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Human-Factors and Power-System Implications of Consumer Electronics-Oriented Vehicle Design and Full-Electric Fleet Deployment

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Abstract: The digitalization of vehicles has accelerated the adoption of touchscreen-based control systems and with the growing push toward full electrification of national vehicle fleets. Their combined implications for driver distraction, road safety, and the electrical infrastructure required to support large-scale vehicle electrification remain insufficiently addressed. The present study offers an essential cross-sector perspective for contemporary resilience planning by combining human-factors analysis with system-level energy considerations. This study investigates these issues by examining both the human-machine interaction demands imposed by touchscreen-centric interfaces and the energetic and infrastructural consequences of replacing all gasoline-powered passenger cars in Italy with battery electric vehicles. The methodology integrates a numerical model of driver visual distraction with empirical findings from recent eye-gaze studies. Touchscreen interactions are decomposed into phases of visual reorientation, cognitive decision-making, pointing movement, actuation, and refocusing. This framework allows estimation of total eyes-off-road time and the corresponding blind-driving distance. Model outcomes are systematically compared with measured interaction durations from controlled experimental studies. The results show that touchscreen interactions require significantly longer visual engagement than predicted by idealized human-machine interaction models, particularly for multi-step tasks such as navigation and address entry. In parallel, national fuel consumption data are used to approximate the annual distance traveled by gasoline vehicles on Italian motorways and ordinary roads. These distances are converted into electrical energy demand using representative consumption values, and the associated average and installed charging powers are computed for fast-charging, slow public charging, and universal home-charging scenarios. From an energy-system perspective, replacing all gasoline vehicles with electric vehicles would require charging power levels that exceed the current Italian peak electrical load by a wide margin, especially under a full home-charging configuration. Overall, the findings suggest that touchscreen-based interfaces lead to significant increases in driver workload, while large-scale fleet electrification imposes substantial demands on the national power system. These results underscore the need for safer interface designs and for electrification strategies that incorporate human, infrastructural, and system-level constraints.

Keywords: Automotive safety; Human factors; Touchscreen interfaces; Vehicle conspicuity; Driver distraction

1 Introduction

Recent developments in automotive design increasingly mirror the evolution of consumer electronics. Vehicles are now marketed as integrated digital platforms, emphasizing oversized touchscreens, battery-centric architectures, and minimalist cockpit layouts. Although such innovations align with prevailing market trends, they also introduce substantial safety concerns. Several years ago, a young computer engineer claimed that the automotive sector was on the verge of a major electronic revolution. At the time, this assertion seemed exaggerated, given that automobiles were already equipped with advanced electronic systems, such as common-rail injection, traction control, and various safety devices, suggesting that digitalization had largely matured. Subsequent developments, however, revealed that the initial prediction underestimated the extent of the forthcoming transformation. Technical departments have become increasingly dominated by software-driven design processes and by professionals trained primarily in computer science rather than in automotive engineering. This shift has redefined the automobile itself. Contemporary vehicles often resemble complex digital artefacts, sometimes marketed as "spacecraft", despite lacking fully autonomous or instrument-based driving capabilities. Drivers must still rely predominantly on external visual cues to ensure safe operation, highlighting a pronounced mismatch between cockpit digitalization and core driving requirements. One of the most prominent consequences of this shift is the assimilation of vehicles into large smartphones. Expansive touch-screen interfaces have become central control nodes, despite mounting evidence that such systems impose significant cognitive and visual burdens on the driver. Their adoption has coincided with regulatory pressures associated with the "green transition", including the push toward mandatory electrification, increasingly stringent emission regulations, and the proliferation of driver-assistance and safety technologies that are not yet sufficiently validated. The resulting technological ecosystem is complex, fast-evolving, and not yet fully understood in terms of its implications for human performance and road safety. This article addresses two key domains that have remained largely underexamined in both public and technical discourse. First, it analyzes human–machine interaction challenges associated with touch-screen–based control systems, with particular emphasis on the absence of tactile feedback—a design choice widely recognized as suboptimal and detrimental to driving safety. Second, it examines human-factors issues related to battery-dependent vehicle architectures and evaluates the energetic and economic ramifications of large-scale reliance on fully electric vehicles, arguing that the exclusive adoption of such technologies imposes significant human, infrastructural, and systemic costs. By foregrounding human-factors considerations, this article seeks to clarify how interface design decisions and electrical-system architecture influence driver workload, situational awareness, and crash-avoidance performance, dimensions that remain insufficiently addressed in contemporary vehicle development. The analysis underscores the need for a more balanced approach to automotive innovation, one that integrates digital capabilities without compromising the fundamental requirements of safe and cognitively manageable vehicle operation.

2 Background and Motivation

The automotive industry's shift toward digitalization has emphasized immersive infotainment systems and smartphone-like interfaces. Despite improvements in user experience for non-driving tasks, evidence indicates that touchscreen-heavy control schemes significantly increase cognitive and visual workload. This study synthesizes peer-reviewed literature in automotive human factors, ergonomics, and traffic safety. Empirical findings from simulator studies, field observations, and accident reports are integrated to assess the combined impact of interface digitization and diminished vehicle conspicuity. In the automotive industry, leadership structures and technical departments have shifted from being dominated by mechanical engineers to being increasingly driven by software and electronics engineers, while management has increasingly been drawn from MBA programs with a financial background. Consequently, the sector has transitioned from an analog, internal-combustion vehicle to a digital, smartphone-like electric vehicle. The widespread adoption of touchscreens and other interfaces that require continuous visual feedback, which is intrinsically hazardous during driving, has progressed with minimal scrutiny from the relevant regulatory authorities. For example, the absence of an emergency shut-off mechanism comparable to the traditional ignition key, the lack of at least one manually operable window capable of functioning even in the event of battery failure, which is critical in situations such as vehicle submersion, the inability to open the doors when the battery is depleted, and the difficulty for first responders to locate external handles or release mechanisms all highlight a substantial deficiency in systematic risk assessment in current vehicle designs.

3 Touchscreen-Centric Interfaces and Driver Distraction

Touchscreen interfaces lack the haptic feedback that drivers traditionally rely on when interacting with physical controls such as knobs, switches, and mechanical buttons. The absence of tactile confirmation forces drivers to divert their gaze from the roadway. Multiple studies report statistically significant increases in glance duration and task completion time when touchscreens replace analog controls. As a result, touchscreen-heavy layouts are associated with an increased risk of crashes, particularly in dynamic traffic scenarios that require rapid hazard detection.

3.1 Numerical Simulation of Eyes-Off-Road Interaction Time

This section presents a numerical simulation of the time required for a driver to redirect visual attention toward an in-vehicle touchscreen, navigate a hierarchical menu, activate a control, and refocus their gaze on the forward roadway. The model follows established findings on visual distraction and human-machine interaction [1–3].

3.1.1 Model

The total interaction time is decomposed into a look-in phase, a sequence of per-level selection operations, and a look-back phase:

$$T_{total} = T_{look\_in} + \sum_{j=1}^{d} T_{level,i} + T_{look\_back} \tag{1}$$

The total interaction time T_{total} represents the overall duration required for a driver to shift visual attention from the forward roadway to an in-vehicle touchscreen, navigate a hierarchical menu, activate a control, and subsequently refocus gaze on the road. It is composed of a look-in phase T_{look_in}, a sequence of per-level interaction times $T_{level,i}$ and a look-back phase T_{look_back}.

The visual reorientation time is modeled as:

$$T_{look\_in} = t_{sacc\_lat} + t_{sacc\_dur} + t_{fix\_init} \tag{2}$$

The look-in time T_{look_in} consists of saccadic latency t_{sacc_lat}, saccadic movement duration t_{sacc_dur}, and the initial fixation time on the interface t_{fix_init}.

Each menu level requires cognitive decision time, pointing time, activation, and an intermediate fixation:

$$T_{level} = T_{decision}(m) + T_{move}(A, W) + T_{act} + T_{fix\_between} \tag{3}$$

Each menu level requires a decision time $T_{decision}(m)$, modeled using the Hick–Hyman law as a function of the number of alternatives m; a pointing or movement time $T_{move}(A, W)$, modeled using a Fitts-like formulation based on target distance A and width W; a control activation time T_{act} and an intermediate fixation time between selections $T_{fix\_between}$. The look-back time T_{look_back} represents the visual reorientation from the interface to the roadway and is assumed to be equal to the look-in time. The variable A represents the movement amplitude, defined as the distance between the initial pointer position and the target control on the touchscreen, while W denotes the effective width of the target, reflecting its tolerance for pointing accuracy.

Decision time uses a Hick-Hyman law [4]:

$$T_{decision}(m) = c + d \log_2(m) \tag{4}$$

The parameters c and d are empirically derived constants in the Hick–Hyman law, where c represents the baseline decision time and d scales the increase in decision time as a function of the number of choices.

Pointing time uses a Fitts-like law [5]:

$$\begin{aligned} T_{move}(A, W) &= a + b \cdot ID \\ ID &= \log_2\left(\frac{A}{W} + 1\right) \end{aligned} \tag{5}$$

The look-back time is assumed equal to the look-in time. The parameters a and b are empirically determined coefficients in the Fitts-like movement model, with a representing the intercept or baseline motor response time and b scaling the effect of task difficulty on movement time. The index of difficulty quantifies the motor task complexity and is computed as a logarithmic function of the ratio between movement amplitude A and target width W, capturing the speed–accuracy trade-off inherent in touchscreen pointing tasks.

3.1.2 Parameters and baseline calculation

For illustrative purposes, the following representative parameter values are adopted. The lateral acceleration time constant is set to t_{sacc_lat} = 0.20 s, and the duration of the acceleration response to t_{sacc_dur} = 0.03 s. The initial fixation time is assumed to be t_{fix_init} = 0.10 s, with a cognitive processing constant of c = 0.15 s and an information-processing rate of d = 0.07 s/bit. Motor-response parameters are defined as a = 0.20 s and b = 0.10 s/bit. The actuation time is specified as T_{act} = 0.05 s, while the interval between successive fixations is set to $T_{fix\_between}$ = 0.30 s. Spatial target characteristics are represented by an amplitude of A = 0.10 m and a width of W = 0.02 m. The interface structure is characterized by a menu depth of m = 5 and a decision difficulty level of d = 3.

Look-in time:

$$T_{look\_in} = 0.20 + 0.03 + 0.10 = 0.33s \tag{6}$$

Decision time per level:

$$T_{decision}(5) = 0.15 + 0.07 \cdot \log_2(5) \approx 0.313 \tag{7}$$

Fitts' index of difficulty:

$$ID = \log_2(6) \approx 2.585 \tag{8}$$

Movement time:

$$T_{move} = 0.20 + 0.10 \times 2.585 = 0.459 \text{ s} \tag{9}$$

Per-level time:

$$T_{level} = 0.313 + 0.459 + 0.05 + 0.30 = 1.121 \text{ s} \tag{10}$$

Total task time:

$$T_{total} = 0.33 + 3 \times 1.121 + 0.33 = 4.02 \text{ s} \tag{11}$$

3.1.3 Distance travelled during eyes-off-road

The road distance D travelled while the driver is visually off-road is:

$$D = v \cdot T_{total} \tag{12}$$

To illustrate the magnitude of the effect, consider three representative driving speeds. At v = 30 km/h (8.33 m/s), the corresponding distance is approximately 33.5 meters. At 50 km/h (13.89 m/s), this distance increases to about 55.9 meters. At a higher speed of 90 km/h (25.00 m/s), the distance reaches roughly 100.6 meters. Table 1 and Figure 1 show the sensitivity of T_{total} to menu depth d and target width W (computed with the same equations). Values are rounded.

Table 1. Sensitivity of T_{total} to menu depth d and target width W

d	$W = 0.01$ m	$W = 0.02$ m	$W = 0.03$ m	$W = 0.04$ m
1	1.79 s	1.74 s	1.72 s	1.71 s
2	2.98 s	2.87 s	2.81 s	2.78 s
3	4.16 s	4.02 s	3.95 s	3.92 s
4	5.34 s	5.16 s	5.06 s	4.98 s

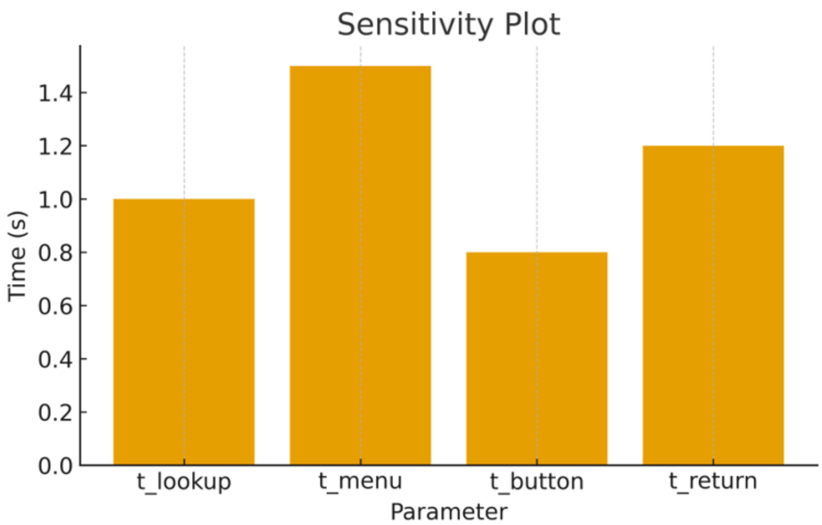

Figure 1. Sensitivity of the total eyes-off-road interaction time to the contributions of look-in, menu navigation, button activation, and look-back phases in the baseline model

A recent report, produced by The Foundation for Industrial and Technical Research (Stiftelsen for industriell og teknisk forskning, SINTEF) in collaboration with Nord University on behalf of Trygg Trafikk and the insurance company Fremtind, documents the extent to which in-vehicle touchscreens divert driver attention from the driving task. The study involved 44 participants who were instructed to perform a set of common touchscreen interactions while driving. Eye-gaze behavior and attention distribution were recorded using a gaze-tracking camera [5–14]. The results show that touchscreen-based tasks impose substantial visual and cognitive demands. Entering a navigation address was identified as the most demanding activity, requiring an average eyes-on-road time of 15.7 seconds. Music selection and radio tuning required approximately 10 to 11 seconds, while temperature adjustments, the least demanding task, still required an average of 3.4 seconds of visual distraction. The report emphasizes that these durations translate directly into periods during which the driver is effectively operating the vehicle without visual control of the traffic environment. Even short interactions correspond to significant blind-driving distances. For example, entering an address while traveling at 22 km/h results in approximately 12 meters of blind travel, whereas a 2-second music interaction at 63 km/h corresponds to more than 30 meters. Such interruptions are considered critical from a road-safety perspective. The findings are further supported by insurance data from Fremtind, which indicates a marked increase in traffic accidents in recent years, attributed in part to inattention caused by touchscreen interfaces. The study concludes that touchscreen-based vehicle controls pose a measurable safety risk, underscoring the need for regulatory and design interventions to minimize driver distraction.

A comparison between the measured touchscreen interaction durations reported by SINTEF and the predictions of the numerical model developed in this work reveals systematic discrepancies (see Table 2). These differences provide insight into the cognitive and operational mechanisms that govern driver interaction with modern human-machine interfaces. The first observation concerns the model's relative underestimation of total interaction time, particularly for complex tasks such as navigation input. While the experimental results indicate an average eyes-off-road duration of 15.7 s during address entry, the model predicts approximately 4 s. This gap arises because the model decomposes the task into a sequence of discrete operations (initial visual orientation, decision time, pointing movement, activation, and between-level transitions). Although this structure captures the generic components of an interaction, it does not account for the recursive and error-prone characteristics of real text-entry tasks. Address input typically involves multiple characters, predictive menus, correction steps, and intermittent verification of intermediate results, none of which are represented in the current formulation. Consequently, the model approximates a single menu-level traversal, whereas the actual interaction consists of many tightly coupled sub-operations with cumulative temporal overhead. For intermediate tasks such as music or radio selection, measurements (10–11 s) again exceed the model prediction (4 s). This discrepancy can be attributed to interface-specific factors, including scrolling, hierarchical search depth, inconsistent iconography, and variable touchscreen response latency. The model presumes an idealized interface with uniform decision complexity and deterministic pointing movements. In contrast, real displays introduce variable cognitive load due to menu density, item layout, and the need for repeated visual confirmations, which increase both fixation time and motor execution latency. Even for the simplest task, temperature adjustment, the measured value (3.4 s) exceeds the model estimate (1.1 s). This suggests that drivers incur an additional attentional cost associated with refocusing, verifying system response, and reorienting their gaze back to the traffic environment. These overheads align with the finding that any touchscreen interaction imposes a reorientation penalty that is not explicitly modeled but constitutes a measurable component of total distraction. Overall, the discrepancies suggest that the proposed model effectively captures the structure of human-machine interaction, but underestimates the multiplicative effects of microtasks, verification steps, and visual refocusing. The findings highlight the importance of incorporating stochastic elements, interface-dependent parameters, and reorientation costs in future refinements of the model. Such enhancements would enable more realistic predictions of eyes-on-road time and support the design of safer in-vehicle interfaces.

Table 2. Comparison between measured touchscreen interaction times and the numerical model of eyes-off road time

Task Type	Measured Eyes-Off-Road Time (s)	Model-Predicted Time (s)	Notes
Temperature adjustment	3.4	$T_{total} \approx 1.12$	Single-level interaction
Music/radio selection	10–11	$T_{total} \approx 4.02$	Three-level menu model
Navigation address entry	15.7	$T_{total} \approx 4.02$	Model underestimates multi-step input

4 Simplified Assessment of the Requirements of a Full-Electric Vehicle Network (Gasoline Fleet Only) and Its Impact on the Italian National Power System and Drivers

4.1 Estimation of Annual Gasoline Refueling Events in Italy

4.1.1 Assessment of annual gasoline refueling demand in Italy

Based on ministerial data for the Italian motorway network of 2024, the total annual gasoline volume is 306.82 million liters out of a combined gasoline and diesel volume of 1,025.86 million liters, corresponding to a gasoline share of approximately 0.30. Assuming an average refueling amount of 30 liters per transaction, the annual number of gasoline refueling events on motorways is estimated as $306.82 \times 10^6 / 30$, yielding approximately 10.2 million events per year. This assumption is consistent with empirical refueling behavior reported in the literature, where average gasoline refueling volumes typically range between 25 and 40 liters per stop [15, 16]. For the ordinary road network, the total number of active filling stations in Italy (22,654) is reduced by the 443 motorway service areas, resulting in 22,211 stations. Using the reported average annual throughput of 1.35 × 10^6 liters per station, the total fuel volume delivered outside motorways is approximately 2.998 × 10^{10} liters. Comparable station-level throughput values have been reported in international energy and transport statistics for mature European fuel distribution networks [16–20]. Applying the same gasoline share of 0.30, the estimated annual gasoline volume in the ordinary network is 0.30 × 2.998 × 10^{10} = 8.97 × 10^9 liters. Dividing by the same average refueling amount of 30 liters yields 8.97 × 10^9 / 30 = 2.99 × 10^8, corresponding to approximately 299 million gasoline refueling events per year outside the motorway network [6, 7].

4.1.2 Comparison of total annual time spent for refueling on motorways in Italy

The annual volume of gasoline delivered on Italian motorways is 306.82 million liters. Assuming an average refueling amount of 30 liters per stop, the number of gasoline refueling events N_{ref} per year is 1.02 × 10^7. If an all-electric fleet required the same number of energy stops, and each fast-charging session (from 20 percent to 80 percent state of charge) lasted 1 hour, the total annual time T_{EV} spent charging would be approximately 1.02 × 10^7 hours. For gasoline vehicles, assuming an average refueling duration of 5 minutes (i.e, 5/60 hours), the total annual time T_{ICE} spent refueling is 9.38 × 10^5 hours. The difference between the two cases is therefore ΔT = 9.38 × 10^6 hours, which corresponds to approximately 9.4 million additional hours per year. Expressed in continuous human time, the annual refueling time amounts to approximately 1168 years for electric vehicles and 97 years for gasoline vehicles, implying an additional time burden of around 1070 years equivalent when relying exclusively on one-hour fast-charging sessions. The imbalance between refueling and charging times has been widely recognized as a critical barrier to large-scale adoption of electric vehicles, particularly for long-distance travel [17, 18].

4.1.3 Human and economic implications of time lost to fast-charging operations in Italy

The total annual time spent in fast-charging operations on motorways, estimated at approximately 1.02 × 10^7 hours, represents a substantial cumulative burden relative to the national vehicle fleet. Compared with the 8.52 × 10^5 hours required for conventional gasoline refueling, the difference amounts to roughly 9.38 × 10^6 additional hours per year. This corresponds to more than one thousand years of aggregate human time effectively removed from productive, personal, or social activities. From a transport economics perspective, time spent in non-productive mobility-related activities represents a direct welfare loss, as extensively discussed in the literature on derived travel demand and time valuation [17]. Such a time displacement carries significant economic implications. From a macroeconomic perspective, the value of time lost due to charging delays may be reflected in reduced labor productivity, longer travel times, and higher opportunity costs for individuals and businesses. Even with conservative time valuations, the monetary equivalent of millions of lost hours quickly reaches levels that are non-negligible relative to the operating costs of the national transportation system. Moreover, the widespread imposition of prolonged charging times introduces logistical inefficiencies, including longer queues, reduced network throughput, and the need for larger station footprints to accommodate simultaneous charging events. These effects compound the direct time costs borne by users and amplify the societal burden associated with an all-electric fleet operating under slow and fast-charging constraints. It is also worth noting that this estimate considers motorway charging only and neglects the additional time lost during extra-urban charging events, which would further increase the overall human and economic impact. Taken together, these losses underscore the importance of evaluating charging-time externalities as a central parameter in large-scale electrification planning, rather than treating them as a secondary or purely technical consideration.

4.2 Estimated Annual Electricity Demand for an All-Electric Vehicle Fleet on Motorways in Italy

Using Italian ministerial data for motorway fuel sales [9], the annual volume of gasoline delivered on Italian highways is 306.82 million liters. Assuming an average fuel consumption of 7 liters per 100 km for gasoline vehicles, the total distance D traveled by gasoline cars on motorways is computed as D = (306.82 × 106) / 7 × 100 $\approx$ 4.38 × 109 km. If the entire fleet were replaced by battery-electric vehicles with an average motorway consumption of 20 kWh per 100 km, the corresponding annual electricity demand E would be E = D × (20 / 100) $\approx$ 8.76 × 108 kWh. This result corresponds to roughly 0.88 TWh. This value represents the additional electrical energy required annually on Italian motorways if all gasoline-powered vehicles currently operating on the network were replaced by electric vehicles with the assumed consumption level. If all charging events on motorways occur in fast-charge mode, with an assumed charging efficiency of 0.88 (see Figure 2), the corresponding energy drawn from the electrical grid is E_{grid} = E / 0.88 = 0.95 TWh. If motorway charging facilities operate daily from 07:00 to 19:30, the total operational hours per year are 4,562.5. The corresponding average electrical power P_{avg} required to sustain the annual motorway charging demand is approximately 218 MW. Using an analogy with fuel station operations for gasoline vehicles, where the installed refueling power is approximately twenty times higher than the average refueling power used, the same scaling factor can be applied to motorway fast charging. Similar scaling factors between average and installed power capacity have been identified for fast-charging infrastructure, reflecting peak-demand design constraints and requirements to avoid queuing [19]. The installed electrical power P_{inst} required to support peak charging demand is therefore estimated to be approximately 4.36 GW, which would need to be available on the Italian motorway network to ensure that fast-charging operations can meet peak demand conditions.

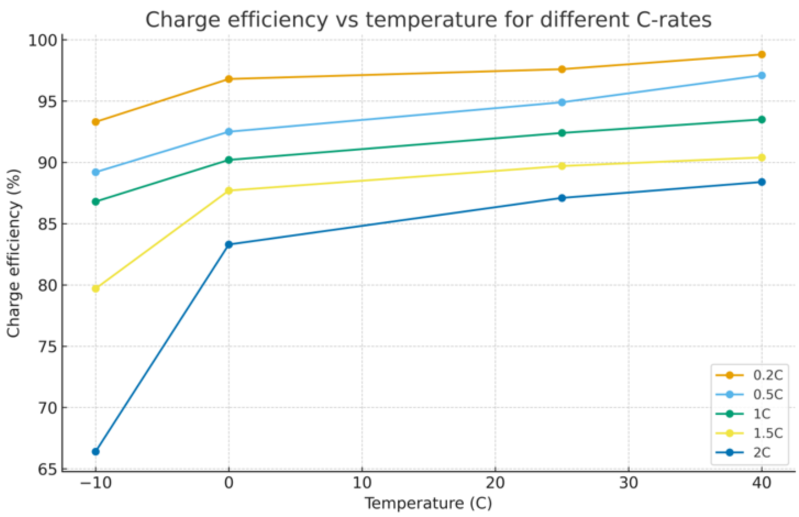

Figure 2. Charge efficiency versus C-rate for different cell temperatures, based on experimental data

4.3 Estimated Annual Electricity Demand Outside Motorways for an All-Electric Vehicle Fleet in Italy

Using the previously derived values, the annual volume of gasoline delivered outside the motorway network is estimated at 8.97 billion liters. Assuming an average fuel consumption of 5 liters per 100 kilometers for gasoline vehicles, the corresponding annual distance travelled outside motorways is approximately 1.79e11 kilometers. If the same mileage were supplied by battery electric vehicles with an average electricity consumption of 10 kilowatt-hours per 100 kilometers, the resulting annual electricity demand would be 17.9 TWh. When accounting for a slow-charging efficiency of 0.95, the total electrical energy drawn from the grid increases to 18.8 terawatt-hours per year. Assuming slow charging is available for 6 hours per day, the total number of charging hours per year is 2190. Dividing the annual energy requirement by this number of hours leads to an average power demand of 8.6 GW on the ordinary road network. Applying the same ratio observed at motorway refueling stations, where installed capability is roughly 20 times the average delivered power, the installed electrical capacity required for slow public charging is approximately 172 GW. Considering only Euro 4 and newer passenger cars circulating in Italy in 2024, estimated at 33.04 million units, each vehicle would require at least one dedicated home charging point with a minimum installed capacity of 5 kilowatts. The resulting nationwide installed capacity for home charging alone is therefore about 165 GW. This capacity would be required in addition to the existing and planned public charging infrastructure. For reference, the historical peak electrical load of the Italian power system is about 60 GW, and the additional installed capacity required for a fully electrified fleet is of the same order of magnitude as more than half of the average electrical power corresponding to Italy's annual electricity production of roughly 320 TWh. Table 3 and Figure 3 summarize these main results, distinguishing the contributions from motorway fast charging, public slow charging on the ordinary road network, and nationwide home charging. When compared with other major European countries, the required installed capacity also exceeds the national peak loads of France (approximately 90 GW), Germany (approximately 80 GW), and Spain (approximately 45 GW), as shown in Figure 4. These orders of magnitude are consistent with comparative European assessments of road transport energy demand and infrastructure scaling, which highlight the exceptional challenge posed by universal home-charging scenarios [20]. These comparisons highlight the scale of the infrastructure expansion needed to support a universal home-charging model for a fully electrified passenger vehicle fleet and underline the need for coordinated planning at both national and European levels. From a system-level perspective, these results demonstrate that large-scale fleet electrification does not merely involve adding charging points but rather demands a profound transformation of the electrical system. The combined installed capacity for motorway fast charging, public slow charging, and home charging exceeds current national peak demand by several multiples. This implies that the electrical grid would have to support new simultaneous peak loads that are far higher than those historically encountered. Such a shift requires extensive reinforcement of transmission and distribution networks, construction of new primary and secondary substations, and a substantial increase in short-circuit power capability and voltage regulation capacity. Moreover, without coordinated scheduling strategies, unmanaged home charging could generate highly synchronized evening peaks, while public charging hubs could create local overloads on distribution feeders. This situation highlights the need for smart charging, demand response mechanisms, local energy storage, and possibly vehicle-to-grid integration to smooth load profiles. At the national scale, the aggregate charging demand would require additional dispatchable generation or large-scale storage to ensure system adequacy during periods of high demand. At the European level, increased interconnection capacity and cross-border balancing would become essential to accommodate fluctuating charging loads and maintain security of supply. Overall, the magnitude of the required installed charging capacity and the associated grid impacts indicate that the transition from internal combustion engine vehicles to battery electric vehicles must be approached as a major infrastructure and system planning challenge. Without comprehensive, multi-level coordination involving transmission system operators, distribution operators, regulators, and policymakers, it would be challenging to ensure the robustness, reliability, and long-term sustainability of a fully electrified road transport sector.

Table 3. Summary of average and installed electrical power requirements for an all-electric fleet in Italy

Scenario	Average Power	Installed Power
Motorways (fast charging)	$P_{avg} \approx 2.18 \times 10^5$ kW	$P_{inst} \approx 4.36 \times 10^6$ kW
Ordinary network (public slow charging)	$P_{avg} \approx 8.6 \times 10^6$ kW	$P_{inst} \approx 1.72 \times 10^8$ kW
Home charging (Euro 4 + cars)		$P_{home} \approx 1.65 \times 10^8$ kW
National peak demand (reference)	$P_{peak,nat} \approx 6.0 \times 10^7$ kW	

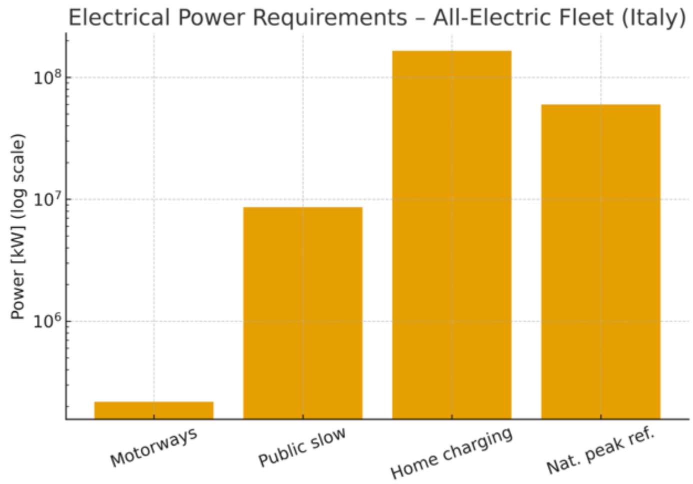

Figure 3. Relative contribution of each charging mode to the total electrical power demand of a fully electrified vehicle fleet in Italy

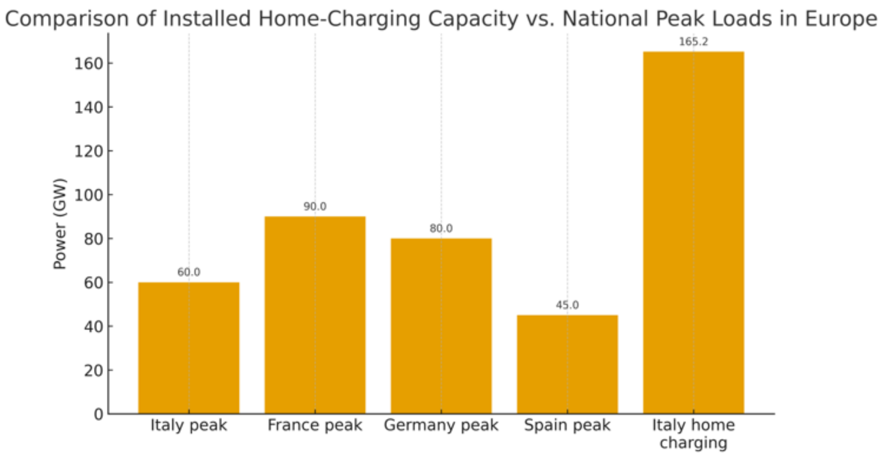

Figure 4. Installed electrical power required for a universal home-charging system for the Italian passenger car fleet compared with the national peak demand levels of Italy, France, Germany, and Spain [11–14]

5 Discussion

Before presenting the quantitative results, it is important to discuss the broader context and the underlying assumptions that frame the analysis. Recent studies highlight how energy consumption trends in the transport sector are strongly influenced by regulatory frameworks, technological maturity, and infrastructure availability, rather than by propulsion technology alone [21, 22]. Road transport remains a dominant contributor to final energy demand and greenhouse gas emissions in Europe, despite significant improvements in vehicle efficiency and fuel standards over the last decade [23]. Several authors have noted that aggregate energy and emissions indicators may mask substantial differences across vehicle classes, operational profiles, and usage patterns, thereby limiting the direct comparability of different propulsion solutions when boundary conditions are not carefully defined [24]. Moreover, the ongoing digitalisation of mobility systems and the integration of advanced monitoring and control strategies are expected to play a non-negligible role in optimising energy use and reducing emissions at system level, independently of the specific powertrain adopted [25]. Finally, it should be noted that scenario-based analyses, such as those adopted in this work, are inherently sensitive to assumptions on fleet renewal rates, fuel availability, and policy evolution. As discussed in the literature, these factors can significantly affect long-term projections and should therefore be considered when interpreting the results presented in the following section [26].

6 Results

This study evaluated two interconnected aspects of modern automotive design: the safety implications of touchscreen-centric in-vehicle interfaces and the large-scale electrical and infrastructural consequences associated with a fully electric passenger vehicle fleet in Italy. The results highlight that contemporary touchscreen systems impose significant visual and cognitive demands on drivers. Measured eyes-off-road intervals for common infotainment tasks, such as navigation input or media selection, substantially exceed the predictions of simplified human-machine interaction models, confirming that touchscreen operation introduces cumulative overheads related to visual reorientation, error correction, and repeated verification. These findings reinforce concerns raised by recent empirical research, which demonstrates that touchscreen-based control architectures materially degrade situational awareness and increase the likelihood of attentional failures during driving. The second part of the analysis quantified the electrical requirements of replacing all gasoline-powered vehicles with battery-electric vehicles across Italian motorways and the general road network. The results show that, even under simplified assumptions, the average and installed charging power needed to sustain a fully electric fleet would exceed current national peak electrical demand by a large margin. In particular, the installed capacity required for a universal home-charging model (approximately 0.165 TW) would be nearly three times the historical Italian system peak of 60 GW and exceed the national peak loads of major European countries, such as France, Germany, and Spain. When these demands are combined with charging-time overheads, which amount to millions of additional hours per year relative to gasoline refueling, the cumulative human and socioeconomic burden becomes substantial. Overall, the findings indicate that the transition toward fully digital cockpit interfaces and large-scale electrification introduces safety, energetic, and infrastructural challenges that are not yet adequately accounted for in current regulatory or industrial strategies. The results underscore the need for future vehicle design and electrification policies to balance digital innovation with human-factors constraints and realistic assessments of electrical system capacity, ensuring that technological advancements do not compromise road safety, energy resilience, or the operational efficiency of national transportation networks.

Data Availability

The data used to support the research findings are available from the corresponding author upon request.

Conflicts of Interest

The author declares no conflicts of interest.

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