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Preparing Italy's charging infrastructure for rapid vehicle electrification

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Italy is the 3rd largest vehicle market among the 27 European Union member states after Germany and France. In 2019, 2020, and 2021, registrations of new passenger cars reached 1.92 million, 1.38 million, and 1.46 million, respectively. As such, the country plays a key role in the transition from internal combustion engine to electric vehicles as a strategy for meeting climate goals and improving local air quality, both of which benefit the health of people and the environment. To support this transition, the extension of the public charging infrastructure network will be crucial. This working paper assesses the electric vehicle charging infrastructure necessary in Italy by 2030 compared to what was installed at the end of 2020.

Introduction

The electric vehicle share of Italy's passenger car market has seen robust growth recently, rising from 1% of all new passenger car registrations in 2019 (about 17,000 vehicles) to more than 4% in 2020 (almost 60,000 vehicles) and more than 9% (about 138,000 vehicles) in 2021.[1] But these sales shares remain well below the European average of 3% in 2019, 11% in 2020, and 19% in 2021.[2] Electric vehicles in this analysis include battery electric vehicles (BEVs) with no gasoline or diesel engine, and plug-in hybrid electric vehicles (PHEVs) that can operate without petroleum but have a backup gasoline engine when exceeding electric range.

Italy has a successful history of introducing alternative fuel vehicles, but registrations are currently dominated by hybrid electric vehicles (HEVs) and natural and liquefied petroleum gas vehicles. In 2020, HEVs accounted for 16% of total new passenger car registrations, while natural and liquefied petroleum gas vehicles represented 9%. This was 4 and 7 percentage points above the European Union average, respectively. By contrast,

1 ACEA, "Fuel types of new cars: electric 10.5%, hybrid 11.9%, petrol 47.5% market share full-year 2020," (4 February, 2021), https://www.acea.auto/fuel-pc/fuel-types-of-new-cars-electric-10-5-hybrid-11-9-petrol-47-5-market-share-full-year-2020/; ACEA, "Fuel types of new cars: battery electric 9.1%, hybrid 19.6% and petrol 40.0% market share full-year 2021," (2 February, 2022), https://www.acea.auto/fuel-pc/fuel-types-of-new-cars-battery-electric-9-1-hybrid-19-6-and-petrol-40-0-market-share-full-year-2021/

2 Peter Mock, "Market Monitor. European passenger car registrations January-December 2020," (January 2021), https://theicct.org/sites/default/files/publications/MarketMonitor-EU-jan2021.pdf; Sandra Wappelhorst, Uwe Tietge, Georg Bieker, and Peter Mock, "Europe's CO2 emission performance standards for new passenger cars: Lessons from 2020 and future prospects" (Washington, D.C.: International Council on Clean Transportation, September 2021), https://theicct.org/publications/eu-ev-pv-co2-emission-performance-sept21; Peter Mock, "Market Monitor. European passenger car registrations January-December 2021," (January 2022), https://theicct.org/publication/market-monitor-eu-jan-to-dec-feb22/.

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new BEV and PHEV registrations were below the EU average. BEVs in Italy accounted for over 2% of new passenger car registrations in 2020 (EU over 5%), while PHEVs accounted for 2% (EU just over 5%). Similarly, in 2021 new registrations of HEVs as well as natural and liquefied petroleum gas vehicles, were higher in Italy compared to the EU by 9 and 7 percentage points respectively, while BEV and PHEV registrations were lower by about 4 percentage points each.

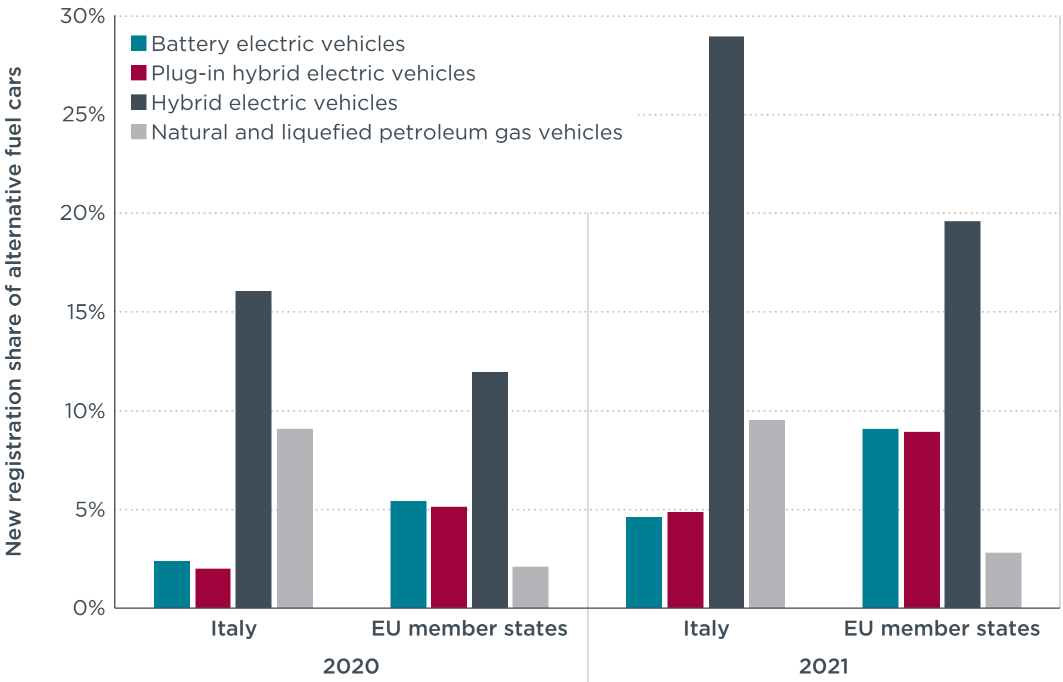

Figure 1. Share of new alternative fuel passenger car registrations in Italy and the 27 European Union member states (excluding Malta) in 2020 and 2021 (Source: ACEA, 2022)

Italy's success in adopting hybrid and natural and liquefied petroleum gas vehicles suggests it can leverage this experience for greater penetration of BEVs and PHEVs.

As of the end of 2020, Italy had about 16,000 chargers to support its electric vehicle fleet. This number is sufficient for today's electric vehicles, but the number will have to increase dramatically to accommodate the growth in electric vehicles in the coming decade. To better understand varying regional charging needs, in this working paper, the number of home, work, public, and fast chargers needed will be estimated for Italian metropolitan and nonmetropolitan areas in the 2021–2030 period. We also assume the electric vehicle share of total new passenger car registrations will be 27% by 2025 and 68% by 2030. The focus of the paper is on passenger cars, which account for most new vehicle registrations and vehicles on the road in Italy and across Europe.[3] Light commercial vehicles and motorcycles are excluded from the analysis.

Nationally, infrastructure and vehicle deployment is guided by the National Plan for Electric Vehicle Charging Infrastructure (PNire), which was adopted in 2012 and updated in 2016. The Plan set a target of up to 13,000 normal chargers and up to 6,000 fast charging stations by 2020 (at that year's end, 12,000 normal chargers and 1,700 fast chargers were in place), at a ratio of "one public charging station to every eight private charging stations," and to have a stock of 130,000 electric vehicles on the country's roads.[4] The updated plan from the end of 2021 sets a target of 32,000 fast

3 European Automobile Manufacturers Association (ACEA), "ACEA Report. Vehicles in use. Europe," (January 2021), https://www.acea.auto/files/report-vehicles-in-use-europe-january-2021-1.pdf.

4 Italy Ministry of Infrastructure and Transport, "Piano Nazionale Infrastrutturale per La Ricarica Dei Veicoli Alimentati Ad Energia Elettrica," June 20, 2016, https://www.governo.it/sites/governo.it/files/PNire.pdf.

and ultra-fast chargers by 2030.[5] Future targets for charging stations and vehicles are currently being discussed. Private entities have pledged to build more than 300 fast chargers[6] and utilities have partnered with automakers to install more than 3,000 fast chargers by 2025.[7]

Market characterization of vehicles and charging

The following section describes regional differences in vehicle uptake as well as background information on charging infrastructure in Italy in terms of technical specifications, housing stock, and home charging access.

Table 1 shows the charging terminology used in the analysis related to power level, applicable standards, and current type. This report's terminology for normal (less than or equal to 43 kW) and fast (greater than 43 kW) charging is based on the methods applied across different regions in previous ICCT reports. The typical power is shown in the second column and generally normal chargers are only up to 22 kW. Alternating current chargers can reach 43 kW, but few car models can use the full capacity. Likewise, there are some direct current chargers lower than 50 kW, but greater than 50 kW is more likely.

Table 1. Charger terminology, power level, standards, and current type

Terminology in this report	Typical power levels	Standards included in this report	Current type
Normal	Approximately 3 kW – 22 kW	Chargers with Type 2 connectors	Alternating current
Fast	50 kW – 350 kW	Chargers with CHAdeMO, CCS, or Tesla connectors	Direct current

Market overview for electric vehicles and charging infrastructure

New vehicle registrations are a proxy for new vehicle sales and for electric vehicle uptake. Electric vehicle registrations as a share of passenger cars in 2020 is measured by metropolitan area according to the European Union's Metropolitan Region definition.[8] Categorization of the nonmetropolitan areas of Italy follows NUTS 2 statistical areas defined by the European Union as "basic regions for the application of regional policies."[9]

Figure 2 shows electric vehicle sales across Italian metropolitan and nonmetropolitan areas as a percentage of new passenger vehicle sales. There are 21 metropolitan areas outlined in thin black lines. The remaining 21 nonmetropolitan areas are delineated by thick gray lines. The nonmetropolitan areas are shown with diagonal lines to distinguish them from metropolitan areas. The top ten areas by population as well as areas of interest are labeled.

5 Government of Italy, "Piano Nazionale Di Represa Resilienza," April 2021, https://www.governo.it/sites/governo.it/files/PNRR.pdf.

6 Autostrade per Italia, "Business Plan Presentation: Engineering, Sustainable Development, Mobility Systems, New Travel Technologies," http://www.autostrade.it/documents/10279/45471524/piano_industriale_ENG.pdf.

7 Enelx, "Enel X and Volkswagen Team up for Electric Mobility in Italy," July 13, 2021, https://corporate.enelx.com/en/media/press-releases/2021/07/enel-x-and-volkswagen-team-up-for-electric-mobility-in-italy.

8 Eurostat, "Metropolitan Regions," accessed May 5, 2020, https://ec.europa.eu/eurostat/web/metropolitan-regions/background.

9 Eurostat, "NUTS - Nomenclature of Territorial Units for Statistics," accessed July 1, 2021, https://ec.europa.eu/eurostat/web/nuts/background.

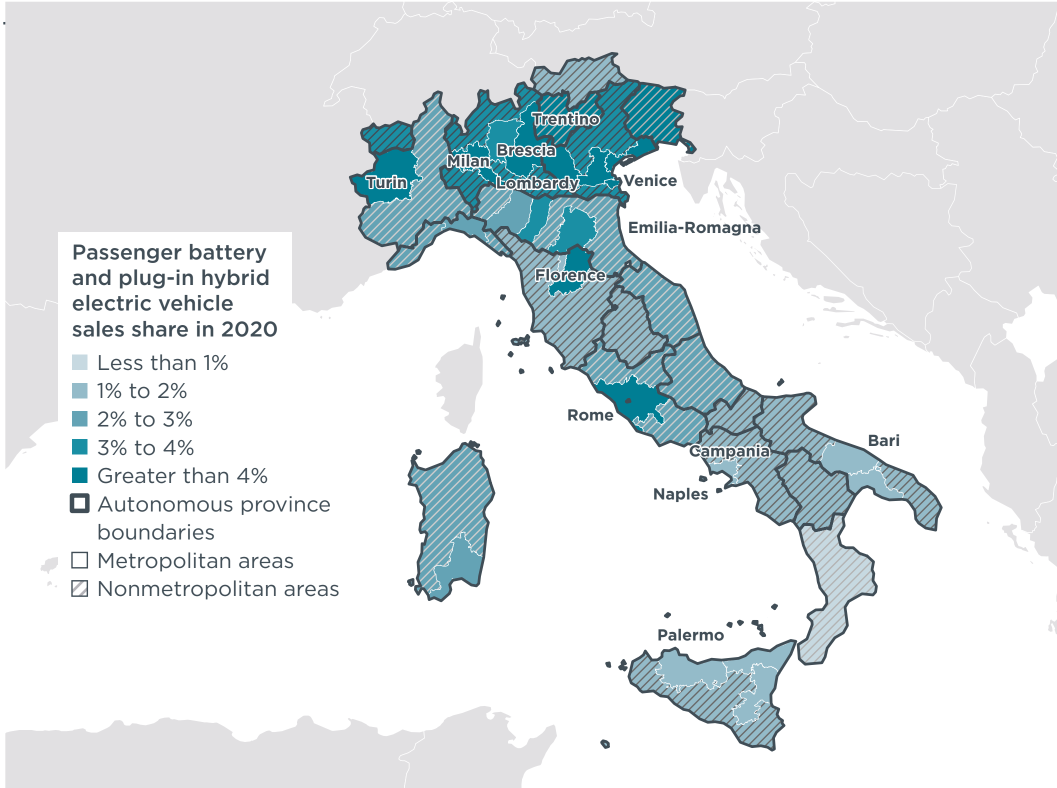

Figure 2. Electric vehicle share, including BEVs and PHEVs, of new passenger car registrations in 2020

The map in Figure 2 shows that the electric passenger car share was highest in Florence, Venice, and the province of Trentino. In general, electric vehicle uptake is highest in the north of the country and lower in the south. Rome is an exception with high uptake in the central part of the country.

Current charger counts are estimated from Eco-Movement.[10] As of December 31, 2020 there were 13,766 away-from-home chargers in Italy excluding standard wall outlets with type C, F, or L sockets. The extent to which private or semi-private workplace chargers are included in these counts is unknown. Figure 3 shows the number of chargers per million population. This is a measure of how prevalent infrastructure is, independent of the number of electric vehicles in the area. Areas that are relatively high on a charger-per-million-population basis have better charger coverage, enhancing driver convenience.

10 Eco-Movement, "Purchased Dataset on Charger Locations. Data through December 31, 2020," 2021.

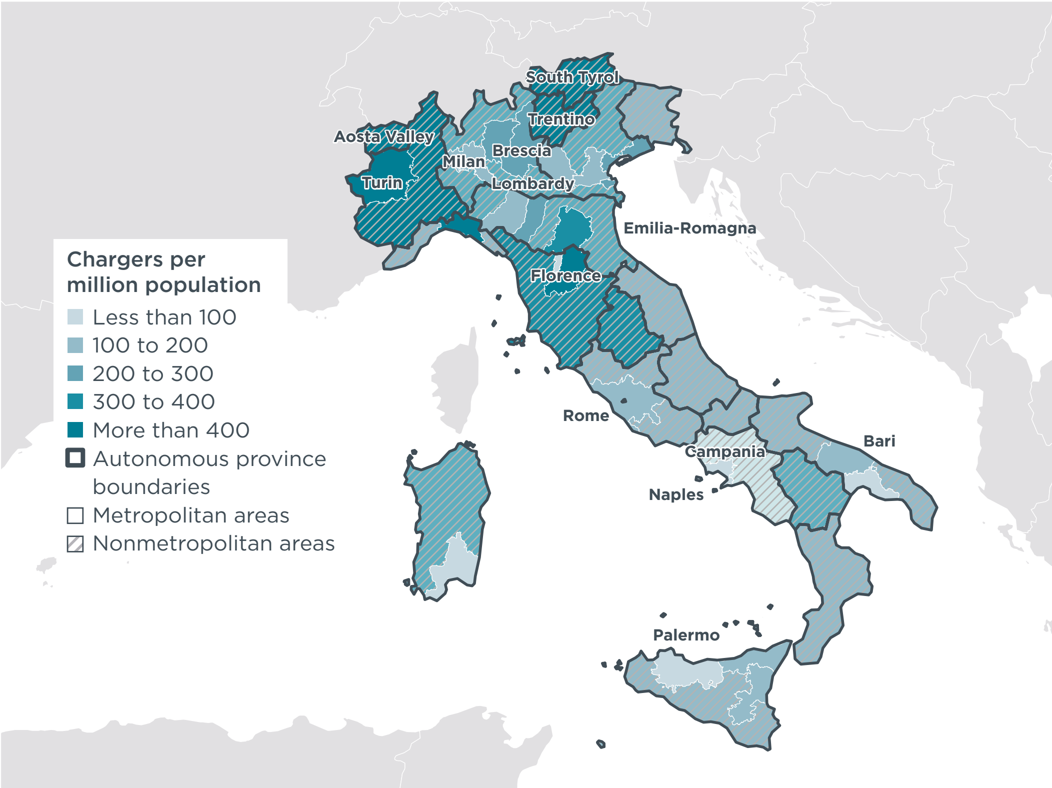

Figure 3. Chargers per million population

The highest degree of coverage is in the north of the country. Among metropolitan areas, Florence has the highest ratio at 723 chargers per million inhabitants with the autonomous provinces of Trento, South Tyrol, and Aosta Valley having 666, 1,286, and 1,871 chargers per million population, respectively. These autonomous province populations are small, partially explaining the high ratio. Additionally, as resort areas they attract tourists who may need charging at their destination.

Vehicle charging infrastructure scenarios

This section explains the approach for modeling charging infrastructure in Italy from now until 2030. The modeling mirrors current charging trends and data and adapts parameters to reflect expected changes in range, vehicle technology, home charging availability, and charging speed. We make estimates for normal speed charging at work, normal public charging, and fast charging for each metropolitan and nonmetropolitan area based on the characteristics of each area.

Overview of methodology

The methodology employed to estimate charging needs is described more fully in other U.S.- and Europe-based studies,[11] and only a brief review of methods is provided here.

11 Michael Nicholas, Dale Hall, and Nic Lutsey, "Quantifying the Electric Vehicle Charging Infrastructure Gap across U.S. Markets" (Washington, D.C.: International Council on Clean Transportation, January 23, 2019), https://theicct.org/publications/charging-gap-US; Michael Nicholas and Nic Lutsey, "Quantifying the Electric Vehicle Charging Infrastructure Gap in the United Kingdom" (Washington, D.C.: International Council on Clean Transportation, August 27, 2020), https://theicct.org/publications/charging-gap-UK-2020; Michael Nicholas and Sandra Wappelhorst, "Regional Charging Infrastructure Requirements in Germany through 2030" (Washington, D.C.: International Council on Clean Transportation, October 21, 2020), https://theicct.org/publications/regional-charging-infra-germany-oct2020; Michael Nicholas and Sandra Wappelhorst, "Spain's Electric Vehicle Infrastructure Challenge: How Many Chargers Will Be Required in 2030?" (Washington, D.C.: International Council on Clean Transportation, January 27, 2021), https://theicct.org/publications/spain-charging-infra-jan2021.

Fast chargers with two ports that cannot be used simultaneously are counted as one charger in our analysis. For Italy, we estimate that for every 100 fast charger ports, only 55 ports can be used at a time, for a fast charger port-to-charger ratio of 1.8-to-1. Results from other studies that use ports as a basis for measurement can be compared to our results only if they incorporate this ratio.

Results for charging are presented in four categories: home, work, public, and fast charging. The categories are grouped by the activity done while charging. The model incorporating the assumptions above is outlined in Figure 4. The blue rectangles represent each step in the model, while the gold rectangles indicate the data and assumptions necessary for each step. The first step defines the number of vehicles to serve and the bottom step is the charger cost estimate by charging category.

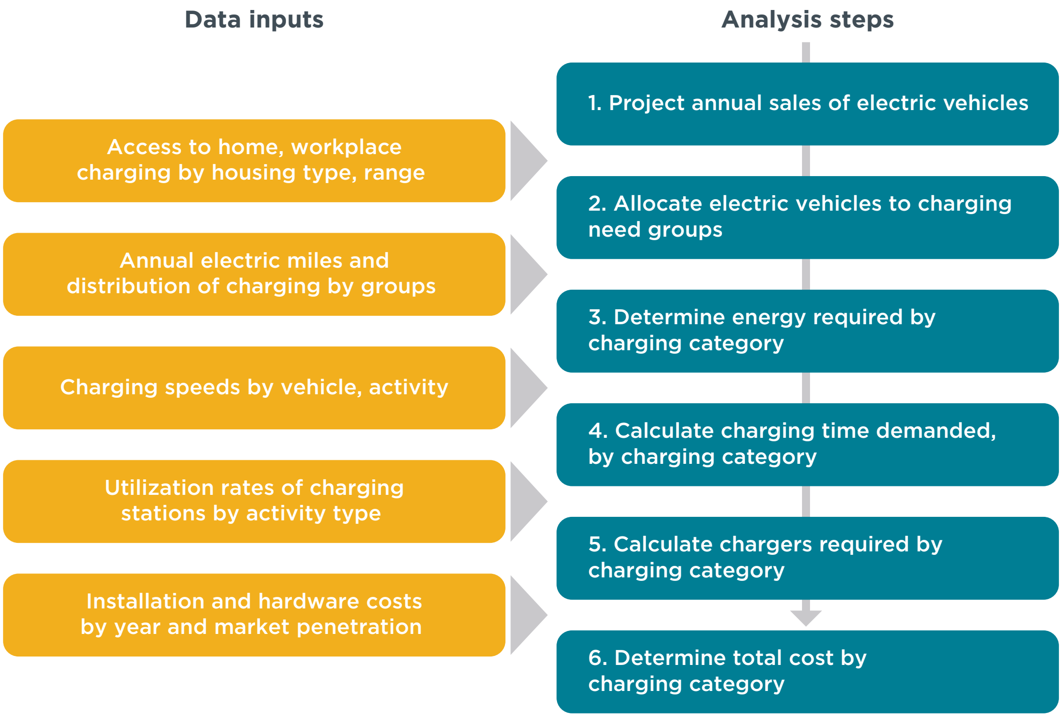

Figure 4. Model to estimate chargers needed to serve electric vehicles

The data inputs are drawn from many sources including commercially available data and other analytical research. Data areas, the variables that depend on these data, and the relevant sources for these data are shown in Table 2.

Table 2. Data sources for key variables

Data area	Variables	Source
Population	Population by NUTS 3 statistical area and future projections	Eurostat [a]
Housing	Number of dwellings in houses and apartments Population by dwelling type	Eurostat [b] Eurostat [c]
Metropolitan area definitions	Definition of metropolitan areas in Italy	Eurostat [d]
Electric vehicle sales by NUTS 3 area	Registrations of new electric vehicles, including battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs)	IHS Markit [e]
Vehicle ownership	Vehicles per capita Vehicle stock by NUTS 2	ACEA [f] Eurostat [g]
Commuting	Number of commuters in Italy Commute mode	Eurostat [h] Istat [i]
Existing charging infrastructure	Counts of charging outlets in Italy	Eco-Movement [j]
Charging infrastructure to electric vehicle relationships	Ratios of electric vehicles to charge point, based on market size and/or electric vehicle share	Nicholas, Hall, & Lutsey [k] Nicholas & Hall [l] Hall & Lutsey [m]
Charging behavior	Observed charging rates of charging for residential, workplace, public, and DC fast chargers	Tal et al. [n] Dodson and Slater [o] Schaufenster Elektromobilität [p]
Vehicle travel	Annual vehicle miles traveled	Odyssee - Mure [q]

Note: NUTS = Nomenclature of territorial units for statistics

[a] Eurostat, "Population on 1 January by Broad Age Group, Sex and NUTS 3 Region," 2020, https://ec.europa.eu/eurostat/web/products-datasets/-/demo_r_pjanaggr3.

[b] Eurostat, "Conventional Dwellings by Occupancy Status, Type of Building and NUTS 3 Region," 2011, https://ec.europa.eu/eurostat/web/products-datasets/-/cens_11dwob_r3.

[c] Eurostat, "Distribution of Population by Degree of Urbanisation, Dwelling Type and Income Group - EU-SILC Survey," 2020, http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ilc_lvho01&lang=en.

[d] Eurostat, "Metropolitan Regions," accessed May 5, 2020, https://ec.europa.eu/eurostat/web/metropolitan-regions/background.

[e] IHS Markit Copyright © IHS Markit, 2020. All rights reserved., "Purchased Dataset on Vehicle Registrations by European NUTS 3 Statistical Areas. Data through December 31, 2020.," 2021.

[f] European Automobile Manufacturers Association, "Vehicles per Capita by Country," accessed June 30, 2020, https://www.acea.be/statistics/tag/category/vehicles-per-capita-by-country.

[g] Eurostat, "Stock of Vehicles by Category and NUTS 2 Regions," 2018, http://ec.europa.eu/eurostat/product?code=tran_r_vehst&language=en&mode=view.

[h] Eurostat, "Employment and Commuting by Sex, Age and NUTS 2 Regions," accessed June 30, 2020, http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=lfst_r_lfe2ecomm&lang=EN.

[i] Italy National Institute of Statistics, "Means of Transport and Daily Travel for Work and Study - Year 2019," 2020, https://www.istat.it/it/files//2020/05/Uso-mezzi-e-spostamenti_Tavole.xlsx.

[j] Eco-Movement, "Purchased Dataset on Charger Locations . Data through December 31, 2020.," 2021.

[l] Michael Nicholas and Dale Hall, "Lessons Learned on Early Electric Vehicle Fast-Charging Deployments" (Washington, D.C.: International Council on Clean Transportation, August 1, 2018), https://theicct.org/publications/fast-charging-lessons-learned.

[m] Dale Hall and Nic Lutsey, "Emerging Best Practices for Electric Vehicle Charging Infrastructure" (Washington, D.C.: International Council on Clean Transportation, October 4, 2017), https://theicct.org/publications/emerging-best-practices-electric-vehicle-charging-infrastructure.

[n] G. Tal, J.H. Lee, and M Nicholas, "Observed Charging Rates in California," Working Paper (University of California, Davis, 2018), https://itspubs.ucdavis.edu/index.php/research/publications/publication-detail/?pub_id=2993.

[o] T. Dodson and S. Slater, "Electric Vehicle Charging Behaviour Study" (Element Energy, 2019), http://www.element-energy.co.uk/wordpress/wp-content/uploads/2019/04/20190329-NG-EV-CHARGING-BEHAVIOUR-STUDY-FINAL-REPORT-V1-EXTERNAL.pdf.

[p] Schaufenster Elektromobilität, "Abschlussbericht der Begleit- und Wirkungsforschung 2017 [Final Report and Impact of Accompanying Reserarch]," 2017, https://www.bridging-it.de/media/download/ep30_abschlussbericht_2017_der_begleit-_und_wirkungsforschung.pdf.

[q] Odyssee - Mure, "Sectoral Profile - Transport," accessed December 14, 2020, https://www.odyssee-mure.eu/publications/efficiency-by-sector/transport/transport-eu.pdf.

Italian electric vehicle market scenarios

Step one in the model is projecting electric vehicle sales as a percentage of passenger car sales. Although Italy's initial electric vehicle uptake is slow, our scenario assumes that Italy catches up to the European average electric vehicle share detailed in another report.[12] The electric vehicle sales (BEV and PHEV) share is modeled as 27% of all new vehicle sales by 2025 and 68% by 2030.

12 Peter Mock and Sonsoles Díaz, "Pathways to Decarbonization: The European Passenger Car Market, 2021–2035" (Washington, D.C.: International Council on Clean Transportation, May 19, 2021), https://theicct.org/publications/decarbonize-EU-PVs-may2021.

Electric and conventional vehicle sales are estimated based on vehicle registrations from IHS Markit, which details registrations at a local level (NUTS 3 resolution).[13] We assume new vehicle registrations will remain at 2019 levels through 2030 to reflect policies against the growth in private passenger car dependence. Further we ignore any slump in sales due to the COVID-19 health crisis in 2020. The number of yearly new electric vehicle registrations rises from approximately 60,000 in 2020 to 520,000 in 2025 and 1.3 million in 2030. BEVs were 56% of electric vehicle sales in 2020, and our scenario assumes the sales share rises to 70% by 2030 with the remaining electric vehicle sales being PHEVs.

We model used car flows from areas of higher new car registrations to areas of lower new car registrations. We use historical vehicle stock per capita to determine how many vehicles should eventually be located by area. If the percentage of average sales per capita exceeds historical stock per capita, new electric vehicles migrate so that stock will equalize after a three-year delay, simulating an average lease term or the length of time a new vehicle is held before sale. In 2020, areas for which electric vehicles were relatively more popular remain more popular in 2021. By 2025, these regional electric vehicle popularity differences disappear and electric vehicle sales as a share of conventional new car sales is common across all of Italy.

Vehicle retirement is assumed to follow vehicle retirement for conventional vehicles.[14] The electric vehicle stock is shown in Figure 5. In 2030, cumulative electric vehicles reach 1.8 million in 2025 and 6.3 million in 2030.

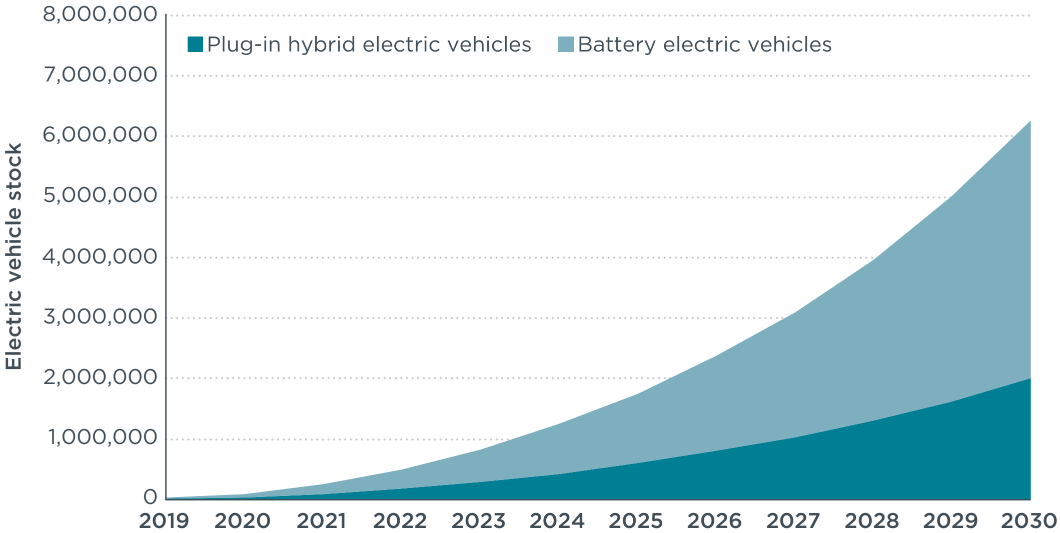

Figure 5. Scenario for electric vehicle stock in Italy up to 2030

These numbers are in line with government electric vehicle stock estimates of 4 million BEVs and 2 million PHEVs on the road in 2030,[15] although this analysis assumes a higher percentage of BEVs at 70% of the electric vehicle market versus the government estimate of 66.7%.

13 IHS Markit Copyright © IHS Markit, 2020, All rights reserved, "Purchased Dataset on Vehicle Registrations by European NUTS 3 Statistical Areas. Data through December 31, 2020.," 2021.

14 ACEA, "ACEA Report: Vehicles in Use – Europe 2019," 2019, https://www.acea.be/uploads/publications/ACEA_Report_Vehicles_in_use-Europe_2019.pdf.

15 Ministry of Infrastructure and Transport, "Integrated National Energy and Climate Plan - Italy," December 2019, https://ec.europa.eu/energy/sites/ener/files/documents/it_final_necp_main_en.pdf.

Allocation of electric vehicles to charging need groups

Step two in the model outlined in Figure 4 is to differentiate charging needs and behavior by vehicle type (BEV/PHEV), commuting status, and availability of overnight charging at or near home. This results in eight charging need groups as shown in Table 3.

Table 3. Charging need groups modeled

Vehicle type	Commuting status	Home charging
BEV	Commuter	Home
BEV	Commuter	No home
BEV	Non-commuter	Home
BEV	Non-commuter	No home
PHEV	Commuter	Home
PHEV	Commuter	No home
PHEV	Non-commuter	Home
PHEV	Non-commuter	No home

Vehicle type is important because BEVs do not have a gasoline backup engine and the battery is larger, both of which prompt more charging than PHEVs. By 2030, 70% of new electric vehicle passenger car registrations are modeled to be BEVs. Commuting status determines whether work charging is used and affects other charging behavior. In Italy 70% of commuters commute by car every day, meaning 59% of all cars are used for commuting in Italy.[16]

The model uses housing type as a proxy for determining if home charging is likely to be available and to determine the size of the charging need groups. There are three categories of housing in Italy as defined by Eurostat: single-dwelling buildings defined as having a private entrance at ground level, two-dwelling structures which may not have a private ground level entrance, and three-or-more-dwelling buildings which include a mix of flats and attached houses.[17] The most recent housing census to provide comprehensive data on the breakdown of households by dwelling structure type in Italy by NUTS 3 dates from 2011.[18] Table 4 estimates the breakdown of vehicles by housing type.[19] Row one shows the percentage of dwellings by type in Italy. Row two shows the vehicle ownership by dwelling type. One-dwelling houses have more cars per household, so the share of cars is larger than the share of dwellings. Row three shows the estimate of the distribution of electric vehicles by dwelling type. As there are no current surveys to estimate this metric in Italy, international examples are used and applied to Italy.[20] In row three, the electric vehicle stock approaches that of conventional vehicles by housing type in row two. By 2030, sales match the distribution in row two, but a time lag exists to transition vehicle stock to conventional vehicle distributions.

16 Italy National Institute of Statistics, "Means of Transport and Daily Travel for Work and Study - Year 2019," 2020, https://www.istat.it/it/files//2020/05/Uso-mezzi-e-spostamenti_Tavole.xlsx.

17 Eurostat, "Conventional Dwellings by Occupancy Status, Type of Building and NUTS 3 Region," 2011, https://ec.europa.eu/eurostat/web/products-datasets/-/cens_11dwob_r3.

18 Eurostat.

19 Eurostat, "Distribution of Population by Degree of Urbanisation, Dwelling Type and Income Group - EU-SILC Survey," 2020, http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ilc_lvho01&lang=en; European Automobile Manufacturers Association, "Vehicles per Capita by Country," accessed June 30, 2020, https://www.acea.be/statistics/tag/category/vehicles-per-capita-by-country.

20 Schaufenster Elektromobilität, "Abschlussbericht der Begleit- und Wirkungsforschung 2017 [Final Report and Impact of Accompanying Reserarch]," 2017, https://www.bridging-it.de/media/download/ep30_abschlussbericht_2017_der_begleit-_und_wirkungsforschung.pdf.

Table 4. Distribution of vehicle stock by vehicle type and building type

	One-dwelling buildings	Two-dwelling buildings	Three-or-more-dwelling buildings
Percentage of dwellings	20%	17%	63%
Conventional passenger vehicle stock by dwelling type in 2020	25%	20%	55%
Electric passenger vehicle stock by dwelling type in 2020	39%	20%	41%
Electric passenger vehicle stock by dwelling type in 2030	28%	20%	52%

In Table 5, housing type is used to estimate home charging availability utilizing international examples[21] and adjusting for the Italy context. The availability of home charging by housing type, called the "home charging availability multiplier" is shown in row one. That availability is multiplied by the vehicle stock in Table 4 in 2020 and 2030 to obtain the charging availability by housing type in rows two and three. The total availability of home charging for each year is listed in the total column.

Table 5. Scenarios for electric vehicle owner housing type and access to home charging

	Electric vehicles in one-dwelling buildings	Electric vehicles in two-dwelling buildings	Electric vehicles in three-or-more-dwelling buildings	Total
Home charging availability multiplier	92%	83%	48%	-
Percentage of total Italian electric vehicle stock with home charging available in 2020	36%	17%	20%	72%
Percentage of total Italian electric vehicle stock with home charging available in 2030	26%	16%	25%	67%

Overall, 67% of electric car owners are assumed to have home charging available in 2030. Although the home charging availability in three-or-more-dwelling buildings is listed as 48%, this represents a continued large investment in home charging and near-home charging, as little exists today. This will require funding, utility involvement, and building standards incorporating charging access at or near home.

Energy required by charging category

The third step in the model is to determine the total energy that electric vehicles will need and assign them to the home, work, public, or fast charger categories. Energy needs for the vehicle stock are apportioned according to breakdowns in Table 6 which approximate the percentages of a 2020 analysis of electric vehicle drivers. These classifications result in eight basic charging need groups.

21 G. Tal, J.H. Lee, and M Nicholas, "Observed Charging Rates in California," Working Paper (University of California, Davis, 2018), https://itspubs.ucdavis.edu/index.php/research/publications/publication-detail/?pub_id=2993; T. Dodson and S. Slater, "Electric Vehicle Charging Behaviour Study" (Element Energy, 2019), http://www.element-energy.co.uk/wordpress/wp-content/uploads/2019/04/20190329-NG-EV-CHARGING-BEHAVIOUR-STUDY-FINAL-REPORT-V1-EXTERNAL.pdf; Schaufenster Elektromobilität, "Abschlussbericht der Begleit- und Wirkungsforschung 2017 [Final Report and Impact of Accompanying Reserarch]."

Table 6. Energy breakdown by location of charging

Vehicle type	Commuting status	Home charging	Home energy	Work energy	Public energy	DCFC energy	Vehicle kilometers traveled per year	Percent vehicle kilometers traveled that are electric	Vehicle kilometers traveled per year that are electric	Percent of vehicle stock in 2030
BEV	Commuter	Home	75%	15%	5%	5%	12575	100%	12575	32%
BEV	Commuter	No home	0%	55%	20%	25%	12575	100%	12575	15%
BEV	Non-Commuter	Home	85%	0%	5%	10%	7105	100%	7105	19%
BEV	Non-Commuter	No home	0%	0%	40%	60%	7105	100%	7105	9%
PHEV	Commuter	Home	70%	25%	5%	0%	12575	70%	8803	10%
PHEV	Commuter	No home	0%	65%	35%	0%	12575	40%	5030	5%
PHEV	Non-Commuter	Home	90%	0%	10%	0%	7105	50%	3552	6%
PHEV	Non-Commuter	No home	0%	0%	100%	0%	7105	10%	710	3%

Notes: BEV = Battery electric vehicle; PHEV = plug-in hybrid electric vehicle; DCFC = direct current fast charger

The kilometers indicated above are converted into energy needed using efficiency numbers from representative vehicles. BEVs and PHEVs have efficiencies of .17 kilowatt-hours per kilometer and .18 kilowatt-hours per kilometer, respectively, slightly higher than in other countries due to Italy's preference for smaller vehicles. Efficiency is assumed to remain constant over the study period as efficiency improvements will be negated by an assumed increase in vehicle size and weight compared to today's vehicles.

The early market is modeled to have a higher prevalence of commuters than the later market. In 2021, the percentage of electric vehicles used for commuting is estimated at 70% and is modeled to reduce to 62% by 2030, which approaches the current percentage of all cars used for commuting. The share of electric vehicle stock used for commuting in 2030 is 59%. This drop in the number of vehicles used for commuting reduces the relative need for workplace charging.

Charging hours and charger power

The fourth step in the model is to estimate the average charger power and the average number of hours that a charger is actively charging per day in each category. We do not use the peak capacity of a charger, but rather the power delivered to the vehicle. For example, a PHEV typically draws 3.4 kW regardless of the power of the charger it plugs into. The average rate of power draw for normal chargers is estimated at 7 kW for BEVs and 3.4 kW for PHEVs. For fast charging, the average rate per charger increases by year starting at 35 kW in 2021 and 80 kW in 2030. Higher power is possible, but power sharing, a tapering charge rate at the end of a charge, and a variety of car capabilities suggest a lower average power than the charger can provide.

Charger utilization and number of chargers

The fifth step in the charging infrastructure model shown in Figure 4 is to determine the number of chargers. Charger output power in kW and hours of active power draw per day are used to estimate kWh per day and per year, per charger. The kWh determined above for the entire electric vehicle market is divided by this average utilization to get the number of outlets needed.

The model results suggest increasing utilization in hours per day, with increasing electric vehicle penetration, as shown in other studies.[22] As the market is nascent in Italy, with few areas of high penetration, other European examples are used to forecast the utilization trend.[23] The average daily utilization in hours of active power draw for normal public charging is estimated by the following equation:

$$\text{Average daily hours of usage} = 0.832 \times \text{LN (EV per million population)} - 4.902$$

This equation was derived from the inspection of Italian charger data and comparison to benchmarked studies elsewhere.[24] Using a natural log (LN) function bounds the utilization at higher electric vehicle penetrations.

Workplace charging utilization is modeled to remain constant at 6 hours per day on weekdays throughout the study period. Since chargers are less likely to be used on weekends, the average hours of use per day falls to 4.3 hours.

Fast charging is assumed to follow a similar trend to normal charging such that average usage in hours climbs with market development. Since BEVs are the primary users of fast charging, the utilization is a function of BEV penetration. There are two equations used for fast chargers, one for metropolitan areas and one for nonmetropolitan areas, which are expected to have lower utilization based on lower population density.[25] The equations used to define this relationship are:

For metropolitan areas,

$$\text{Average daily hours of usage} = 0.593 \times \text{LN (BEVs per million population)} - 2.733$$

For nonmetropolitan areas,

$$\text{Average daily hours of usage} = 0.483 \times \text{LN (BEVs per million population)} - 3.021$$

Again, these are averages across the entire year and across a metropolitan area; some chargers will have much higher utilization. Additionally, certain days of the week will have higher usage than the average and some lower. Finally, this utilization only represents the hours used by private passenger cars. Other usage by ride-hailing and light commercial vehicles is not reflected.

The number of chargers in the model is determined using the variables of charger power and utilization defined above. The estimated output per charger in a year is equal to the utilization in hours of power draw × charger output (kW) × 365.25 days per year.

Lastly, home charging and highway fast chargers are calculated in another way. Home charging depends on the housing type of vehicle owners as described above. Highway fast charger counts rely on outside analyses and are added at a rate of one fast charger for every 1,500 BEVs in metropolitan areas and one fast charger for every 1,000 vehicles in nonmetropolitan areas.[26] These chargers are in addition to the fast chargers detailed above and are assumed to have power available over 150 kW.

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22 Michael Nicholas, Dale Hall, and Nic Lutsey, "Quantifying the Electric Vehicle Charging Infrastructure Gap across U.S. Markets" (Washington, D.C.: International Council on Clean Transportation, January 23, 2019), https://theicct.org/publications/charging-gap-US; M Nicholas and S. Wappelhorst, "Quantifying Germany's Electric Vehicle Charging Infrastructure Gap through 2030" (The International Council on Clean Transportation, forthcoming 2020).

23 Michael Nicholas and Nic Lutsey, "Quantifying the Electric Vehicle Charging Infrastructure Gap in the United Kingdom" (Washington, D.C.: International Council on Clean Transportation, August 27, 2020), https://theicct.org/publications/charging-gap-UK-2020.

24 Nicholas, Hall, and Lutsey, *Quantifying the Electric Vehicle Charging Infrastructure Gap across U.S. Markets*.

25 Nicholas and Wappelhorst, *Regional Charging Infrastructure Requirements in Germany through 2030*.

26 P. Jochem, E. Szimbac, and M. Reuter-Oppermann, "How Many Fast-Charging Stations Do We Need along European Highways?" *Transportation Research Part D.*, 2019, 120–29, https://www.sciencedirect.com/science/article/pii/S1361920919300215?via%3Dihub.

Summary of data inputs

The inputs for the future scenarios described above are summarized in Table 7. Each of these inputs affects the number of chargers.

Table 7. Summary of data inputs and assumptions for the charging infrastructure model

	2021	2030
Electric vehicle stock	89,092	6,300,000
Market share of electric new car registrations	4.0%	68%
Portion of BEV and PHEV new car registrations	54% BEV, 46% PHEV	75% BEV, 25% PHEV
Dwelling type where electric cars reside	One dwelling = 39% Two dwelling =20% Three or more dwelling = 41%	One dwelling = 28% Two dwelling = 20% Three or more dwelling = 52%
Home charging availability by dwelling type	One dwelling = 92% availability Two dwelling = 83% availability Three or more dwelling = 48% availability	
Commuter share of electric new car registrations	70%	59%
BEV average charging acceptance rate for normal charging	7 kW	
PHEV average charging acceptance rate	3.4 kW	
Workplace charging daily utilization in hours	6 on weekdays, 0 on weekends	
Public charging daily utilization in hours	Average daily hours = 0.832 * LN (electric vehicles per million population) – 4.902	
Fast charging daily utilization in hours for metropolitan areas	Average daily hours = 0.593 * LN (BEV per million population) – 2.733	
Fast charging daily utilization in hours for nonmetropolitan areas	Average daily hours = 0.483 * LN (BEV per million population) – 3.021	
Fast charging outlet to charger ratio	1.8:1	—
Fast charging kW acceptance per charger	35 kW	80 kW
BEVs per high power highway fast charger	1,500 in metropolitan areas, 1,000 in nonmetropolitan areas	
Electric vehicle electricity consumption	BEVs 0.173 kWh/km, PHEVs 0.182 kWh/km	
Average vehicle kilometers per year	Commuter 12,600 km, noncommuter 7,100 km	

Note: BEV = Battery electric vehicle; PHEV = plug-in hybrid electric vehicle; DCFC = direct current fast charger; LN = natural log

Cost inputs

This section details the cost inputs and assumptions for the charger scenario in this report (step 6, Figure 4). Costs are taken from estimates completed by Ricardo for the European commission.[27] The costs estimates are shown in Table 8. The study identifies costs for 5 categories of chargers: 7 kW, 22 kW, 50 kW, 150 kW, and 350 kW. Costs for power levels not specified in the Ricardo report are interpolated or estimated using a German study and are shown in gray cells.[28] There are four cost categories: grid connection, installation, planning, and hardware. We assume that the grid connection cost in the Italian case is intended to pay for grid maintenance and is borne by the customer or rate payers in general. Installation is the cost for electricians and related civil work, planning is the cost to design an installation, and hardware is the cost of the charger unit itself. Total costs for a charger and installation in 2020 are shown in the last column.

27 Ricardo et al., "Evaluation of the Directive on the Deployment of Alternative Fuels Infrastructure as Cited in: Proposal for a Regulation of the European Parliment and the of the Council on the Deployment of Alternative Fuels Infrastructure, and Repealing Directive 2014/94/EU of the European Parliament and of the Council," July 14, 2021, https://ec.europa.eu/info/sites/default/files/revision_of_the_directive_on_deployment_of_the_alternative_fuels_infrastructure_with_annex_0.pdf.

28 National Platform on Electromobility, "Charging Infrastructure for Electric Vehicles in Germany," 2015, http://leonardo-energy.pl/wp-content/uploads/2016/11/Technical-prediction_en_Document_3_Charging-Infrastructure-for-Electric-Vehicles.pdf.

Table 8. Initial cost assumptions for 2020

Type	Capacity (kW)	Grid connection cost	Planning	Installation	Hardware	Total
Home charging type F outlet	3.7	€500	€0	€500	€0	€1,000
Home charging	3.7	€500	€0	€500	€500	€1,500
Home charging	7 or 9	€500	€0	€833	€667	€2,000
Normal charger	7, 11 or 22	€1,250	€1,000	€2,052	€2,137	€6,439
Normal workplace charger	7, 11 or 22	€1,250	€900	€1,847	€2,137	€6,134
Normal public charger	7, 11 or 22	€1,250	€1,100	€2,257	€2,137	€6,744
Fast charging	50	€5,000	€1,500	€16,875	€28,125	€51,500
Fast charging	150	€15,000	€4,500	€20,000	€70,000	€109,500
Fast charging	350	€35,000	€10,500	€60,000	€170,000	€275,500

Note: Gray cells indicate interpolation from values in the report. Home charging costs are adapted from public charging costs

Fast charging costs are linearly interpolated based on power. Workplace charging installation and planning costs are 10% lower than average normal charger costs and public chargers are 10% higher than average installation and planning costs due to differences in site characteristics and coordination difficulties, consistent with other studies.[29] If public chargers are used for work purposes, they are categorized as public for the cost scenarios. Our scenario categorizes 33% of workplace charging as publicly accessible.[30] Hardware costs are assumed to drop 3% per year until 2030.

Economies of scale are modeled to reduce some costs in relation to the number of chargers per site including the grid connection, installation, and planning costs. The baseline costs in Table 8 are assumed to reflect the per-charger costs of a two-charger site with costs for a one-charger site at 125% of these costs, costs at 3–5-charger sites at 90% of these costs, and 75% at sites with 6 or more chargers per site.[31]

The proportion of fast chargers at each site size holds steady at 5%, 13%, 15%, and 67% for all years up through 2030. The number of normal chargers per site, however, is assumed to be a function of the number of electric vehicles per million population. As areas have higher electric vehicles per million population, the proportion of sites with 6 or more chargers per site increases. Because the electric vehicle and charging infrastructure in Italy is in its early stages, the relationship modeled relies on other studies.[32] The relationship between electric vehicle penetration and site size is shown in Figure 6.

29 Michael Nicholas, "Estimating Electric Vehicle Charging Infrastructure Costs across Major U.S. Metropolitan Areas" (Washington, D.C.: International Council on Clean Transportation, August 12, 2019), https://theicct.org/publications/charging-cost-US.

30 G. Tal, J.H. Lee, and M Nicholas, "Observed Charging Rates in California," Working Paper (University of California, Davis, 2018), https://itspubs.ucdavis.edu/index.php/research/publications/publication-detail/?pub_id=2993.

31 electric power research institute, "Electric Vehicle Supply Equipment Installed Cost Analysis," 2013, https://www.epri.com/research/products/000000003002000577.

32 Michael Nicholas, "Estimating Electric Vehicle Charging Infrastructure Costs across Major U.S. Metropolitan Areas" (Washington, D.C.: International Council on Clean Transportation, August 12, 2019), https://theicct.org/publications/charging-cost-US.

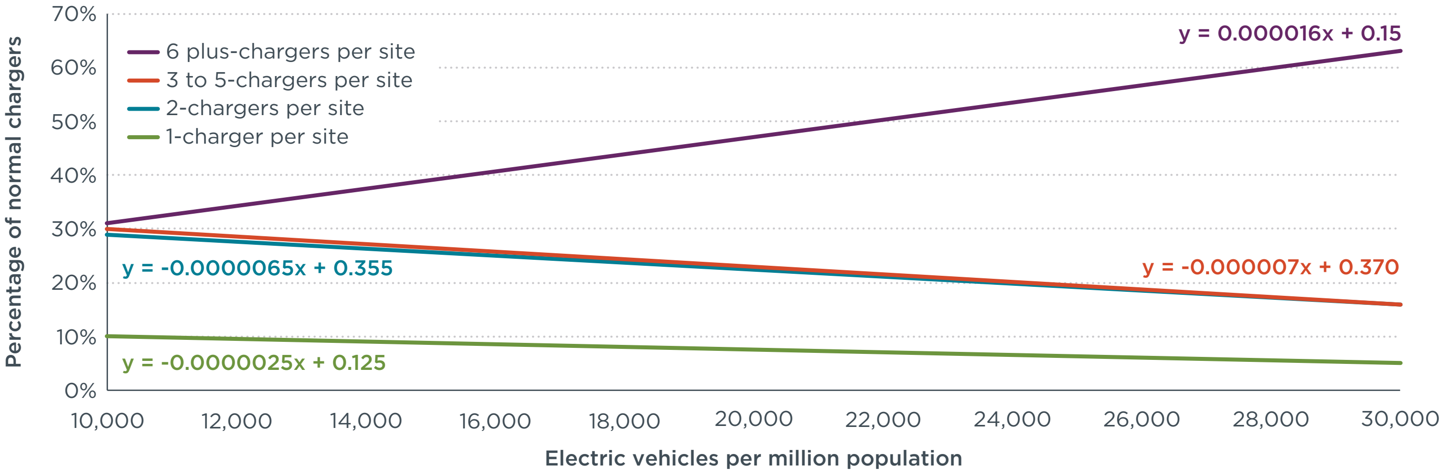

Figure 6. Percentage of public normal chargers by site size as a function of electric vehicles per million population

Vehicle penetration below 10,000 electric vehicles per million population or above 30,000 are assigned the site size ratios nearest those values. Because of the continually increasing market size in Italy, the average cost per charger declines steadily. By 2025 the countrywide average reaches 30,000 electric vehicles per million population, but each region reaches this threshold in different years.

Fast chargers need to be further disaggregated into 50 kW, 150 kW and 350 kW buckets to determine costs. In 2021 350 kW fast chargers represent 18% of the chargers to be installed with the remainder split evenly between 50 kW and 150 kW. By 2030, 350 kW fast chargers become 38% of the market with the remainder evenly split between 50 kW and 150 kW. As stated previously, there is infinite variation in how site power and charger power can be combined and the ratios above are primarily meant to capture the average cost elements.

Home charging assumptions

Table 9 details the home charging availability by power among those who have home charging. The type F wall outlet is a household outlet appropriate for use with the convenience charger that comes with the car. The 3.7 kW and 7–9 kW chargers are permanently installed. PHEVs with a smaller battery are more likely to use a wall outlet or lower power charger. BEVs are more likely to require higher power. The type of dwelling also affects the availability of charging in our scenario, with apartments having less access to wall outlets, but also less access to 7–9 kW chargers.

Table 9. Home charger type by vehicle and dwelling characteristics

Vehicle type	Dwelling type	Home charger type		
		Type F wall outlet 3.7 kW	3.7 kW charger	7–9 kW charger
PHEV	1 dwelling	70%	29%	1%
	2 dwelling	70%	29%	1%
	Apartment	20%	70%	10%
BEV	1 dwelling	20%	40%	40%
	2 dwelling	20%	40%	40%
	Apartment	10%	70%	20%

The ratios above may change based on many factors. For example, wall outlets may be less used if installation of a dedicated unit is low-cost and easy. There are encouraging programs that make installing a home charger more likely. Some utilities in Italy will install a home charger and because of this, coordination for necessary grid upgrades may be easier, suggesting that more permanent chargers with potentially higher power can be expected.[33] Additionally, smart charging coordinated by the utility may be better able to utilize existing grid capacity and avoid costly upgrades.

Home charging cost is estimated by the number of home chargers defined in Table 5 multiplied by the costs in Table 8. Apartment installation is assumed to be 1.65 times more expensive than at a one-dwelling or two-dwelling structure.[34] The standard home panel capacity in Italy is approximately 3 kW. Adding a car charger can take another 3.7 kW–9 kW. Often 6 kW of total home power can be used without any physical upgrades, with only a surcharge on one's bill for the extra capacity. Requesting more can require physical upgrades to the utility lines or transformers. Because of this, 3.7 kW is more prevalent in our scenario even though higher power may be desired by the customer.

Evolution of charging over time

As charging conditions evolve, the number of vehicles per charger changes from 2021 to 2030. Increasing utilization and increasing power decrease the number of chargers necessary in the future despite some increase in the percentage of drivers with no overnight home charging. Figure 7 shows two ratios over time, one for electric vehicles per normal work and public charger, in purple, and one for BEVs per fast charger, in red.

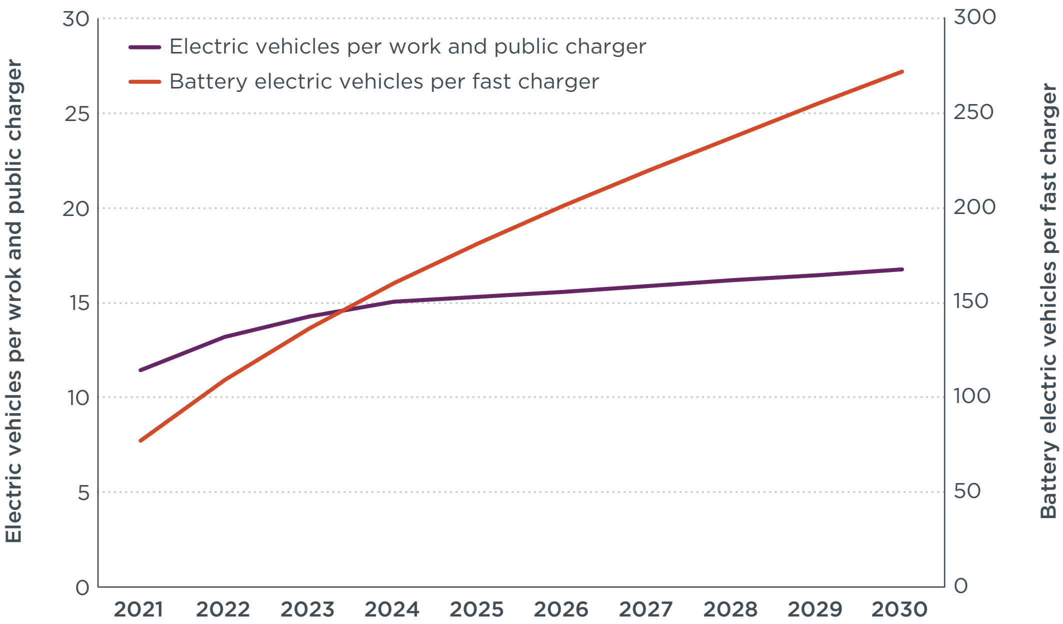

Figure 7. Electric vehicles per work and public charger and battery electric vehicles supported per fast charger

The figure shows that for normal charging at work and public locations, electric vehicles per charger increases from 11 in 2021 to 17 in 2030. For fast charging, BEVs per charger increases from 80 in 2021 to more than 250 in 2030. The ratios reflect that in an early market, geographic coverage is more important than utilization, but as desired coverage is achieved, capacity is added to relieve congestion at popular locations. These ratios

33 Enel, "OpenCharge: Enel X and Enel Energias Electric Vehicle Charging Solution," 2021, https://www.enel.com/media/explore/search-press-releases/press/2021/04/open-charge-enel-x-and-enel-energias-electric-vehicle-charging-solution-.

34 Michael Nicholas, "Estimating Electric Vehicle Charging Infrastructure Costs across Major U.S. Metropolitan Areas" (Washington, D.C.: International Council on Clean Transportation, August 12, 2019), https://theicct.org/publications/charging-cost-US.

vary by metropolitan area. The increasing utilization suggests an improving business case for charger installation as the market develops.

Results

Italy needs 123,000 away-from-home chargers by 2025 and 386,000 chargers by 2030. This section provides an overview of the results. Comparisons are made among metropolitan areas and between metropolitan and nonmetropolitan areas.

Figure 8 depicts the needed electric vehicle charger counts for 2025 and 2030 in the top 10 metropolitan or nonmetropolitan areas by population. The number of chargers is shown on the vertical axis among four categories of chargers. Existing charging by location in 2020 is shown as a gray bar. For 2025 and 2030, workplace, public, and fast charger needs are shown separately. The height of the stacked bars represents the total number of chargers needed in 2025 or 2030.

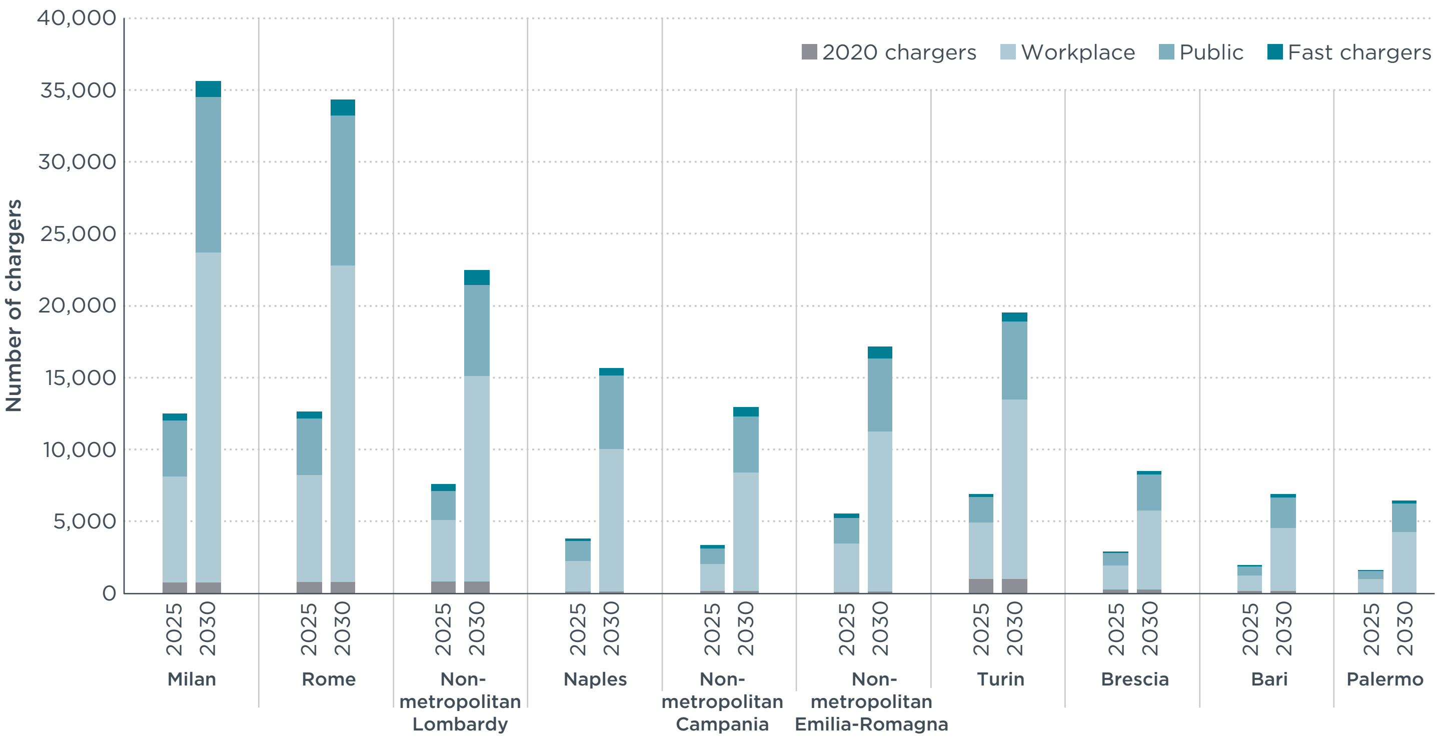

Figure 8. Chargers existing in 2020 versus chargers needed by 2025 and 2030 for selected metropolitan and nonmetropolitan areas

Exact numbers can be found in the Appendix for precise comparison. Although the metropolitan areas and provinces are ordered by population, some areas with less population have greater needs due to higher vehicle stock and home charging availability differences. Turin, for example, has a comparatively high passenger car stock per capita and high car sales, but ranks 7th lowest in terms of home charging availability among areas studied. Nonmetropolitan Campania by contrast has low new car sales, and higher home charging availability. In general, nonmetropolitan areas will need fewer chargers per vehicle due to the increased availability of home charging. The number of workplace chargers exceeds the number of public chargers due to higher expected demand for charging at work (because of the high car commuting rate), which demonstrates the importance of charging at or near centers of employment. However, much of the charging done while at work may be in public garages or other locations available to the general public, so there will be a sizable number of publicly available chargers classified as workplace above. Finally, some public chargers are used in the daytime by the public and at night by nearby residents. These chargers are classified as public due to their daytime usage pattern.

Table 10 summarizes the overall charging infrastructure needs in Italy for 2025 and 2030, including overall results for the metropolitan and nonmetropolitan areas and comparisons to chargers installed through 2020. This analysis indicates that total chargers in Italy must increase from 14,000 to 123,000 by 2025. To meet the electric vehicle goals through 2030, 386,000 chargers will be needed. Nine times more charging will be needed in 2025 than existed in 2020, and 29 times more charging will be needed by 2030. The annual growth rate in charging to reach these targets is 45% from 2020 to 2025 and 36% from 2020 to 2030.

Table 10. Summary of Italy charging infrastructure needs

		68% electric vehicle share in 2030		
	Year	**Metropolitan areas**	**Non-metropolitan areas**	**Italy overall**
Total non-home chargers (public, workplace, fast)	**2019**	5,830	7,936	13,766
	2025	66,999	58,921	125,920
	2030	199,463	194,133	393,595
Electric vehicle stock	**2025**	948,884	882,842	1,831,726
	2030	3,075,845	3,253,836	6,329,681
Projected future charging needs compared to 2020	**2025**	11.5	7.4	9.1
	2030	34.2	24.5	28.6
2020 as percentage of future chargers needed	**2025**	9%	13%	11%
	2030	3%	4%	3%
Annual increase in chargers from 2019 to meet 2025 and 2030 needs	**2025**	50%	40%	45%
	2030	38%	34%	36%

Figure 9 shows the public charging infrastructure in place in 2020 as a percentage of the chargers needed by 2025 with a 68% sales share of electric passenger cars in each metropolitan area by 2030. The remaining nonmetropolitan areas are defined by the NUTS 2 statistical boundary. The national average charging in place in 2020 is 11% of what is needed in 2025, and 3% of what is needed by 2030. The figure shows that some areas in 2020 had less than 5% of the needed charging in 2025, while others had more than 20%. The colors indicate the charging level as a percentage of charging installed as of the end of 2020 that will be needed by 2025. For example, if there are 100 chargers installed in 2020 but 1,000 are needed by 2025, this would be at a 10% level. Darker red colors indicate a larger charging gap (the difference between the charging level and charging needed in 2025) than lighter colors.

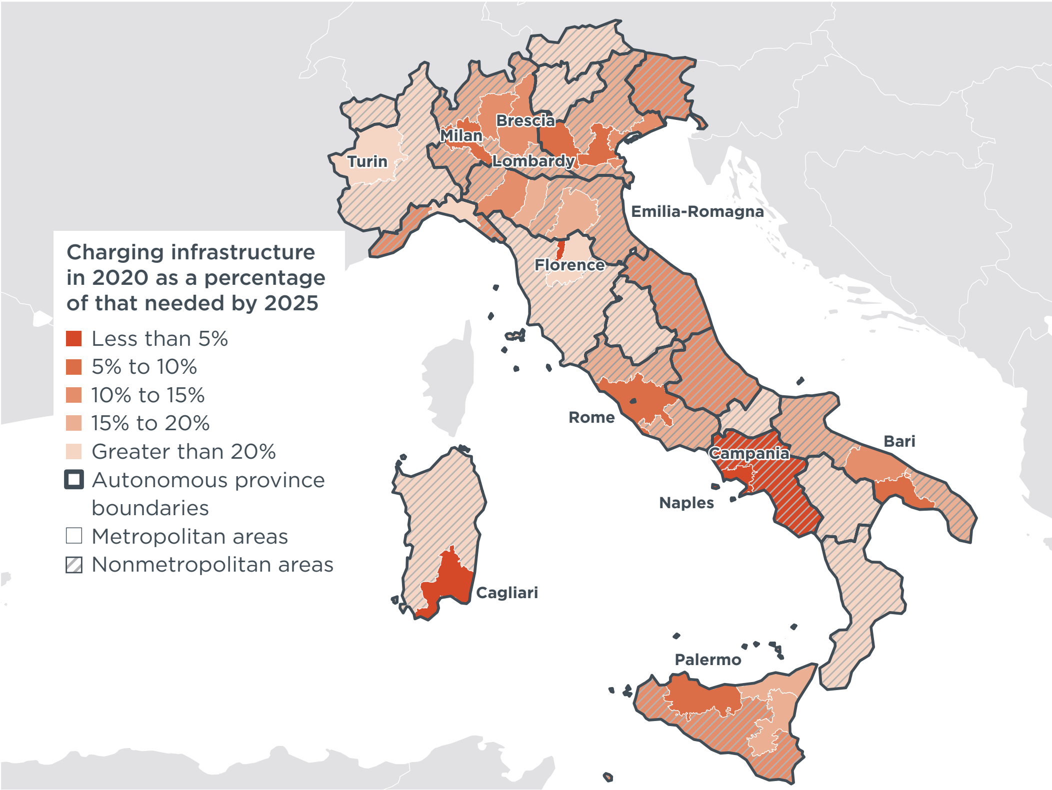

Figure 9. Percent of non-home charging infrastructure installed as of 2020 that will be needed by 2025

Figure 9 shows that areas in the south have a larger non-home charging gap than areas in the north. Metropolitan areas have a larger gap than nonmetropolitan areas. This is partly due to more access to home charging outside of metropolitan areas. The largest gaps exist in Naples, Cagliari, and nonmetropolitan Campania. Although nonmetropolitan areas have lower non-home charging gaps, home charging is proportionally more important, suggesting that policy efforts to assure home charging are especially important in these areas.

Sensitivity Analysis

The main scenario above and the division of energy displayed in Table 6 is a likely scenario based on available data and trends. However, depending on factors such as home charging access and charging behavior, there are other possible paths to filling future charging needs. In order to explore these pathways, a sensitivity analysis is performed which varies home charging availability, usage of workplace charging, and availability of daytime charging, which may be desirable to directly use excess solar power for charging.

The scenarios in Figure 10 show the percentage increase or decrease in the number of chargers compared to the base scenario which has a 67% availability of overnight home or near-home charging. There are four categories: home chargers, combined workplace and public normal chargers, fast chargers, and all non-home chargers (workplace, public, and fast chargers). For example, in the first row, home charging availability is increased such that 92% of drivers can charge overnight at or near their homes, similar to the access that single-dwelling homes have. This corresponds to a decrease in the number of workplace, public and fast chargers.

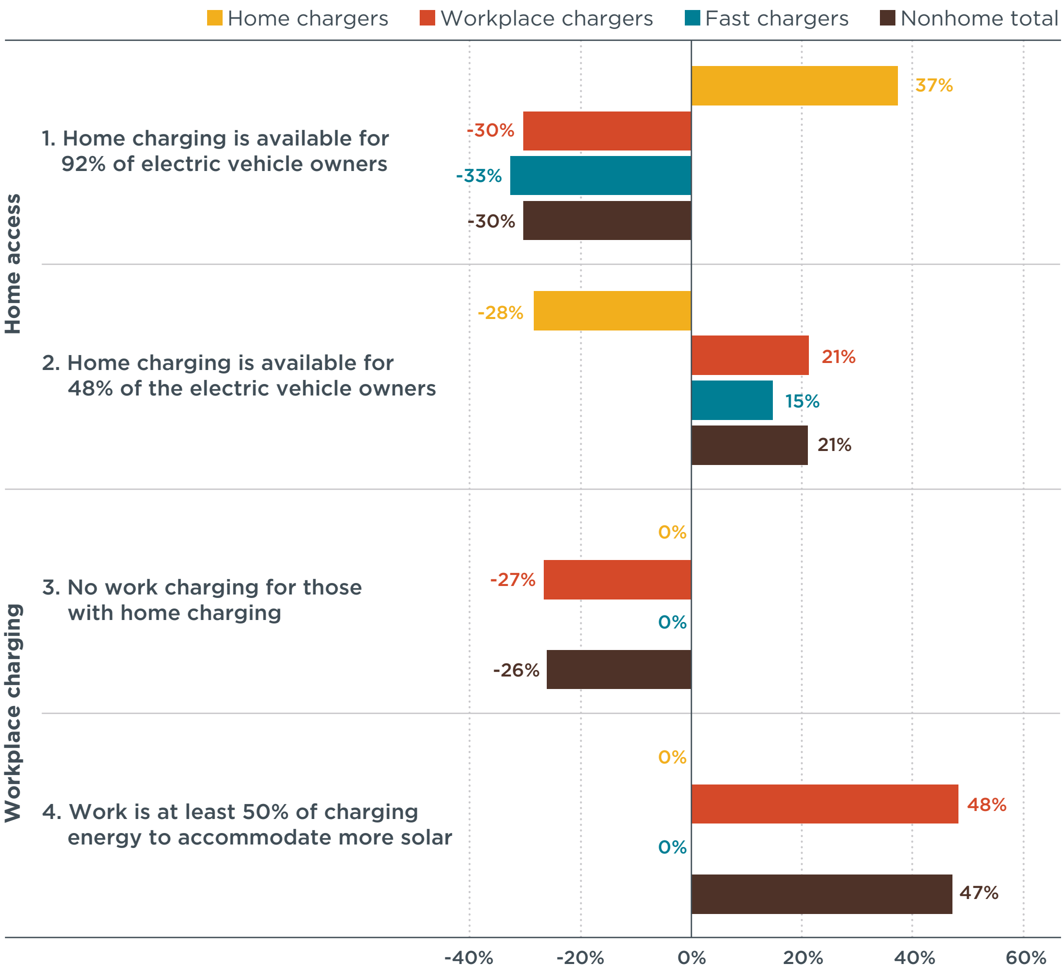

Figure 10. Sensitivity analysis with different charging availability and behavior

The sensitivity analyses reveal a few insights. First, home charging has a large effect on the need for public charging. Reaching 92% home charging access in sensitivity case 1 or even the 67% access to home charging in the base scenario will require large investments and programs to encourage home charging. Without these investments, the 48% home access in sensitivity case 2 is a distinct possibility and an increase in workplace, public, and fast charging would be required to compensate.

Providing only workplace charging for those with no home charging, as demonstrated in case 3, would decrease the need for workplace charging. But in a future where workplace charging is encouraged regardless of home access in order to access solar power generation as in case 4, large increases in workplace charging would be needed. Finally, the combined scenarios show the effect of multiple strategies.

Cost analysis

Costs are estimated for new chargers needed to support an additional 6.2 million vehicle stock from 2021 to 2030. Cost assumptions and methods are detailed in the cost inputs section above. Costs are separated into cost for home chargers and non-home chargers including work, public, and fast charging. Figure 11 shows the yearly costs for non-home chargers on the left, and for home chargers on the right. In 2021, the cost for all non-home charging is projected to require €160 million, while home charging for the same year requires €200 million. By 2030, annual non-home costs rise to over €540 million while home charging climbs to €1.5 billion. The line in the left figure represents the cost per electric vehicle sold in the same year as the annual cost estimate and corresponds to the right axis.

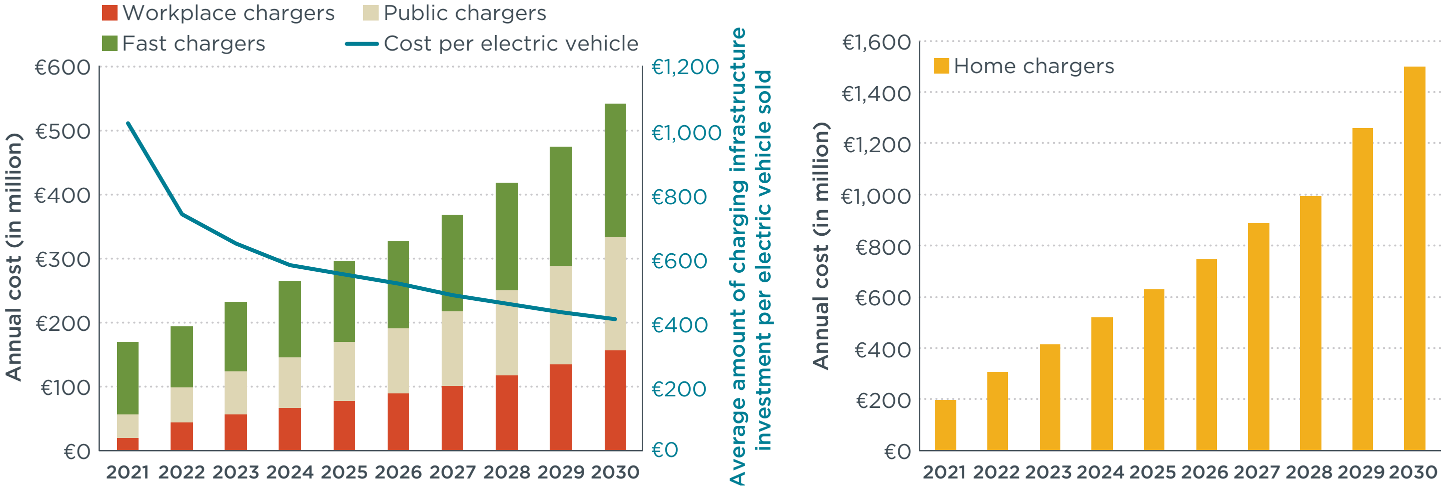

Figure 11. Yearly cost for non-home chargers (left) and home chargers (right)

In 2021 non-home charging is 46% of all charger costs, but in 2030 non-home charging only represents 27% of charger costs. This is due to more expensive home charging in apartments as apartment dwellers are more likely to buy electric vehicles, and due to better utilization of public charging. The cost per non-home charger declines every year primarily due to higher utilization of public chargers, but also lower hardware costs in the future. Table 11 summarizes the total number of chargers and the total costs by category with the average costs in the final column.

Table 11. Summary of new chargers needed between 2021 and 2030 with associated costs

Charging category	Chargers to be installed	Total 2021–2030 cost (billion euro)	Average 2021–2030 cost per charger
Home chargers	4,143,615	€7.5	€1,799
Work chargers	168,175	€0.8	€4,711
Public chargers	196,938	€1.1	€5,552
Fast chargers	14,844	€1.3	€89,841
All chargers	4,523,572	€10.7	€2,359

Government programs for public charging infrastructure

The analysis shows that public charging infrastructure requirements will be significant in Italy until 2030. We find similar results in France,[35] Germany,[36] and the United Kingdom[37] which together with Italy formed the top four markets in Europe as measured by new passenger car registrations in 2020.[38] This section gives examples of charging programs in these countries from which Italy can draw lessons.

35 Marie Rajon Bernard, Dale Hall, and Nic Lutsey, "Charging infrastructure to support the electric mobility transition in France" (Washington, D.C.: International Council on Clean Transportation, November 2021), https://theicct.org/publications/france-evs-infrastructure-transition-nov21.

36 Michael Nicholas and Sandra Wappelhorst, "Regional Charging Infrastructure Requirements in Germany through 2030" (Washington, D.C.: International Council on Clean Transportation, October 21, 2020), https://theicct.org/publications/regional-charging-infra-germany-oct2020.

37 Michael Nicholas and Nic Lutsey, "Quantifying the Electric Vehicle Charging Infrastructure Gap in the United Kingdom" (Washington, D.C.: International Council on Clean Transportation, August 27, 2020), https://theicct.org/publications/charging-gap-UK-2020.

38 Sandra Wappelhorst, Uwe Tietge, Georg Bieker, and Peter Mock. "Europe's CO_2 emission performance standards for new passenger cars: Lessons from 2020 and future prospects" (Washington, D.C.: International Council on Clean Transportation, September 2021), https://theicct.org/publications/eu-ev-pv-co2-emission-performance-sept21.

The extension of the charging infrastructure network will be key to meeting the demand of a growing electric passenger car stock. Looking at past development of the public charging infrastructure network and comparing Italy with Germany, France, and the United Kingdom, Italy is lagging these other leading European passenger car markets.[39] While the ramp-up of total public charging points started in France, Germany, and the United Kingdom in 2014 and 2015, this only happened in Italy in 2018 (Figure 12, left). We find a similar pattern if we look at charging infrastructure deployment per capita (Figure 12, right).

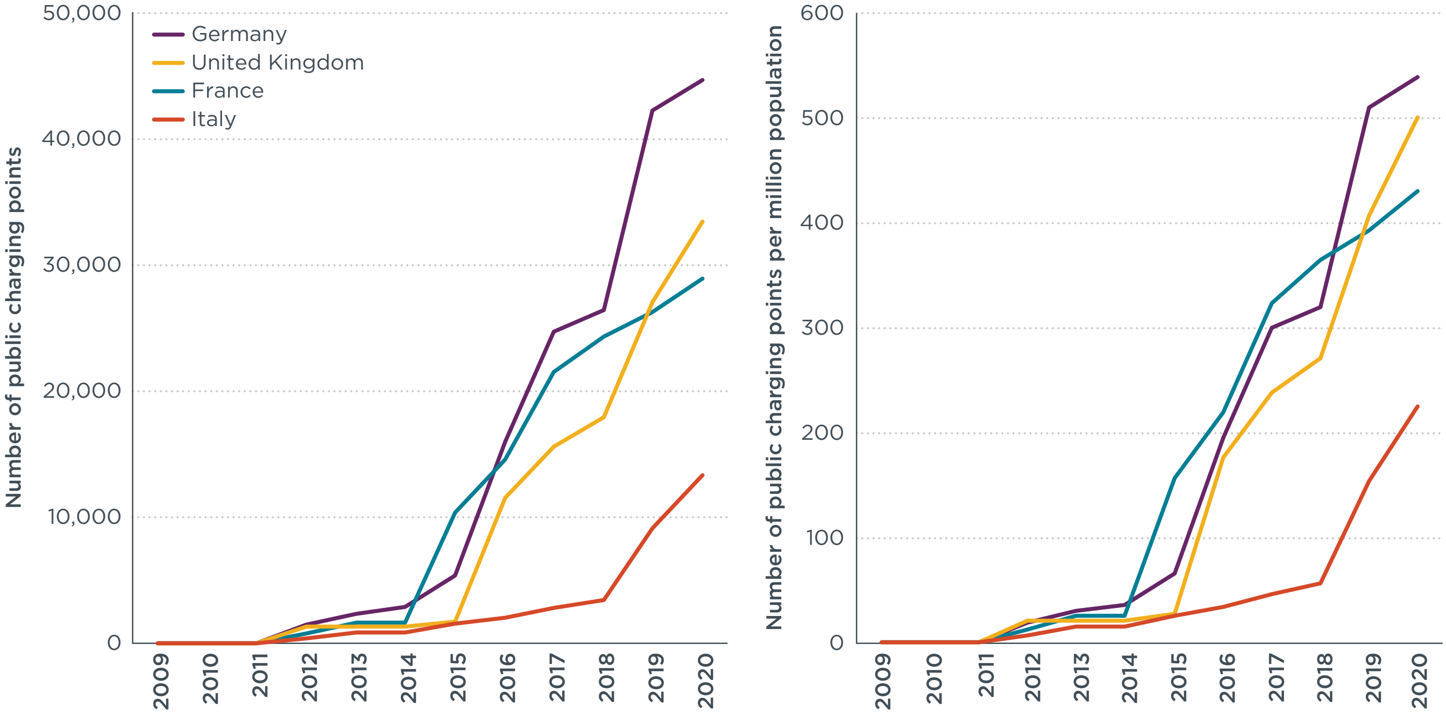

Figure 12. Development of public charging points on a total (left) and per capita (right) basis in France, Germany, the United Kingdom, and Italy since 2009

To extend the charging infrastructure network, government investment will be crucial in the coming years. Italy reached their normal charging infrastructure targets for the end of 2020 based on the government's National Plan for Electric Vehicle Charging Infrastructure (PNire)[40] from 2016. The target for normal charging points ranged from 4,500 to 13,000 (more than 12,000 points were established by the end of 2020). For fast charging, the target was 2,000 to 6,000 stations throughout the country by the end of 2020 (the actual value was more than 1,200 charging points).

Based on the Decree of the Prime Minister from February 2018 (Program Agreement between the Ministry of Infrastructure and Transport and the Regions for the construction of an infrastructure network for the charging of vehicles powered by electricity), the national government provides up to 35% of financing for the construction of charging stations in the case of normal power and up to 50% if fast charging. The remainder must be borne by third parties such as regions, autonomous provinces, or municipalities.

The national governments of Germany, France, and the United Kingdom have secured significant funding as part of various programs for the deployment of charging

39 European Alternative Fuels Observatory (EAFO), "Countries, Infrastructure, Electricity, Normal and High-Power Recharging Points (2020)" 2020, https://www.eafo.eu/countries/european-union/23640/infrastructure/electricity.

40 ANIE Federation, "PNIRE 2015 update," (2019), https://anie.it/focus_post/aggiornamento-pnire-2016/?contesto-articolo=/focus/e-mobility/attivita-emobility/#.YQL5wBMzbQ1.

infrastructure over the past years. To secure accessibility for different use cases, those programs have covered a variety of beneficiaries to build up public, workplace, and/or home charging facilities. All three governments have also committed significant funding for the years to come. The figure below shows key government funding programs and budgets starting in 2021 (as of November 2021). The funding amounts are displayed per capita and per year for better comparison (Figure 13). For example, the fifth bar from the top shows €16 per capita total, with €4 spent per capita each year from 2021 to 2024.

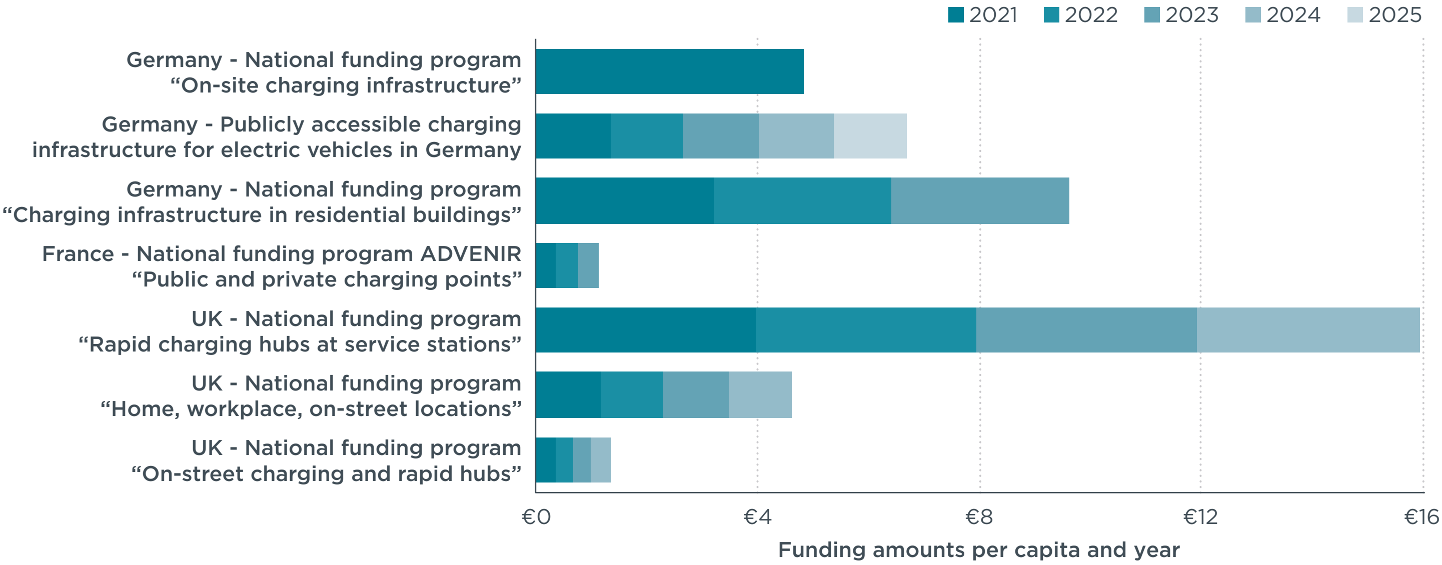

Figure 13. Amounts of key national funding programs for charging infrastructure deployment in Germany, France, and the United Kingdom. Note that UK funding is shown for the full year and not the financial year.

The numbers in Figure 13, compared to the per capita expenditure in Italy suggested by the cost model totals in Figure 11, divided by current Italy population yields a per capita expenditure total of €7 for 2021, rising to €39 in 2030.

In Germany, to accelerate the construction of on-site charging stations at everyday destinations such as supermarkets, hotels, restaurants, or municipal facilities, small- and medium-sized companies, small municipal utilities, local authorities, retail establishments, hotels, and catering industries can request funding for charging infrastructure. The government covers 80% of the investment costs and is investing €300 million between April and December 2021[41], which translates to a per capita investment of almost €5. Furthermore, the government will provide another €500 million for the newly launched funding program "publicly accessible charging infrastructure for electric vehicles in Germany" from summer 2021 to the end of 2025. On average, the government would fund the extension of the public charging infrastructure network as part of this program with more than €1 per capita per year. Another governmental funding scheme in Germany targets non-public home and workplace charging, initially providing €500 million in funding. Beneficiaries are private owners, apartment owners' associations, tenants, and residential landlords such as private individuals, companies, and housing associations. The funding program started at the end of 2020 with no ending date set. By the end of June 2021, funds of €530 million had been requested for about 620,000 charging points. Due to the success, the government added €300 million of funding and

41 NOW GmbH, "Charging Infrastructure," (2021), https://www.now-gmbh.de/foerderung/foerderprogramme/ladeinfrastruktur/#:~:text=April%20bis%2031.,des%20Aufbaus%20von%20Ladeinfrastruktur%20einreichen.&text=Die%20F%C3%B6rderung%20hat%20ein%20Volumen,Antr%C3%A4ge%20(%E2%80%9EWindhundverfahren%E2%80%9C)

extended the program to the end of 2023.[42] Considering a 3-year program running time, this would constitute an average yearly investment of more than €3 per capita per year.

France has secured governmental funding also as part of the COVID-19 recovery plan "Fast charging stations." For 2021 and 2022, the government invests €100 million for the deployment of fast chargers on highways and national roads.[43] This amount translates to about €0.7 per capita per year.

The United Kingdom has also secured funding for various schemes.[44] The following discussion applies to the financial year 2021/2022 to 2024/2025, starting in April each year. One scheme will support the rollout of rapid charging hubs at every service station on the national motorways and major A-roads with £950 million (€1.06 billion) between 2021 and 2025 (on average a yearly fund of about €4 per capita). Another key program is a £275 million (€309 million) fund to extend support for charge point installation at homes, workplaces, and on-street locations (more than €1 per capita per year between the financial years 2021/2022 and 2024/2025). Another £90 million (€101 million) has been secured to fund local charging infrastructure to roll out larger on-street charging schemes and rapid hubs in England which equals an average of €0.3 per capita over four years.

Next to governmental funding at national levels, there are also programs at state or local levels. In terms of funding, there is also support from the private sector. For example, the ADVENIR program in France has secured a budget of €100 million between 2020 and 2023 with a goal of financing more than 45,000 new charging points by 2023.[45] To benefit from the program, only charging points serving a parking space benefit from assistance. The fund targets charging infrastructure facilities at residential buildings, public companies, and individuals, on roads, high-power charging stations and hubs, and the modernization of public charging points. Per capita, this amount would be €0.4 per year.

Conclusions

Although Italy lags behind much of Europe in terms of electric vehicle market share, recent sales and new policies suggest a very fast growth rate for the future. This will require large investments in charging infrastructure to support these vehicles. This paper models a scenario where electric vehicles reach a 68% sales share by 2030 and estimates the charging needed by metropolitan area and year by charger type. The cost for home, workplace, public, and fast charging is estimated.

We make the following high-level findings.

Continued growth is needed for all charging types. Metropolitan areas in particular require more normal work and public chargers as well as fast chargers. For electric vehicles to reach a sales share of 68% of all vehicles by 2030, approximately 380,000 normal speed chargers (public and workplace) and 16,000 fast chargers are needed. Metropolitan areas have only 9% of the charging needed by 2025 compared to 14% in non-metropolitan areas. Charging will need to grow 50% per year until 2025 in cities and 38% per year in nonmetropolitan areas. Our scenarios assume that strong growth

42 NOW GmbH, "The funding program for private charging stations is increased by a further 300 million euros,"(16 July 2021), https://www.now-gmbh.de/aktuelles/pressemitteilungen/foerderprogramm-fuer-private-ladestationen-wird-um-weitere-300-millionen-euro-aufgestockt/

43 Ministère de la Transition écologique. "France Relance – Bornes de recharge rapide pour véhicules électriques [France Relance - Fast charging stations for electric vehicles], (15 February 2021), https://www.ecologie.gouv.fr/france-relance-bornes-recharge-rapide-vehicules-electriques

44 HM Treasury, "Spending review 2020," (2020), https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/938052/SR20_Web_Accessible.pdf

45 ADVENIR, "The ADVENIR program: Financing of charging points private or open to the public by the EWCs," (n.d.), https://advenir.mobi/le-programme/

in home charging will be needed as well, requiring government and utility support in funding and coordinating installations. More than 50% of electric vehicle owners live in apartments by 2030, suggesting that particular focus be given to installing overnight charging at or near apartments.

Charging infrastructure costs will be significant but decline per vehicle over time. The total cost estimate for chargers installed between 2021 and 2030 is €3.2 billion for non-home charging and €7.5 billion for home charging. However, for each car added, the marginal cost for non-home chargers needed to support that car decreases from €1,000 in 2021 to €400 in 2030. The declining cost is due to increasing utilization over time for away-from-home chargers, economies of scale at increasingly large charging installations, and a reduction in hardware cost.

International examples provide guidance on successful infrastructure strategies and needed investment. The model for Italy suggests that a per capita investment of €7 per year in 2021 is needed, rising to €39 per year in 2030. Peer countries with more developed charging networks, like Germany and the U.K., are already providing public charging investments of about €5 per capita annually through a number of popular programs, providing examples for Italy. Not all the investment need come from the government, however, and a cost share has been instituted for most government charger programs in the UK and Germany. A very popular program in Germany targeting homeowners and private business received requests for 620,000 charging points totaling €530 million. In the UK, more than €1 billion is being spent on fast charging along highways over 4 years, and over €100 for on-street charging.

Appendix

This Appendix provides normal (public and workplace) and fast charging infrastructure needs for individual metropolitan areas and nonmetropolitan areas in 2025 and 2030.

Table A1. Charging infrastructure needs through 2030

Metropolitan area	2020 normal chargers	2020 fast chargers	2025 electric vehicles	2025 normal chargers	2025 fast chargers	2030 electric vehicles	2030 normal chargers	2030 fast chargers
Milan	742	54	168,784	12,050	501	521,409	34,532	1,144
Rome	742	25	173,919	12,185	500	504,363	33,264	1,099
Naples	109	6	47,098	3,646	159	228,969	15,144	508
Turin	983	40	102,768	6,694	269	305,570	18,925	611
Brescia	231	24	43,928	2,819	114	136,737	8,271	267
Bari	147	3	26,747	1,876	77	107,541	6,679	219
Palermo	87	3	23,600	1,566	63	107,399	6,253	200
Bergamo	215	11	36,994	2,463	102	119,501	7,434	242
Catania	158	4	20,294	1,345	55	91,020	5,344	171
Bologna	338	18	37,748	2,665	108	120,933	7,821	257
Florence	704	16	57,324	3,847	140	143,353	8,965	292
Padua	125	7	37,957	2,264	82	110,117	6,091	191
Verona	91	12	34,545	2,172	84	106,475	6,243	199
Venice	208	13	36,418	2,133	91	93,456	5,619	180
Genoa	324	9	19,796	1,481	63	72,791	4,865	163
Messina	85	1	12,044	783	31	54,713	3,127	99
Taranto	40	-	9,533	624	25	44,391	2,540	81
Cagliari	21	-	15,333	929	36	57,714	3,191	100
Reggio Emilia	133	2	19,656	1,242	49	64,742	3,791	121
Parma	79	2	15,560	1,008	40	52,718	3,130	100
Prato	16	2	8,838	593	23	31,932	1,924	62
Nonmetropolitan Lombardy	807	45	115,647	7,148	481	372,155	21,455	1,091
Nonmetropolitan Campania	156	14	47,999	3,137	228	215,637	12,325	638
Nonmetropolitan Emilia-Romagna	654	68	80,674	5,236	356	276,355	16,373	840
Nonmetropolitan Tuscany	728	50	76,873	4,917	333	284,046	16,405	832
Nonmetropolitan Veneto	439	45	72,342	4,329	284	244,289	13,461	672
Nonmetropolitan Apulia	317	8	38,931	2,444	174	170,359	9,412	481
Nonmetropolitan Piedmont	830	20	66,699	3,997	263	236,278	12,965	646
Nonmetropolitan Sicily	224	9	36,197	2,202	154	168,207	8,994	450
Nonmetropolitan Calabria	358	15	36,809	2,368	170	168,264	9,511	486
Nonmetropolitan "The Marches"	258	13	43,323	2,819	196	161,324	9,512	488
Nonmetropolitan Lazio	222	36	34,241	2,146	149	138,578	7,749	394
Nonmetropolitan Abruzzo	209	9	32,750	2,069	143	129,469	7,357	374
Nonmetropolitan Friuli-Venezia Giulia	203	17	40,323	2,407	160	130,866	7,335	369
Nonmetropolitan Sardinia	268	4	24,244	1,399	96	94,227	4,980	247
Nonmetropolitan Umbria	303	1	25,715	1,617	109	98,993	5,592	281
Nonmetropolitan Liguria	98	37	18,917	1,317	94	65,442	4,108	218
Nonmetropolitan Basilicata	123	9	11,035	702	50	49,462	2,779	142
Nonmetropolitan Trentino	338	25	40,838	2,440	153	104,925	6,164	304
Nonmetropolitan South Tyrol	588	97	24,240	1,526	99	87,352	5,054	250
Nonmetropolitan Molise	57	-	5,525	341	24	26,075	1,420	71
Nonmetropolitan Aosta Valley	223	11	9,518	611	35	31,532	1,820	88
All metropolitan areas	5,578	252	948,884	64,385	2,614	3,075,845	193,153	6,309
All nonmetropolitan areas	*7,403*	*533*	*882,842*	*55,170*	*3,751*	*3,253,836*	*184,770*	*9,362*
Italy total	12,981	785	1,831,726	119,555	6,365	6,329,681	377,924	15,672