (as heat pumps). Consistent with the trend of the last decade, a reduction of final energy consumption has been registered in 2020 with respect to 2019: -2% in the residential sector, with energy saving of 0.6 billion m^3, and -12% in the service sector, with a marked reduction of 1 billion m^3 also due to the covid-19 pandemic.

The overall final energy saving in 2020 has been equal to 62.8 TWh, making possible to obtain **cumulative savings of 270 TWh in the period 2014-2020**. The target set for 2020 by the Energy Efficiency Directive, article 7, was 297 TWh of cumulative savings.

Regarding the overall reference European targets, the final aim is to reach complete decarbonization by 2050. In order to achieve this, **by 2030** the intermediate EU targets to be reached are: **-55% of greenhouse gases emitted**, **32% of RES share in the whole system** (including heat/cooling generation, the power system and the transport sector), **32.5% of primary energy saved**. The latter two are currently being updated in order to meet the first-mentioned challenging target, which has been increased from 40% up to 55% through the European Green Deal (COM/2019/640 final).

2. POLICY AND STRATEGY

In order to achieve the European objectives, Italy has been asked (together with all the other EU Countries) to define a roadmap with the targets and the planned reforms and investments to achieve them. In this context, the PNRR - National Recovery and Resilience Plan (Italian Council of Ministers, 2021) has been drafted and with the Next Generation EU - NGEU programme, launched in July 2020 to support the Member States to recover from covid-19 pandemic, it has been established that at least 37% of the overall 191.5 billion of euro that EU has assigned to Italy for investments and reforms must be addressed to measures and actions to tackle the climate change. The targets to be achieved in each energy sector are still under definition, but in Italy two main documents have been edited and are currently in operation: PNIEC (Integrated National Energy and Climate Plan) and LTS (Long-Term Strategy). The first one reflects the European directives for 2030 into national targets; the second one defines the national roadmap towards complete decarbonization in 2050.

2.1 POLITICAL GOALS AND AGREEMENTS

The targets defined in PNIEC (Ministry of Economic Development, 2019), for the year 2030, are:

- 33% reduction of greenhouse gases emission from industries belonging to the Emission Trading System (ETS) registry; 43% reduction of GHG emission from the industries not in ETS. (these targets are referred with respect to the year 2005);
- 30% of the overall final energy consumption should be met by renewable energy sources (RES), which translates in a share of RES in the transport sector of 22%, a share of 55% in the electricity sector and a share of 34% in the heating sector;
- energy consumption reduction of 43%.

Concerning the thermal sector, the reduction of the heat consumption would be achieved through the building stock refurbishment, carried out together with the replacement of the individual heating sources with less emitting and more efficient solutions. More specifically, there are five financial instruments already active in Italy to promote the diffusion of renewable energy sources:

- tax deductions for the refurbishment of buildings and the replacement of the existing heating solutions with renewable sources as solar thermal, heat pumps, geothermal and biomass boilers. The estimated average annual investments driven by this financial instruments are: 68.3 M€ for the solar thermal, 133 M€ for heat pumps, 3.5 M€ for geothermal plants and 40.4 M€ for biomass plants;

- the so-called Heat Bill (Conto Termico), introduced since 2013 to allow the taking-up and pursuit of energy efficiency activities by the Public Administration. In this case the foreseen average annual investment are: 70.8 M€ for solar thermal, 37.3 M€ for heat pumps and 144.7 M€ for biomass plants;
- the introduction of the so-called White Certificates, which are securities that certify the energy savings achieved by various parties through the implementation of specific interventions;
- obligation to integrate renewable energy sources in buildings;
- support schemes for Municipalities to facilitate investments in energy efficiency activities and to promote sustainable local development.

In the transport sector, an increased use of biofuels and a progressive electrification is envisaged, with a total of 6 million of electric vehicles in circulation.

The Long-Term Strategy (Ministero dell'Ambiente e della Tutela del Territorio e del Mare; et al., 2021), which aims to the complete decarbonization in 2050, requires:

- a 40 % reduction of the final energy consumption;
- a RES coverage of about 85%-90% of the final energy consumption;
- an overall electrification of more than 50% in the transport sector.

These targets would allow to completely abate the emission of CO_{2eq} from the civil and transport sector and to reduce the CO_{2eq} emissions from the industrial sector up to 15-35 Mtoe and up to 50 Mtoe in the non-energetic sectors, as agriculture. In order to give a starting reference, in 2019 the estimated GHG emissions accounted for 418 Mtoe $CO_{2eq,}$ of which 42% from the industrial sector, 25% from the transport sector, 19% from the civil sector, 4 % from the waste treatment sector and 7% from the agriculture.

In the following, the current status for each energy sector in Italy is presented and it is illustrated how the above-mentioned European and National targets have been declined for them.

3. ENERGY SECTORS IN ITALY

3.1 THERMAL SECTOR

The gross final thermal energy consumption estimated in Italy for the year 2020 accounted for about 600 TWh, representing half of the overall gross final energy consumption of 1251 TWh. The civil sector (i.e. residential and service sector, for space heating and domestic hot water) is responsible for about half of the overall 600 TWh of thermal energy consumption. Specifically, 294.1 TWh was the quota associated to the residential sector in 2019, from Eurostat (Eurostat, 2022). The share of renewable energy sources in the thermal sector was equal to 20% in 2020, covering 117.4 TWh. The thermal sector is therefore dominated by fossil fueled solutions, mainly based on natural gas.

3.1.1 DISTRICT HEATING AND DISTRICT COOLING

According to (AIRU, 2020) and (Gestore dei Servizi Energetici, 2020) only 9.133 TWh of thermal energy is supplied through district heating in Italy, representing 2.7% of the heat demanded in the civil sector. In 2019, district heating counts 413 networks in operation, with a total length of about 4551 km and a total heated volume of 366 million m^3. The target defined in the PNRR requires, by 2030, the development of 300 km of efficient district heating networks and the installation of plants and connections finalized to a thermal production of 360 MW from excess heat sources and RES. Indeed, an efficient district heating system is based on RES, waste heat and high efficiency CHP plants, by definition. It is also defined that the available funding will be allocated to the development of new networks in the share of 65% and to the construction of new generation plants in the remaining 35%. If achieved, these targets will bring to 0.23 TWh/year of fossil primary energy saved and 0.04 million tons of CO_2 avoided emissions per year.

Currently, the existing systems are mainly operating in Northern Italy, especially because of the cold climatic conditions, and they account for 98% of the overall heated volume. In particular, the cities of Brescia, Milan and Turin currently represent 42% of the total national DH, managed under public-private partnerships. Few plants are also operating in the central part of Italy, especially in Tuscany, due to the large availability of geothermal heat.

Regions in central/south part of Italy are promising for the opportunity of providing cooling services during summer. District cooling, however, remains very limited: according to (AIRU, 2020), the cooling energy provided to the users through district cooling networks amounts to 129.6 GWh, representing only 1.4% of the thermal energy distributed for space heating and domestic hot water in the same year. The corresponding installed cooling power is equal to

203.8 MW of which 48% is provided by compression chillers collocated at the central plant and 52% by absorption chillers located in the users' substations.

In 55% of the installed DH networks, the heat carrier is hot water (on average: 90°C supply and 65°C return); in 44% of cases is pressurized hot water (average temperature of 120-70°C); in the remaining 1% is vapor. Regarding district cooling the average temperatures are 6°C in supply and 12°C in return.

For what concerns the heat fed into DH networks, 52.5% of the overall provided thermal energy is generated by fossil fuel-based CHP plants; 22% is generated by individual heating solutions mostly fed by natural gas; 25.5% is thermal energy from renewable sources, namely RES as solar thermal and geothermal energy, bioenergy and biomass-based CHPs, heat pumps and industrial waste heat. An illustration from (AIRU, 2020) is reported below:

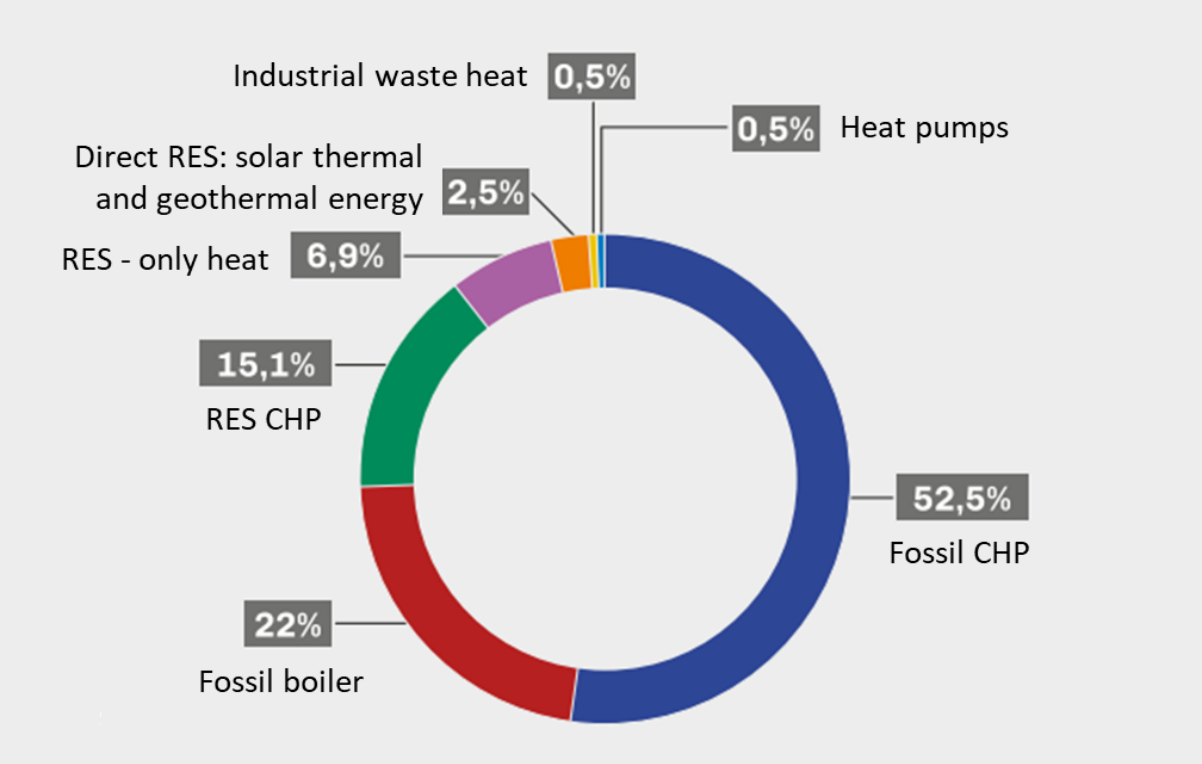


Figure 1: Shares of the technologies installed in 2019 for the production of thermal energy fed into DH networks.

It can be seen that of this share of 25.5% of the overall thermal energy provided, 2.5% is given by geothermal energy and thermal solar; 0.5% is given by recovered industrial waste heat; 0.5% by large heat pumps; 22% is covered by CHPs and boilers fueled with municipal waste, biomass or biofuels. In particular, the municipal waste represents the second fuel the most used in Italy for district heat generation, while bioenergy, and especially biomass, is the third. Even if the first place is still taken by natural gas, which is mainly utilized to meet base load needs, a progressive transition from fossil fuels to renewables can be appreciated in the table

below, from (AIRU, 2020), where the mix of utilized energy sources is reported for the year 2019 compared to the year 2009.

Table 1: Mix of primary energy sources utilized in the existing DH systems in Italy in 2019

	2019		2009	
	Thermal energy [tep]	%	Thermal energy [tep]	%
Natural gas	1,319,031	69.4	1,032,854	74.3
Municipal waste	287,476	15.1	109,525	7.9
Bioenergy (biomass and biofuels)	188,823	9.9	71,615	5.2
Coal	47,825	2.5	48,534	3.5
Oil	2,351	0.1	42,107	3
Geothermal energy	25,239	1.3	10,905	0.8
Industrial waste heat	5,086	0.3	2,090	0.2
Solar thermal	91	0	-	0
Fossil primary energy from Power System	25,945	1.4	71,974	5.2
Fossil total	1,395,152	73	1,195,469	86
RES total	506,715	27	194,135	14

Natural gas is still predominant but it slightly decreased in the last period. Also the other fossil sources show a negative trend, as it can be seen in Figure 2. Meanwhile, renewable sources in Figure 3 show a positive trend: apart from municipal waste and bioenergy which are the most relevant, it is possible to see that geothermal energy more than doubled its former share in 2009, solar thermal made it appearance in the energy mix and industrial waste heat is not yet relevant in term of percentage but its impact in terms of thermal energy more than doubled.

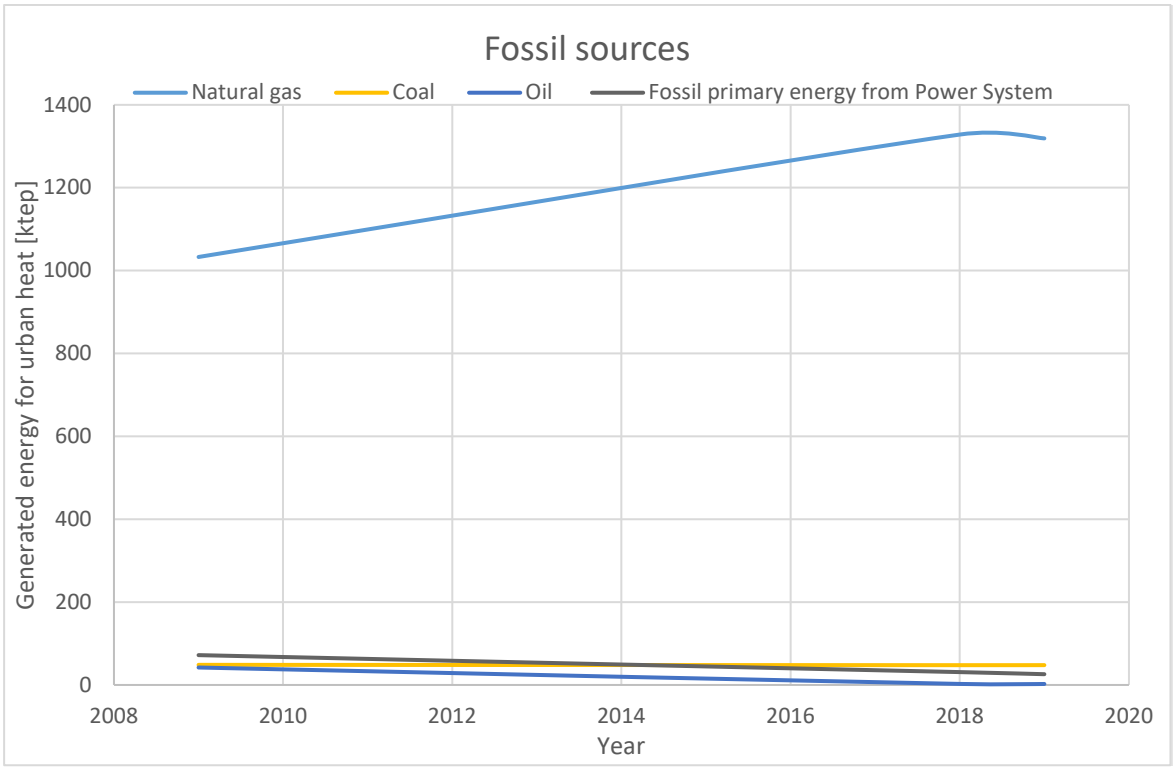


Figure 2: Trends from 2009 to 2019 of primary energy sources of fossil origin utilized in DH systems in Italy.

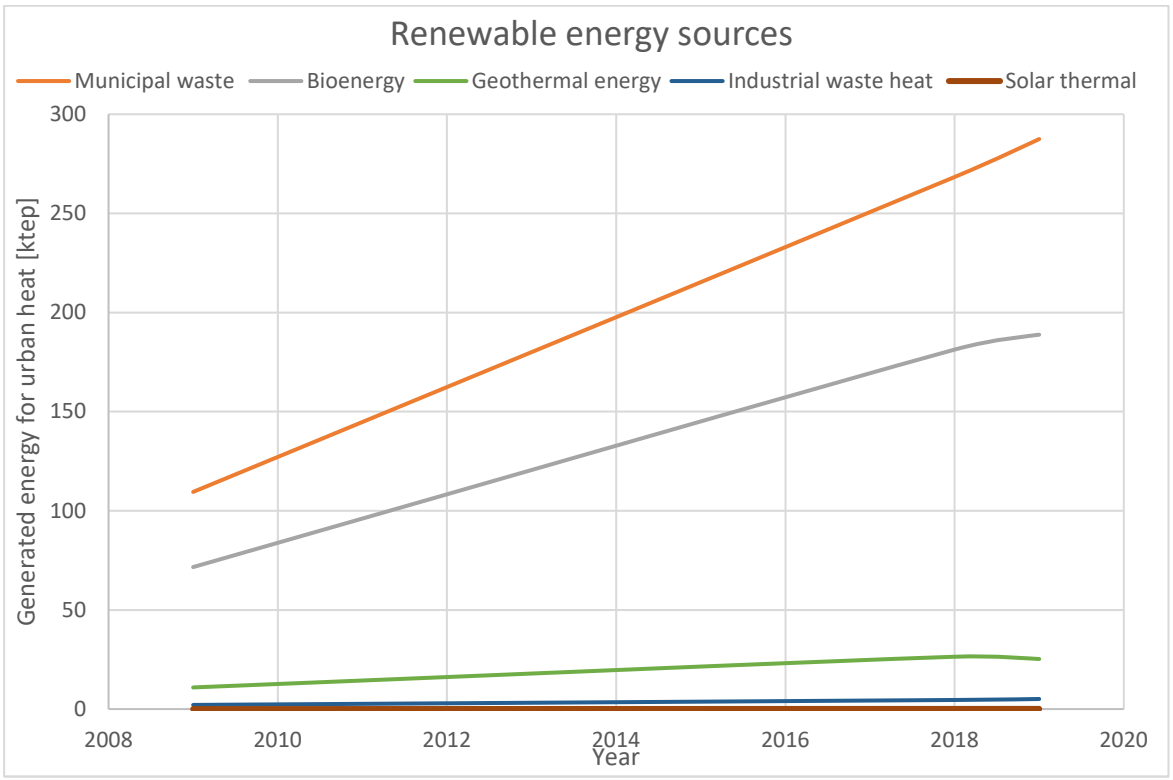


Figure 3: Trends from 2009 to 2019 of primary energy sources of renewable origin utilized in DH systems in Italy.

3.1.2 DISTRICT HEATING AND DISTRICT COOLING – OBSTACLES AND OPPORTUNITIES

Even though increasing trends can be observed for renewable sources, renewable primary energy sources adopted in 2019 cover only one fourth of the total.

The main identified obstacles for RES transition in Italy can be identified in the following:

- RES heating supply sources of district heating are generally more capital intensive than natural gas CHP. DH operation takes place in a highly competitive environment where the choice of heat supplier is principally based on prices. The main alternative to efficient DH is the use of natural gas boilers (or oil boilers in the few areas not yet reached by the natural gas grid), which dominate the heating market.
- There are no many national incentives to DHC, e. g. there are no specific investment grants for DH, despite the long payback time of these systems (above 20 years). Until 2016, district heating and cooling (DHC) projects were supported by white certificates (corresponding to the primary energy saved), but this support scheme has recently been changed and in some cases the incentive has been significantly reduced. As minor support, a reduced Value Added Tax (VAT) is applied to heat sales to residential users supplied with RES or Combined Heat and Power (CHP) and other minor mechanisms are available for particular cases (biomass, geothermal, cogeneration and micro CHP systems). However, these measures proved to be not so effective.
- The short duration of the winter season and the reduced space availability in many areas of the country often makes the fossil heating solution preferable, especially in the absence of regulatory constraints on its development.
- Stakeholders involved in DH admit that this technology is generally perceived as a rather old and inefficient technology. Actions need to be taken in order to get owners, consumers, industries and public authorities more aware of the environmental and social benefits that DH can bring. In this way they would be able to make informed decisions about heating supply options.

A recent study funded by AIRU and conducted by Politecnico di Milano and Politecnico di Torino (Politecnico di Milano & Politecnico di Torino, 2020) demonstrates, however, that by only exploiting the existing renewable or excess heat sources in the whole italian country, 90TWh is the amount of thermal energy that can be conveyed to the buildings through DH networks. By considering that 114TWh is the energy demand from buildings technically connectable to a DH system without required interventions at the substation level, 33% of it can be covered by RES. The current share is 9% and therefore a ten-fold expansion of efficient DHC system (i.e. based on RES and excess heat sources) can be potentially achieved in a technically feasible and cost-effective way.

3.2 POWER SECTOR

At the end of 2020, Italy had a vast availability of net installed electric power of about 116 GW. Thermal power plants account for 61 GW, that is already enough to cover power peaks which are in the range of 60 GW. Renewable energy power is nearly 58 GW out of which 22 GW come from hydropower; 21 GW are from solar power; 10 GW from wind power; 4 GW from bioenergy power; 0,8 GW from geothermal power (Terna, 2016). As the reduced time of functioning due to the increased penetration of RES does not compensate management and other costs, the thermal power plants have been experiencing a decrease of hours of operation in the last 10 years due to the lack of sustainability in the competition with other sources, going from a peak power of 80 GW to 61 GW. Meanwhile the renewable electrical energy sources have seen a strong development, especially due to economic incentives from 2009 and 2012 for solar and wind power. Hydroelectric and geothermal power have remained stable.

In 2021, the electricity mix is composed by 50,5% of thermal production, 36% of renewable energy and 13,5% of import-export balance. The foreign balance is in the historical range registered in the last 20 years, between 8-15 %, and most of the energy comes from Switzerland and France, which in 2019 represented 85% of the imported electric energy (Terna, 2019). The total electric energy consumption is roughly 320 TWh, very close to 2019 level, which demonstrates a full recovery from the pandemic shock (Terna, 2021).

The geography of Italy is very peculiar as it has two big islands, Apennines splitting up the centre and Alps fencing off northern regions from the north. Consequently, interconnections inside and with foreign countries are complicated and costly. Currently, the interconnection capacity is 4350 MW with France, thanks to the new interconnector of 1200 MW; 4240 MW with Switzerland; 500 MW with Greece and 730 MW with Slovenia. Additionally, there are plans to add 1 GW of capacity with Slovenia, 300 MW with Austria, 600 MW with Montenegro; and there is the possibility/predisposition to add other 300 MW with Austria and 600 MW with Montenegro (Terna, 2022). Concerning the internal connectors, the refurbishment of the 400 MW Sardinia-Corsica-Italia link has been approved: the Adriatic link will connect Abruzzo and Marche with a capacity of 1000 MW, while the Tyrrenian link will connect Campania to Sicily and Sicily to Sardinia with a capacity of 1000 MW in 2028. These new internal interconnectors will enable the energy transition as they can deliver renewable energy from South, where solar and wind energy is abundantly available, to North, where demand is concentrated.

Regarding the coming future, the Fit for 55 Package of the European Commission, released in 2021, has changed the path: Europe position is moving towards a strong and prior decarbonization, addressing the 55% reduction of greenhouse gases emissions in 2030. In the electricity sector, this translates in required coal phase-out and multi GWs installation of renewable energy, mainly wind and solar power, which means that Italy is likely to increase the renewable energy targets set out in the National Energy Climate Plan for wind and solar.

The abundant electricity, that will be available in 2030, has to be managed during peak production hours: therefore, the power grid has to be ready and to be coupled with other sectors, such as transport, in order to avoid curtailments.

3.3 INDUSTRIAL SECTOR

Regarding the industrial sector, it is envisaged that the expected reduction of GHG emissions from the electricity sector will lead to a reduction of about 23% in the industrial sector by 2030 vs. 2015 (Ministry of Economic Development, 2019). This is a less marked decline if compared with the trend in the period 2005-2015, in which a reduction of 36% has been registered. It must be taken into account that the reduction registered since 2005 is in part due to the economic crisis of 2008, which depressed consumes and the forecasted economic growth expectations. The effects of the structural changes in the Italian industry and of the increase in the process efficiency can be appreciated by considering that the emission reduction in the following year is less important but stable, even in response to a progressive increase in productivity.

The International Energy Agency (IEA) returns the annual final energy consumption of the Italian energy system with different levels of detail. In *Data and statistics* (IEA, 2022a) it is possible to analyze the industrial sector, by focusing on the four main subsectors shown in Figure 4. For this specific sector, the online website refers to the *Energy Efficiency Indicators* database (IEA, 2022b) where annual data from 2000 for end use sectors are contained.

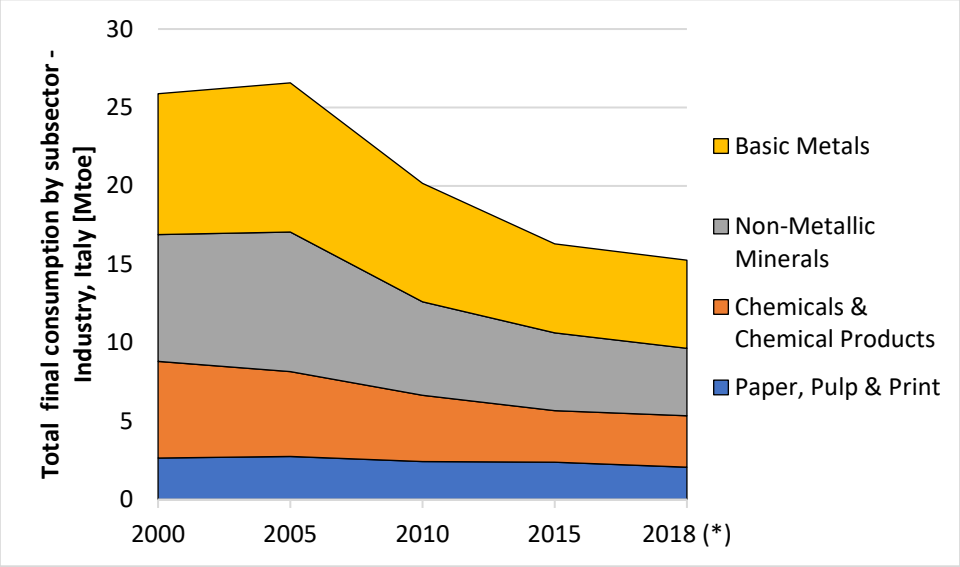


Figure 4 – Total final consumption in industry by subsector in Italy; (*) data are provided with a temporal detail of 5 years (e.g. 2000,2005) plus the most recent available one, here 2018 [Elaborations from (IEA, 2022b)*]*

The overall total consumption goes from 25.9 Mtoe in 2000 to less than 15.3 Mtoe in 2018, with a significant reduction in the chemical and non-metallic minerals sectors (both -47%). A significant reduction in the energy consumption is registered also in the basic metals sector, with a drop of around 37%, while the pulp and paper sector shows a decrease by one fifth (-22%).

Figure 4 represents the main four industrial sectors, but not the overall energy consumption. To complete the description of the Italian energy system, Figure 5 is therefore presented, where data from the *World Energy Statistics and Balances* package are collected (IEA, 2022c).

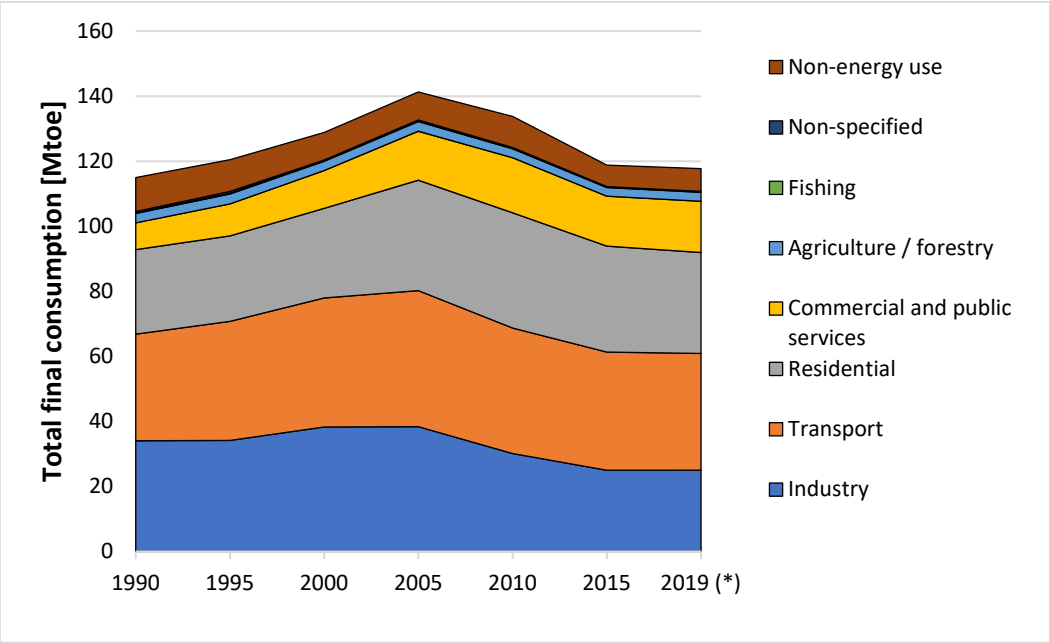


Figure 5 – Total final consumption by sector in Italy; (*) data are provided with a temporal detail of 5 years (e.g. 1990, 2005) plus the most recent available one, here 2019 [Elaborations from (IEA, 2022c)]

It reports the total industrial sector's final energy consumption, that went from 34.1 Mtoe in 1990 to 25 Mtoe in 2019, with a reduction of less than one third (-27%). Being the final energy consumption in industry equal to 24.7 Mtoe in 2018 (IEA, 2022a), it means that the main four subsectors of Figure 4 represent more than 60% of the overall industrial final energy consumption.

In the National Energy and Climate Plan (PNIEC) of 2019 (Ministry of Economic Development, 2019), the Italian Ministry of Economic Development estimated that the final energy consumption for the year 2020 from the industry was equal to 26.5 Mtoe, with associated GHG emissions of 148 Mt of $CO_{2eq.}$ In the scenario defined in the context of PNIEC, these values for

the year 2030 would become: 25.05 Mtoe of final energy consumption and 135 Mt of CO_{2eq} emitted. Transport sector

The final energy consumption for the transport sector in 2019 accounted for 30% of the overall final energy consumption (which total is close to 118 Mtoe), presenting a 10% increase from 32.7 Mtoe in 1990 to 35.9 Mtoe in 2019 (as shown in the previous Figure 5). IEA online database *Energy Efficiency Indicators* (IEA, 2022b) returns the total final consumption in transport by subsectors, as shown in Figure 6.

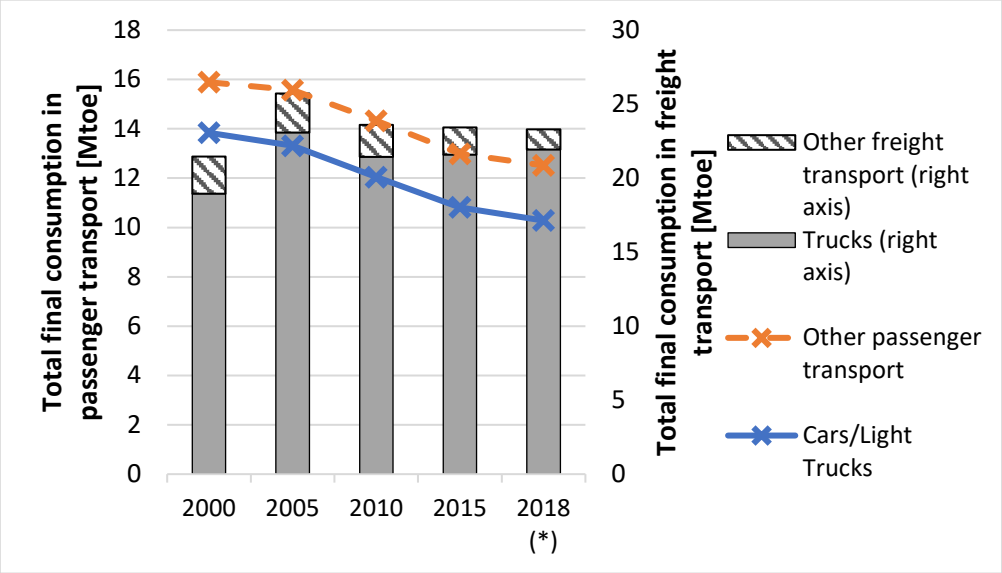


Figure 6 - Total final consumption in transport by subsector in Italy; passenger transport is on the left axis, while freight transport is shown on the right axis; (*) data are provided with a temporal detail of 5 years (e.g. 2000, 2005) plus the most recent available one, here 2018 Source: (IEA, 2022b).

In Figure 6 the passengers and the freight transports are presented. For the former, only cars and light trucks are explicitly mentioned, while the class "Other passenger transport" is obtained as difference between the total final energy consumption for the passenger transport and the previous class. The same structure is used for the freight transport, where a detail is shown for trucks.

In 2018, road transport (i.e. cars/light trucks and trucks) covered more than 87% of the total final energy consumption of the transport sector. It might be then useful to focus on the composition of the stock of vehicles. The Italian association *Automobile Club d'Italia* (ACI) returns an annual picture of the vehicle fleet, by dividing the vehicles in circulation by size, year, European emission standard, fuel type and categories (e.g. cars, trucks, buses) (ACI, 2022). In 2019 Italian ***car fleet*** was made up of more than 39.5 million of vehicles, of which more than 90% (35.6 million units) fueled by conventional fossil fuels, followed by Gas Petroleum Liquid (GPL) propulsion systems (2.6 million), methane (0.9 million) and only a

minor part of electric vehicles. The latter class is divided into pure battery electric vehicles (BEV, 0.02 million) and hybrid electric vehicles (HEV, 0.3 million). Regarding public road transport, in 2019 the fleet was made up of more than 100 thousand of ***buses***, of which almost the total (94%) is fueled by gasoline, a minor part by methane (roughly 5%) and petrol (less than 1%). For freight road transport, ACI estimates 4.2 million of ***trucks*** for the same year, 97% of which are fueled by conventional fossil fuels, and by methane (roughly 2%). In addition to them there are 190 thousand ***road tractors***, fueled by gasoline (99%) and methane (1%).

4. STATUS FOR SECTOR COUPLING

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 (CDP et al.,2019). The electrification of energy consumption and the spread of renewable energy sources emphasize the complexities related to residual load ramp and overgeneration management, confirming the need for flexible technologies such as storage systems, demand-response management, distributed generation management, Power-to-heat, etc. At the core of sector coupling there is the fact that when coupled to a power grid, technologies at this interface effectively also become components of the power system and thus can be modelled as such. Electric boilers, heat pumps, CHPs, electrolysers for hydrogen production, electric vehicles (EVs), storage systems and even the existing gas grid, especially if carrier of biofuels, become interconnected elements of a single unique system. District heating, being an energy infrastructure with a strong local connotation, can be seen as the key technology at the core of sector coupling, facilitating the interconnection between the heating and the power sectors, together with several other energy consuming sectors. From the point of view of DH, these sectors are the heating sector (with the buildings), the power sector (with the large-scale heat pumps and the CHP plants, that currently cover 0.5% of the overall provided thermal energy and 52.5% respectively), the industry (through the excess heat recovery in DH networks), the telecommunication network (with datacenters' excess heat recovery), etc.

DH can also be seen as an effective way to balance the electricity system: especially in future scenario with reduced distribution temperatures and increased proportion of intermittent RES, district heating can balance the fluctuating renewable energies' overproduction in integration with large heat pumps. These are expected to gain an increasing weight in the thermal renewables mix because of their high efficiency and the continuous technological progress in the sector. The provided balancing power could then potentially reduce the need for the electrical grid upgrade, that is expected to be necessary in future since electrification and the diffusion of renewables are showing increasing trends in many OECD countries since many years. In Italy, in particular, the share of electricity in final consumption has grown from 17% in 1990 to 22% in 2017 (CDP et al.,2019).

Eventually, DH can be seen as a big thermal reservoir, by avoiding the release in the environment of heat fluxes at different temperatures and from different sources and, if integrated with thermal storages and power-to-heat systems, by stocking and providing heat when it is more convenient.

Heat pumps covers a very limited share of heat generation in Italian DH (49MW of installed capacity over 9000 MW total power of DH), but they presence it's likely to increase in the upcoming future.

BIBLIOGRAPHY

ACI. (2022). *ACI - Autoritratto*. https://www.aci.it/laci/studi-e-ricerche/dati-e-statistiche/autoritratto.html

AIRU. (2020). *Annuario AIRU 2020*.

Eurostat. (2022). *Disaggregated final energy consumption in households - quantities*. https://ec.europa.eu/eurostat/data/database

Gestore dei Servizi Energetici. (2020). *Teleriscaldamento e Teleraffrescamento 2019. Nota di approfondimento GSE*.

IEA. (2022a). *Data and statistics*. https://www.iea.org/data-and-statistics/data-browser?country=ITALY&fuel=Energy consumption&indicator=ManufacturingConsBySubsector

IEA. (2022b). *"Energy Efficiency Indicators" database*. https://www.iea.org/data-and-statistics/data-product/energy-efficiency-indicators

IEA. (2022c). *"World Energy Statistics and Balances" package*. https://www.iea.org/data-and-statistics/data-product/world-energy-statistics-and-balances

Italian Council of Ministers. (2021). *"Piano nazionale di ripresa e resilienza."* https://www.governo.it/sites/new.governo.it/files/PNRR_2021_0.pdf

Ministero dell'Ambiente e della Tutela del Territorio e del Mare;, Ministero delle Infrastrutture e dei Trasporti;, Ministero delle Politiche agricole Alimentari e Forestali, & Economico;, M. dello S. (2021). *Strategia Italiana Di Lungo Termine Sulla Riduzione Delle Emissioni Dei Gas a Effetto Serra*. 1–100.

Ministry of Economic Development. (2019). *Piano Nazionale Integrato per l'Energia e il Clima*. https://www.mise.gov.it/images/stories/documenti/PNIEC_finale_17012020.pdf

MITE. (2021). *La Situazione Energetica Nazionale Nel 2020*.

Politecnico di Milano, & Politecnico di Torino. (2020). *Valutazione del potenziale di diffusione del teleriscaldamento efficiente sul territorio nazionale*. AIRU.

Terna. (2016). *Impianti di generazione*. 31–71. https:https://download.terna.it/terna/0000/0964/25.PDF

Terna. (2019). *Dati generali 2020*. 1–9. https://download.terna.it/terna/1-DATI GENERALI_8d8e26126475683.pdf

Terna. (2021). *Comunicato Stampa: NEL 2021 DECISO RECUPERO DEI CONSUMI ELETTRICI*. 2020–2021.

Terna. (2022). *TERNA. Progetti Interconnector*. https://www.terna.it/it/chi-siamo/attivita/sviluppo-internazionale